MAINTENANCE SCHEDULING PRACTICES AND PERFORMANCE OF FIRMS IN KENYA ENERGY SECTOR

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DECLARATION

Student Declaration

This research project is my original work and to the best of my knowledge, it has not been presented for award of degree in any other university or college for any other purpose.

Signed: …………………………………… Date: ………………………………….

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Supervisor Declaration

This research project has been submitted for examination with my approval as the University Supervisor.

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DEDICATION

This research is dedicated to my parents late David and beloved mother Christine Chumo for their love expressed through education, guidance and good care.

Special dedication goes to my dear wife Zeddy and our children for their support, encouragement, patience and understanding during my studies.

LIST OF ABBREVIATIONS

CBM	Condition Based Maintenance
CPM	Critical Path Management
ERC	Energy Regulatory Commission
GDC	Geothermal Development Company
GW	Gigawatt
IPP	Independent Power Producers
KenGen	Kenya Electricity Generating Company
Ketraco	Kenya Electricity Transmission Company
KPLC	Kenya Power and Lighting Company
Ksh	Kenya Shillings
kWhr	Kilowatt- hour
MOEP	Ministry of Energy and Petroleum
O&M	Operations and Maintenance
PERT	Program Evaluation Review Technique
RBM	Reliability Based Maintenance

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ABSTRACT

The aim of the research project was to establish maintenance scheduling practices in energy sector in Kenya and to evaluate their relationship with the firms' operations performances in terms of plant availabilities and cost of operations and maintenance.

Power generation availability was considered along cost of operations and maintenance to be best indicators of performance because dispatch of electric energy is controlled nationally on based on demand at any given time.

The research was done with a target population comprising of all energy generation technologies in Kenya that is hydro, geothermal, wind, gas, thermal and wind. The research used primary data that was collected through emailed questionnaires to maintenance engineers and managers of power generation stations who are responsible for day to day operations and maintenance.

The research found out that maintenance scheduling practices are being applied across all the energy generation mix but with varying intensity. Giving priority to critical tasks is strongly applied across all energy generation mix while supervisor's handling daily schedule without necessarily following the laid down program is least applied.

The research established that there is a strong relationship between maintenance scheduling principles and operation performance in Kenya energy sector. It was concluded that maintenance scheduling practices contributes approximately 67% of operations performance.

The study recommended that a further study be carried out to establish the other 33% factors that affect operations performance in order to achieve operations performance excellence in Kenya energy sector.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

A thorough and systematic approach is required to carry out maintenance activities satisfactorily and lack of maintenance management will be reflected on financial performance of a firm (Sinha 2015). Operations and maintenance functions are facing challenges of optimization due to continuous development of world technologies, global competitiveness, safety and environmental requirements (RS Velmurugan2015). Operations management therefore plays major roles in supporting business performance through quality, effectiveness in carrying out activities and profitability.

Good work preparation is required to achieve lowest maintenance costs as a result of elimination of delays and speedy execution; this will raise productivity, decrease downtime and resource usage (Venkatraman2012). Profitability of firms will go higher with higher uptimes because of opportunities to generate revenues and avoid losses through penalties. Substantial amount of resources could be saved in development and implementation of new techniques and systems for effective and efficient maintenance scheduling operations (Oke and Charles 2006). Maintenance scheduling practices study in Kenya energy sector is needed to establish whether it contribute to elimination of delays, decrease of plants downtime and increased profitability. The study will also compare the maintenance scheduling practices in use in Kenyan firms with international practices and make recommendations.

Three common drivers of performance of firms are reliability, productivity and sustainability (Venkatraman 2012). Good performance of firms can be facilitated in terms of profitability, and process safety. The above drivers can be affected by many operations and maintenance factors which have to be handled effectively to realize high performance.

Reducing machine frequency of failure can be achieved through: preventive and predictive maintenance, early equipment replacement or overbuilding of machine which result in high capital cost and maintenance cost as well. Once break down has occurred severity of failures can be reduced by speeding up maintenance work or by providing alternative output during repair works period.

1.1.1 Maintenance Scheduling Practices

Maintenance scheduling is the process whereby all the resources required to execute maintenance activities are planned for execution within a specified time frame (Matt 2015). Maintenance activities carried out during maintenance includes inspection, testing, servicing, repairs and replacement. Maintenance excellence can be achieved by competent staff that are allocated the right jobs and given correct spare parts at the most appropriate time.

There are six principles which create a framework for successful scheduling of maintenance works. The principles of maintenance scheduling are: planning for minimum skill level needed, scheduling and job priorities for critical tasks, scheduling from highest skill and man power available, scheduling for every work hour available, having crew leader to handle current day’s job and measuring performance against compliance to scheduled program (Richard 2013). The principles if correctly applied will greatly contribute to the overall success of maintenance scheduling (Matt 2015).

Effective maintenance and scheduling contribute significantly to overall success of organizations using mechanical machinery and plants to generate their revenues. The major contribution of maintenance scheduling include: reduced maintenance cost as compared to cost of breakdowns, improves safety of equipment and employees, high plant availability as a result of reduced delays and breakdowns, it assist in better utilization of both maintenance and production resources and maximizing efficient use of work time, material and equipment (Oke 2006).

Maintenance scheduling can best be applied for preventive maintenance practices because of duration between planning and execution of activities. Reducing operations and maintenance costs and achieving high service reliability are among the top priorities for managers of utility companies. Preventive maintenance is perhaps the single largest controllable cost of utility (M. Shahidehpour 2000).

1.1.2 Operational performance

Operations are all the processes involved in the sourcing, production, and transportation of products and services to the point of need. This is applicable to all chain of activities in the production of products and services and delivering at the point of need. Operation performance was defined by Nigel, Stuart and Robert (2010) as the measure of operations activities based on five generic objectives of quality, speed, dependability, flexibility and cost. Brown et al, (1994) indicated that performance can be measured using customer satisfaction, financial, product/ quality, employee satisfaction and public responsibility measures. The above performance measures are applicable in the energy firms and carries different weights which varies from one department to another and to overall organization needs.

Operations performance is linked to different department in an organization differently. Production will be more concerned with equipment availability and reliability, engineers with techniques applied, top management with budget performance and accountants with costs. Effective maintenance policy reduces equipment failure rate and increase equipment availability thus reducing cost of production and hence giving an organization competitive advantage (Gerald 2013). Kamau (2014) in his research found out that plant availability in power generation firms greatly affects operation performance among other factors and that maintenance costs are also high.

Operations performance measures guide management in making decisions that will lead to achievement of organization objectives. Many organizations will seek to increase operations effectiveness, revenue and customer satisfaction, while reducing operating costs (Schuman 2005). Operations performance is an indicator on how an organization is moving towards achieving its goals and the actions required to take in order to increase their chances of realizing its goal.

1.1.3 Firms in Kenya Energy Sector

Government of Kenya plays a bigger role in energy sub sector institutional structure as it has a number of bodies with specific objectives. The government bodies comprise of Ministry of Energy and Petroleum (MOEP), Energy regulatory commission (ERC), Geothermal Development Company (GDC), Kenya Generating Company (KenGen), Kenya Electricity Transmission Company (KETRACO), Kenya Power and Lighting Company (KPLC) and Rural Electrification Authority (REA). Private investors do also participate in the energy sector and fall under Independent Power Producers (IPP).

Ministry of Energy and petroleum is responsible for policy formulation that will create a suitable environment for growth, investment and efficient operations in the Kenyan energy sector. Firms in Kenya energy sector are being regulated by Energy Regulation Commission (ERC) as from 2007 in order to protect interest of consumers, investors and stakeholders. The mandate of the commission is to regulate in a fair, transparent and predictive manner in line with government policy and sensitive to stakeholders (Kenya energy Act 2006). GDC is fully owned by government with a mandate of exploring geothermal fields, drilling production wells and managing steam fields with the aim of selling steam to investors in energy sector including KenGen and IPP. KenGen manages all Kenya public power generation facilities which produce approximately 75% of power generated in the country. KETRACO is also a fully government institution created for purposes of developing new high voltage electricity transmission infrastructure to facilitate wide connection and grid interconnectivity to power plants and neighboring countries to facilitate trade. KPLC is the only buyer of electricity obligated by Kenyan laws to buy power from all power generators through a structured power purchase agreement (PPA); KPLC is sole transmitter and distributor of electricity from national grid to consumers in Kenya. IPP have installed capacity of 606MW which constitute approximately 28% of the country's installed capacity and comprises of the following private companies: Mumias –Cogeneration, Ibeafrica power , Tsavo, Gikira Fit hydro, Orpower Geothermal, Rabai Diesel, Thika Power, Gulf Power, Imenti Fit hydro, and Agreko (www.usaid.gov/powerafrica).

Renewable sources of energy like hydro, wind and geothermal are the cheapest and thus preferred currently but the available capacity is not enough to meet the country's demand

and furthermore reliability throughout the year is not guaranteed. Expensive diesel power plants are thus required to supplement power supply especially during dry seasons which automatically raises the cost of power to consumers.

Cheap sources of power generation should be available, reliable and operating at optimum levels as much as possible so as to attract investors and help in reducing or maintaining cost of living (Solomon 2009).

1.2 Research Problem

Maintenance practices in Kenya energy sector affect the fuel cost charge in the electricity bill to final consumers by KPLC. This is because wherever there is low power at a given time from cheap and renewable sources of power generation then from expensively operated diesel plants are operated for continuous electricity supply to consumers. This research will identify existing gaps in maintenance scheduling practices and recommends ways of enhancing them to achieve maximum plant availability for cheap source of electricity generation.

Kenyan energy sector has many research issues that can be addressed so as to solve current challenges which include poor reliability, cost instability, poor infrastructure, maintenance practices, quality of power, and safety of both equipment and personnel.

However there is no research in the Kenyan energy sector which has focused on maintenance scheduling practices which is directly affecting reliability and availability. Matt (2015) noted that maintenance planning and scheduling plays vital roles in the achievement of maintenance excellence. According to Public Utility Research Center University of Florida (2013) more than half of the large firms in Kenya have back- up generators which is an indication of low dependability and reliability of power supply from the power utility.

Many manufacturing firms prefer to carry out preventive maintenance periodically and thus; incorporating scheduling of tasks is of fundamental importance to its success (Hamid 2012). Electricity producing firms in Kenya are mostly under obligation from Kenya Power through power purchase agreement (PPA) to maintain a minimum availability of above 85% (Kamau 2014).

Energy is a major driver of development in Kenya and is well captured in vision 2030; therefore expensive and unreliable energy is a disadvantage to the competitiveness of the country because it will raise the cost of doing business. In September 2013 government of Kenya (GOK) through ministry of energy and petroleum launched 5000 plus Mw program for generating additional power to the national grid within forty months (MOEP website). Best maintenance practices are therefore required to ensure that the expanding power generation will be sustainable and economical to the country. Sound maintenance scheduling is fundamental to success of maintenance which will in turn facilitate production process to generate maximum output (Oke2006).

Maintenance and productivity of firms in energy sector have attracted many researchers because of the challenges in the energy sector and its relationship with operations performance and general success of businesses. Mungatana (2014) focused his research on factors affecting productivity in large thermal power plants in Kenya and Kamua (2014) in his research on maintenance management practices and operations performance in electricity producing stations in Kenya found that maintenance scheduling is widely used. Gerald (2013) and Solomon (2009) compared both maintenance practices and power plants operational performance in Kenya. Oke and Charles (2006) researched on approach for evaluating preventive maintenance scheduling cost. Maintenance scheduling and planning has been demonstrated to be affecting performance of complex systems such as aircrafts (Premaratne2012).

Past studies have not come up with maintenance scheduling practices and its relationship with operations performance in firms in Kenya energy sector. These research seek to investigate how, when and where maintenance activities are being carried out in various types of firms in Kenya energy sector and their effects on operations performance. Understanding this will help players in the energy sector to utilize on maintenance scheduling as a means of reducing costs.

1.3 Research Objectives

The primary objectives of this research are:

i) To establish maintenance scheduling practices commonly used by firms in the Kenyan energy sector.

ii) To determine relationship between maintenance scheduling practices and operation performance of firms in the Kenyan energy sector.

1.4 Value of Study

The study will be beneficial to both top and middle level management to understand the importance of maintenance scheduling and in addressing challenges of maintenance scheduling so as to achieve a higher plant availability and reliability.

The study will also be useful for future planning for the different types of firms in power generation. For those who want to enter into power generation business will be informed by this study on how to negotiate power purchase agreement in terms of availability and reliability and in making decisions regarding maintenance strategies.

This study will also allow maintenance teams of various station to gauge their performances based on maintenance scheduling and hence learn from one another. In addition this study will highlight challenges faced in maintenance scheduling and propose solutions to address the short comings.

The study will also be useful to scholars and those interested in carrying out further research on maintenance scheduling and performance of power generation plants. The findings and research gaps will enable interested parties in developing this new area of study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter first summarizes the importance of maintenance in operations and performance of businesses in the energy sector. The chapter then highlights maintenance issues relating to maintenance scheduling practices and operations performance. There is a review of maintenance scheduling principles and maintenance practices such as conditioned based, time based and reliability based where maintenance scheduling is applied.

Maintenance in power generation is a critical activity because it has an impact in many other sectors of the economy. The way maintenance work is planned, scheduled and carried out affects: availability of production facilities, safety of operations staff and machinery, rate of production, quality of end product and cost of production. The combinations of above factors will in the long run affect the bottom line of companies concerned (Tsang 2002).

Maintenance management is of great importance in maintenance of plants especially complex power generation process where there are many plant technical functions and systems which are interrelated and can cause plant outages. Furthermore some maintenance team deals with events which are very much uncertain and irregular in nature like in cases of breakdowns of machine components or systems. A thorough and systematic approach is necessary in ensuring that maintenance functions are satisfactorily done (Sinha2015). Important pillars that will support effective and efficient maintenance management are information technology, good engineering practices and organization pillar.

It has been acknowledged by many authors that maintenance is a supply chain process with links with both internal and external company processes. To effectively carry out the maintenance process then a holistic alignment with other companies' related processes is important to fulfill external stakeholders' requirements. Alignment both vertically and horizontally between maintenance team and other teams in processes is very important in order to realize effectiveness and efficiency (Peter 2006).There is need to control quality of maintenance actions, scheduling maintenance activities, control of spares and consumables inventory to effectively achieve desired objective of maintenance (Crespo and Gupta 2006).

Liyange and Kumar (2003) and Markeset (2003) noted that there are changes in the way maintenance is being viewed by organizations. They concluded that maintenance was being seen as a value adding process in today's dynamic and competitive business unlike in the past where it was viewed as a way of reducing business risks.

2.2. Maintenance Scheduling Practices

Maintenance scheduling is traditionally seen to be most applicable in preventive maintenance processes Oke (2004). Preventive maintenance is preferred by many organizations because of high costs of breakdown maintenance and its unforeseen interference on production process. Preventive maintenance in its nature will lead to improvement of employees, production systems and equipment safety.

Maintenance scheduling advantages include; minimizing of idle time, reduced breakdowns and delays, effective utilization of human resource from both maintenance and operations leading to lower costs of maintenance. To attain maximum output maintenance scheduling should be supported with continuous improvement, allocation of resources; well documented information of equipment, quality spares availability, skilled workforce and good support from stake holders. Maximum output in Kenyan energy sector is desired because it will address low plant availability and reliability challenges.

Maintenance scheduling for a power plant will be determined by production considerations. The machine parts or equipment to be maintained can be assigned a priority index based on criticality of the unit on production process (Noemi 1994). Emergency maintenance work which directly affects reliability, production process, safety of equipment and personnel will be assigned high priority while routine, preventive and other maintenance works will be assigned criticality index according to priority of tasks among other considerations like availability of personnel and spares.

Plant maintenance can be viewed as a project that contains interrelated and controlled activities and therefore project techniques are being applied (Shinobu 2007). Program evaluation and review technique (PERT) together with critical path management (CPM) are important tools that are being used in maintenance scheduling. The two techniques aid in approximating completion time of maintenance work, allocation of resources and planning of individual activity start and end time. PERT approximate expected activity time by using three estimates that is very optimistic time, most likely time and high pessimistic time (Magutu et al, 2013). PERT recognize the fact that maintenance activities duration are uncertain and hence allocate room for the uncertainties that may result while executing the tasks. While CPM assumes that activity time are deterministic and hence scheduling will be done with certainty to get maintenance completion time.

To be able to use the above tools maintenance team leaders develop a list of all activities to be carried out with immediate predecessors and expected duration for each activity. Once start time of maintenance work is known a Gantt chart is then develop to assist in management and review of maintenance works.

There are various maintenance practices and strategies that have been adopted by different companies with the main aim of minimizing operations and maintenance costs, achieving high plant reliability, attaining high plant production, attaining high plant availability, promoting safety of: employees, environment and machines. Peter (2007) observed that maintenance procedures have been developed so as to address complications and criticality of technical systems alongside their functions.

2.2.1 Maintenance Scheduling Guidelines

Maintenance scheduling principles are very important for success of maintenance work because it gives frame work for scheduling process. The principles will greatly contribute to success of maintenance since it provides guide lines on how scheduling process will be handled at different stages (Richard 2013). Having clear guidelines in the way maintenance work is scheduled in Kenyan energy sector will reduce conflicts and promote utilization of available resources for maintenance work.

Mat (2015) provided six principles of maintenance scheduling principles as: planning for minimum skill level needed, scheduling and job priorities for critical tasks, scheduling from highest skill man power available, scheduling for every work hour available, having crew leader to handle current day's job and measuring performance against compliance to scheduled program. Mat further argued that the principles of maintenance scheduling will lead to utilization of available man hours and skills, aid in handling work according to priority, give room for day's work to be handled by supervisor hence giving room for matching of skills and tasks and finally measuring performance against plan.

2.2.2 Conditioned Based Practices

This technique of maintenance was first put into use by Rio Grande Railways Company shortly before 1950. The company used the technique to monitor coolant, fuels and oil leaks in the engine by detecting changes in pressure and temperature readings. This technique is in use by different firms because it reduces impact of unplanned failures; it is also cheap as compared to other methods because it uses existing subsystems to gather statistical data and can make the whole system to have maintenance intelligence (Ashok 2012).

This is a technology whose aim is to identify maintenance need of an equipment, machine or plant by continuously checking operating conditions and restoring them. It is done to detect failure long before it occurs (Veldman et al., 2011). Conditioned based maintenance (CBM) is a combination of events based on continuous real time monitoring of equipment or systems conditions by use of measuring instruments and sensors embedded on the equipment or external tests taken by portable tools and processed through software. Kelly (1993) noted that CBM was practiced traditionally as inspection – based maintenance. This maintenance technology is most appropriate in the Kenyan energy sector because it eliminate unnecessary plant outage for inspection works and also raises plant availability.

2.2.3Time Based Maintenance Practices

This is a type of preventive maintenance which is scheduled to be done after a given duration with the aim of improving equipment and systems durability and performance by minimizing excess depreciation and impairment. Maintenance activities to be carried out will include cleaning, repairs, inspections, replacements of parts, adjustments, calibrations, tests, among others.

This kind of maintenance will be carried out at set periodic intervals regardless of the status of the plant or equipment. Time based maintenance increase preventive maintenance making it major expense for many industries (Jun- Geol 2007). This kind of maintenance should be avoided as much as possible because it will reduce plant availability especially for cheap sources of power generations.

2.2.4 Reliability Based Maintenance Practices

This has also been refereed by other authors as reliability centered Maintenance. RS Velmurugan (2015) defined RBM as a process which gives priority to plant machinery and systems based on their impact on availability and capacity. This type of maintenance aims to utilize available strategies of maintenance to achieve highest possible capacity and availability while reducing costs. This technique is used to select maintenance activity to be done to ensure that any machine or plant continuously produce what its users require in its present state (Ashok 2012).

The goal of reliability based maintenance is to provide appropriate amount of maintenance at the right time so as to avoid forced plant outage and avoid unnecessary cost at the same time. Facilities, Instruction, standards and techniques USA (2009) in their maintenance scheduling for mechanical equipment noted that this type of maintenance is normally preferred in cases where there is scarcity of skilled man power, diminishing funds and pressure to continue generation due to demand of electric power. Kenyan energy firms also experience scarcity of experts in a given equipment or systems, diminish fund and pressure to continue generating especially when other sources of power generations are not available as a result of drought or breakdowns. In such cases reliability based maintenance can be adapted for the short duration.

2.3 Operations Performance

Effective management of maintenance operations has recently attracted lots of interest from top management of firms because lots of resources can be minimized and hence used for other purposes. The savings comes from innovation and implementation of methodologies and techniques for effective and efficient maintenance scheduling programs (Oke and Charles 2006).

Maintenance plays critical role in ensuring plant asset integrity and process safety and if not well managed can result in tremendous loss of property, environment, life and injuries. There were great loss of property and life when BP (British petroleum) Texas refinery explosion in the year 2005. Leaking Kenya pipeline company fuel pipe line in Kenya 2011 led to secondary explosion and resulted in loss of approximately 100 lives and over a hundred people were hospitalized Red Cross (2011) and cases of fuel spillage on Kenya Pipeline Company line in Makueni county Kenya and KenGen Kipevu thermal plant oil spillage resulted in financial losses and environmental damages in land and sea respectively Daily Nation (16^{th}march, 2016 and 30^{th} Jan, 2012).

2.4 Summary and Conceptual Framework

From the literature above maintenance scheduling is applied in non-urgent work whereby there is adequate time to plan and schedule maintenance activities thus leading to tremendous savings. A well designed maintenance planning and scheduling systems is one of the most effective means of aiding reliability initiatives and development of reliability practices in execution of daily maintenance activities (Rick 2012). Maintenance scheduling performance is affected by people, processes, systems, technology and governance as summarized in **fig. 2.1** below.

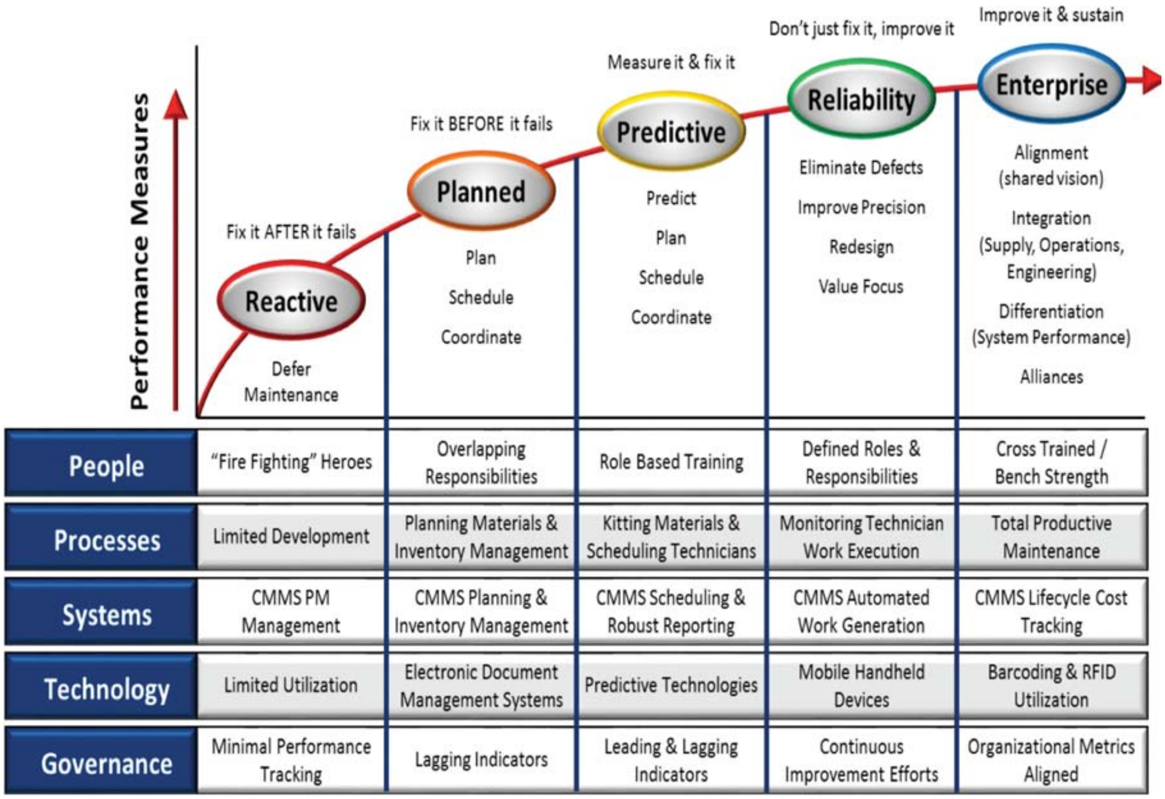
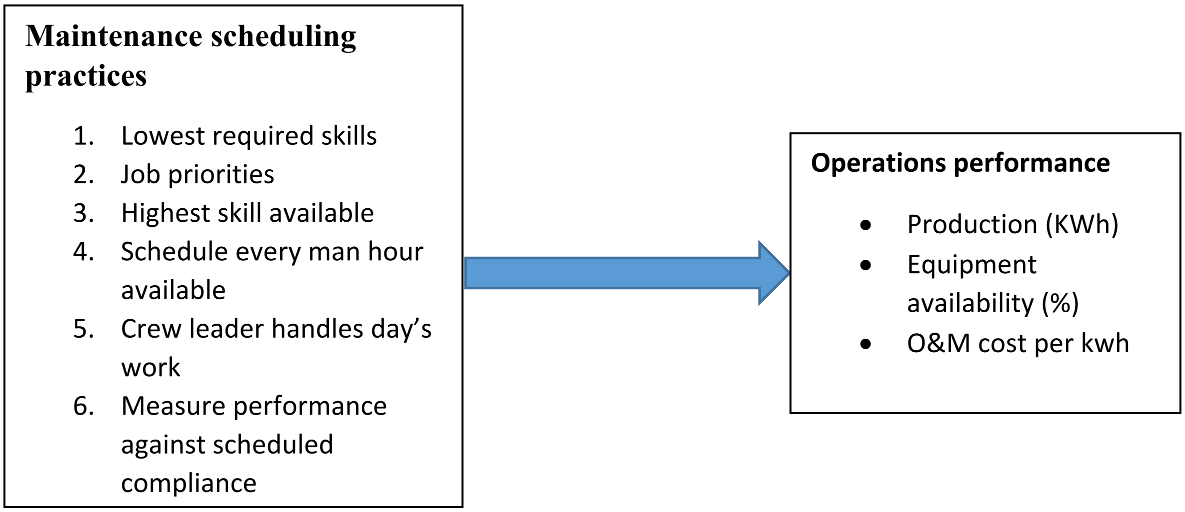


Fig. 2.1 Maintenance Maturity Continuum: Adopted from Mitt (2015) Best practices of maintenance planning and scheduling

It is evident from the literature review that operations performance is a function of plant maintenance. There are also many maintenance practices and maintenance planning and scheduling is one of them. Maintenance scheduling and planning is a supply chain function which involves: Purchasing, inspections, stores, accounting, and technical data base and maintenance supervision.

Fig.2.2 Conceptual framework

Independent Variable **Dependent Variable**



CHAPTER THREE: RESEARCH METHODOLOGY.

3.1 Introduction

This chapter describe plan that was used to generate research questions of maintenance scheduling practices and operations performance in Kenya energy firms. The chapter describe briefly research design, target population, data collection method and data analysis that was be used in the current study.

3.2 Research design

This research involves a cross sectional survey of power generation stations in Kenya both government owned and independent power producers (IPP). Primary data was collected to establish current maintenance scheduling practices, operations performance in terms of plant availability and O&M cost. This research will also adopted descriptive approach so as to compare variables numerically and establish relationships if available.

3.3 Population

By 2013 the power generation mix in Kenya was from: thermal, wind, hydro and geothermal having nine, one, twelve and three stations respectively. It was further found that state owned power stations were generating 87.5% of the total power consumed in Kenya and the other 12.5% by IPP (Gerald 2013).This research targeted to collect data from twenty five power stations to cover all the power generation mix comprising of: Hydro, Geothermal, Thermal, Gas and wind power stations.

3.4 Data collection

This research collected both primary data so as to get relevant information. The data was obtained through a structured questionnaire (Appendix I) which allowed for uniform response and was treated with utmost confidentiality for research purposes only.

This research collected data from Chief engineers and maintenance engineers who are charged with the responsibility of maintaining the power plant and its generation on a day to day basis.

3.5 Data Analysis

Data collected will be coded and cleaned for easy of analysis and interpretation by getting rid of any errors. The data will be analyzed using quantitative methods to determine means, frequencies and standard deviations.

Statistical techniques of linear regression analysis were used to analyze the data of plant availability and scheduled maintenance practices. The proposed model will be of the form:

$$Y = a + b_1X_1+b_2X_2$$

Where: b_1 and b_2 are correlation co-efficient;

Y =Plant performance in terms of monthly availability;

X_1 = Maintenance practices;

X_2 = Number of breakdowns.

The model to Statistical Package for social Sciences (SPSS) was used in the analysis of the data.

The findings of the research have been presented using graphs and tables to reveal information or relationship that may be hidden within the data.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

This chapter gives summarized statistical findings of the research project which were obtained through data analysis. The statistical finding of the research are then discussed and interpreted using the research methodology of linear relationship between maintenance scheduling and operations performance of firms in Kenya energy sector. The research data were obtained exclusively through questionnaires which were emailed to plant managers and engineers in line with research objective.

4.2 Respondents' demographic characteristics

This section analyzed demographic information of individuals who are responsible for operation and maintenance of power generation plants. This was done so as to understand background information, work ability and perception hence getting useful information to the study.

4.2.1 Response Rate

The study had a target of 25 respondents from diverse sources of power generation in Kenya. There were 19 (76%) respondents from this study which is adequate for meaningful analysis. (Mugenda and Mugenda, 1999) noted that at least 70% response is excellent and any analysis from it will be meaningful.

Table 4.1 Response Rate

Target Population	25
Reponses	19
Response Rate	76%

4.2.2Ages of the Respondents

The study obtained the age brackets of respondents with the aim of getting levels of technology applications and acceptance. Technology play a key role in power plants operations and maintenance because of complex machinery systems, processes and monitoring devices. The findings given in Table 4.2 below.

Table 4.2 Ages of the Respondents

		Frequency	Percent	Cumulative Percent
	Below 30	1	5.3	5.3
	30-35	5	26.3	31.6
	35-40	4	21.1	52.6
	40-45	7	36.8	89.5
	45-50	2	10.5	100
Valid	Total	19	100	

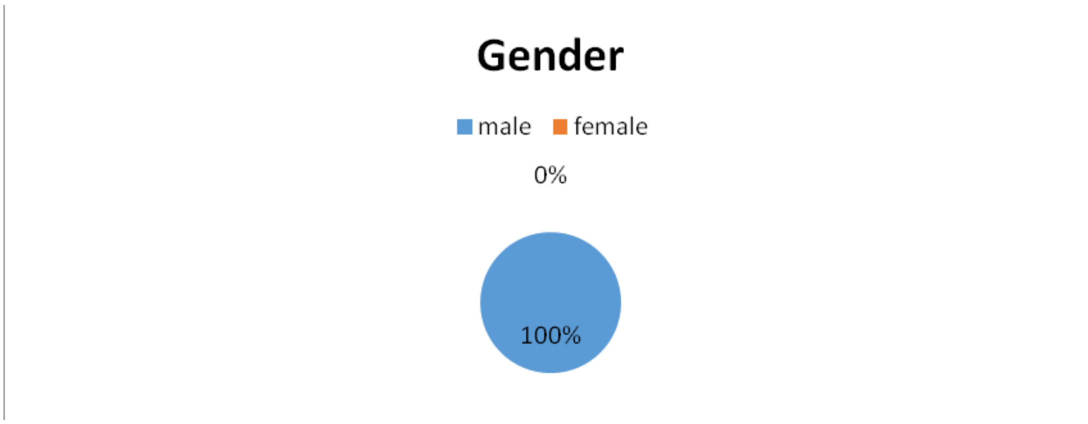
Source: Author (2016)

The study found out that 5.3 percent of the respondents were below 30. 26 percent of the respondents had 30-35 years. 21.1 percent of the respondents had 35-40 years. 36.8 percent of the respondents had 40-45 years 10.5 percent of the respondents had 35-40 years. This implies that respondent population is a young population that has critical responsibility of running and operating the power stations.

4.2.3 Gender of the Respondents

Gender was one of the questions asked under background information. The gender question was sought to reveal the gender impact and disparities on the topic of study

Figure 4.1 is a graphical representation of the gender profile



Source: Author (2016)

It was found out that 100% of the respondents were male. The findings indicate that males dominate in the sector due to mechanical nature of the job that is presumed to be labour intensive and complex in nature by female

4.2.4 Designation

The researcher sought to know the designation of the people task with the responsibility of operations and maintenance of power plants. The findings are as shown in the table below.

Table 4.3 Job Designation of the respondents

	Frequency	Percent	Cumulative Percent
chief engineer	8	42.1	42.1
Engineer	11	57.9	100
Total	19	100	

4.2.5The Plant Year of Commissioning

The researcher sought to find out the Plant year of commissioning. The findings are represented in the table below

Table 4.4 Plant Year of Commissioning

		Frequency	Percent	Cumulative Percent
	Before 1970	1	5.3	5.3
	1971-1980	2	10.5	15.8
	1981-1990	4	21.1	36.8
	1991-2000	3	15.8	52.6
	2001-2010	3	15.8	68.4
	After 2010	6	31.6	100
Valid	Total	19	100	

The findings indicate that over 60 % of the plants were commissioned after the year 1990 indication that majority of the plants are fairly recent and hence of modern technology.

4.2.6 The Preferred maintenance practice

The researcher aimed to find out the preferred maintenance practice. The findings are as given in the table below

Table 4.5 Preferred maintenance practice

		Frequency	Percent	Valid Percent	Cumulative Percent
	Condition based	5	26.3	26.3	26.3
	Time based	13	68.4	68.4	94.7
	Others	1	5.3	5.3	100
Valid	Total	19	100	100	

The findings indicate that most preferred maintenance practice is time based while others are conditional based.

4.2.7 The Frequency of Maintenance

The researcher was interested in finding out the Frequency of maintenance. The findings are represented in the table below.

Table 4.6 Frequency of Maintenance

Frequency of maintenance	Frequency	Percent	Cumulative Percent
Quarterly	1	5.3	5.3
Semi-annually	10	52.6	57.9
Annually	8	42.1	100
Total	19	100	

The findings indicate that maintenance is carried out annually and semiannually.

4.2.8 Breakdown in a month that results in plant outage

The researcher sought to find out the Breakdown in a month that results in plant outage. The findings are represented in the table below

Table 4.7 Breakdown in a month that results in plant outage

		Frequency	Percent	Valid Percent	Cumulative Percent
	1-3	15	78.9	78.9	78.9
	4-6	2	10.5	10.5	89.5
	Above 6	2	10.5	10.5	100
Valid	Total	19	100	100	

The findings indicate that almost all stations have a breakdown in a month that results in plant outage and hence preparedness for repairs is always needed.

4.2.9 Annual Average Plant Availability

The researcher sought to find out the annual average plant availability. The findings are represented in the table below

Table 4.8 annual average plant availability

annual average plant availability		Frequency	Percent	Valid Percent	Cumulative Percent
	76-80	1	5.3	5.3	5.3
	86-90	9	47.4	47.4	52.6
	91-95	8	42.1	42.1	94.7
	Above 95	1	5.3	5.3	100
Valid	Total	19	100	100	

The findings indicate that annual average plant availability is between 86 and 95 days.

4.2.10 Unit Rated Net Output

The researcher sought to identify the unit rated net output (MW) of each of the stations. The findings are represented in the table below

Table 4.9Unit Rated Net Output

unit rated net output		Frequency	Percent	Cumulative Percent
	Below 10	5	26.3	26.3
	11-20	2	10.5	36.8
	21-30	3	15.8	52.6
	31-40	3	15.8	68.4
	41-50	1	5.3	73.7
	51-60	1	5.3	78.9
	61-70	2	10.5	89.5
	Above 70	2	10.5	100
Valid	Total	19	100	

The findings indicated that the unit output that was below 10 was represented by 26.3 percent. That the unit output that was between 11-20 was represented by 10.5 percent, that the unit output that was between 21-30 was represented by 15.8 percent .that the unit output that was between 31-40was represented by 15.8 percent. That the unit output that was between 41-50. Was represented by 5.3 percent .that the unit output that was between 51-60 was represented by 5.3 percent. That the unit output between 61-70 was represented by 10.5 percent. That the unit output that was above 70 was represented by 10.5 percent an indication that output was equally distributed from below 30 to above 70.

4.2.11 Total Annual Sales

The researcher sought to identify the total annual sales made by the Units the previous year. The findings are given in the table below

Table 4.10 Total Annual Sales

The researcher sought to identify the total annual sales made by the Units the previous year

total annual sales	Frequency	Percent	Cumulative Percent
Below 100	3	15.8	15.8
101-200	3	15.8	31.6
201-300	1	5.3	36.8
301-400	3	15.8	52.6
401-500	3	15.8	68.4
801-900	2	10.5	78.9
901-1000	2	10.5	89.5
Above 1000	2	10.5	100
Total	19	100	

The findings indicate that Below 100 was 15.8 percent, between 101-200 was represented by 15.8 percent, between 201-300 was represented by 5.3 percent ,between 301-400 was represented by 15.8 percent, between 401-500 was represented by15.8

percent, between 801-900 was represented by 10.5 percent, between 901-1000 was represented by 10.5 percent and above 1000 was represented by 10.5 percent.

4.2.12 Operation and Maintenance Cost (Ksh/Kwh)

The researcher sought to identify the Operation and Maintenance cost (Ksh/kwh). The findings are provided in the table below

Table 4.11 Operation and Maintenance Cost (Ksh/Kwh)

Annual Operation and Maintenance cost in Millions	Frequency	Percent	Cumulative Percent
0.0-0.20	1	5.3	5.3
0.21-0.40	6	31.6	36.8
0.41-0.60	7	36.8	73.7
0.61-0.80	1	5.3	78.9
0.81-.1.00	1	5.3	84.2
Above 1.00	3	15.8	100
Total	19	100	

The findings indicate that the total annual maintenance cost of between 0-0.20 was incurred by 5.3 percent of the respondents, the total annual maintenance cost of between 21-40 was incurred by 31.6 percent the total annual maintenance cost of between 41- 60 was incurred by 36.8 percent of the respondents the total annual maintenance cost of between 61-.80 was incurred by 5.3 percent of the respondents the total annual maintenance cost of between 81-100 was incurred by 5.3 percent of the respondents the total annual maintenance cost of Above 100 was incurred by 15.8 percent of the respondent.

4.2.13 Type of Electricity Generation

The researcher sought to identify the Type of electricity generation. The findings are represented in the table below

Table 4.12 Type of Electricity Generation

Type of electricity generation		Frequency	Percent	Cumulative Percent
	Hydro	9	47.4	47.4
	Geo	6	31.6	78.9
	GT	1	5.3	84.2
	Thermal	2	10.5	94.7
	Wind	1	5.3	100
Valid	Total	19	100	

The findings indicate that the type of electricity generation was Hydro at 47.4percent, Geo at 31.percent, GT at 5.3 percent Thermal at 10.5 percent Wind at 5.3 percent

4.3: Maintenance Scheduling Practices

The researcher sought to identify the Maintenance scheduling practices. The table below is the mean and the standard deviations of the responses .The mean is the representation of the majority opinion of the respondents in reference to the likert scale data which 1.

=Strongly Disagree 2. = Disagree 3. = Neutral 4. =Agree 5. =Strongly Agree. The findings are represented in the table below

Table 4.13 Maintenance Scheduling Practices

Maintenance scheduling practices	Mean	Std. Deviation
Gives priority to critical tasks	4.58	0.61
Well established frame work for scheduling processes	4.26	0.56
Computer base monitoring system	4.21	1.13
Schedule work for highest skill available	3.95	1.18
Measure performance based on schedule compliance	3.89	0.88
Gantt charts in maintenance scheduling	3.63	0.83
Plan for lowest skill required	3.58	1.12
Utilize all available man hours	3.26	0.93
Supervisor handle day's work without necessarily following schedule program	2.79	1.03

The findings show that the respondents agreed that there is a Well-established frame work for scheduling processes as indicated by the mean of 4.2632 that there is a Computer base monitoring system as indicated by the mean of 4.2105, that they Schedule work for highest skill available as indicated by the mean of 3.9474, that performance is Measured based on schedule compliance as indicated by the mean of

3.8947 that there is use of Gantt charts in maintenance scheduling as indicated by the mean of 3.6316 ,that they Plan for lowest skill required as indicated by the mean of 3.5789.The respondents were neutral in their opinion on whether they Utilize all available man hours as indicated by the mean of 3.263 or whether Supervisor handle day's work without necessarily following schedule program as indicated by the mean of 2.789

4.4 Relationship between maintenance scheduling practices and operations performance.

A regression model was applied to establish the effect of maintenance scheduling practices on operational performance of energy firms in Kenya .The dependent variable is operational performance of energy firms in Kenya while the independent variable is maintenance scheduling practices and cost O&M cost. The analytical model used in analyzing the relationship between the dependent and independent variables is:

Coefficient of determination which explains the level to which changes in the dependent variable can be related to the change in the independent variables or the degree of variation in the dependent variable that is caused by all the four independent variables Statistical package for social sciences (SPSS V 21.0) was used to code, enter and compute the measurements of the multiple regressions.

Table 4.14: Model Summary

Relationship between maintenance scheduling and operational performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.923[a]	.852	.667	.48362	.852	4.601	10	8	.020

R-Squared is applied in statistics to evaluate model fit. R-square is 1 minus the ratio of residual variability. The adjusted R^2 (coefficient of multiple determinations), is the percent of the variance in the dependent explained uniquely or jointly by the independent variables. 67 % of the operational performance of firms in the energy sector could be explained by the combined effect of the predictor variables.

Table 4.4 Summary of One-Way ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.760	10	1.076	4.601	.020[b]
	Residual	1.871	8	.234		
	Total	12.632	18			

The study used One-way ANOVA to determine the degree of significance of the regression model where a probability value of 0.2 was established. This shows that the regression relationship was highly significant in predicting how maintenance scheduling affects operational performance. The F calculated at 5% level of significance was 4.601.since F obtained is greater than the F critical of 3.87, this is an indication that the overall model was significant.

Table 4.5Regression Coefficients results

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-1.1	1.89		-0.58	0.58	-5.46	3.26
Breakdown in a month that results in plant outage	0.05	0.22	0.04	0.23	0.82	-0.46	0.56
Well established frame work for scheduling processes	0.88	0.26	0.59	3.43	0.01	0.29	1.47
Computer base monitoring system	0.5	0.17	0.68	3.02	0.02	0.12	0.88
Gantt charts in maintenance scheduling	0.08	0.21	0.08	0.38	0.71	-0.41	0.57
Plan for lowest skill required	0.24	0.2	0.33	1.21	0.26	-0.22	0.71
Measure performance based on schedule compliance	-0.4	0.15	-0.42	-2.58	0.03	-0.75	-0.04
Supervisor handle day's work without necessarily following schedule program	0.46	0.14	0.56	3.29	0.01	0.14	0.77
Schedule work for highest skill available	-0.15	0.21	-0.21	-0.71	0.5	-0.64	0.34
Gives priority to critical tasks	0.63	0.36	0.46	1.78	0.11	-0.19	1.45
Utilize all available man hours	-0.19	0.24	-0.22	-0.82	0.44	-0.74	0.36

The regression equation above has established that holding all other factors constant (no maintenance scheduling) performance of energy companies would be at -1.1.a unit increase in Breakdown in a month that results in plant outage leads to a 0.05

improvement in performance ,a unit increase in Well-established frame work for scheduling processes lead to a 0.88 improvement in operational performance .a unit increase in Computer base monitoring system lead to a 0.5 improvement in operational performance ,a unit increase in Gantt charts in maintenance scheduling lead to a 0.08 improvement in operational performance, a unit increase in Plan for lowest skill required lead to a 0.24 improvement in operational performance, a unit increase in Measure performance based on schedule compliance lead to a -0.4 improvement in operational performance a unit increase in Supervisor handle day's work without necessarily following schedule program lead to a 0.46 improvement in operational performance ,a unit increase in Schedule work for highest skill available lead to a -0.15 improvement in operational performance, a unit increase in Gives priority to critical tasks lead to a 0.63 improvement in operational performance a unit increase in Utilize all available man hours lead to a -0.19 improvement in operational performance .

4.5 Interpretation of the Findings

From the above regression model, the study found out that adoption of maintenance scheduling practices enhances the operational performance of firms in the Energy sector .The independent variables that were studied explain a substantial 67% of the operational performance of as represented by adjusted R2 (0.667). This then shows that the independent variable is related to 67% of operational performance other factors and random variations which were not studied in this research contribute 33% of the total operational performance.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter summarizes the findings, conclusions and the recommendations of the researcher based on the objectives of the study.

5.2 Summary of the findings

This section provides a summary of the findings from the interpreted data.

5.2.1 Maintenance scheduling processes

It was evident that the maintenance practices in Kenya energy sector have different levels of application. The order of maintenance practices in terms of level of application is as follows;

Priority of critical task was found to be widely applied and given highest importance among other maintenance practices followed by established framework for maintenance practices, use of computer based monitoring systems, scheduling from highest available skill, measurement of performance based on compliance to schedule program and use of Gantt charts in that order.

Supervisor handling a day’s work is the least applied maintenance practice across Kenya energy sector followed by utilization of available man hours and planning for lowest skill required respectively.

There’s need to empower supervisor’s to handle day’s work and also utilize available manpower to significantly improve operation performance.

Maintenance scheduling practices and operation performance off firms are strongly related by approximately 67%. Therefore any energy firm targeting to improve operation performance should develop system and processes to improve maintenance scheduling practices.

There is at least a breakdown in all types of Kenyan power generation power plants.

5.3 Conclusion

Based on the study findings there's a strong relationship between maintenance scheduling practices and operation performance of power generation in Kenya. It was also evident that highest priority is given to critical task and supervisors are not empowered to take charge of daily program.

5.4 Recommendation

In relation to the findings maintenance supervisors should be empower and given authority to plan and take control of daily maintenance activities and make minor changes if required in the scheduled tasks. Empowered supervisors will be beneficial in utilization of maintenance resources including man power.

Utilization of available man power should also be given more priority because this will reduce the total cost of maintenance and hence improve operations performance. Lastly another maintenance practice that need to be given more attention by managers of power plants is planning for lowest required skills required for any given task. The lowest skilled required to carry out task should be clearly defined and complied to so as to improve the quality of maintenance.

5.5 Suggested Areas of further studies

Given that maintenance scheduling practices contributes to operations performance by 67% then there is need to research on other 33% factors that affect performance. This research on the remaining factors might lead to zero or reduced plant breakdowns and thus lead to operation excellent.

APPENDIX I: QUESTIONNAIRE

INTRODUCTION

This is to kindly request for your attention to fill below questionnaire which is designed to collect information regarding **Maintenance Scheduling and Operations performance in firms in Kenya Energy sector**. The information obtained shall be treated with utmost confidentiality for academic purposes only. Your participation is highly appreciated.

SECTION A: PRELIMINARY INFORMATION

1. What is your age group?

   Below 30: (   ) 30 – 35 (   ) 35 – 40 (   ) 40 – 45 (   ) 45 – 50 (   ) Above 50 (   )

2. What is your gender? Female ( ) Male ( )
3. Your designation?
   i. Manager (   );
   ii. Chief Engineer (   );
   iii. Technician (   ).
   iv. Others …………………………………………………
4. Give name of your Company…………………….

   …….Station……………………..
5. Which year was your plant commissioned? ………………………

6. If there are many units of generation in 5 above give years of commissioning provide as:

    i. Unit 1……………………….;
    ii. Unit 2……………………….;
    iii. Unit 3……………………….;
    iv. Unit 4……………………….;
    v. Unit 5 ……………………….;
    vi. Unit 6 ……………………….;
    vii. Unit 7 ………………………..

SECTION B: MAINTENANCE SCHEDULING PRACTICES

7. To what extent has your firm implemented the following maintenance scheduling practices in an effort to improve performance: Please use a tick (√) to select the most appropriate answer in relation to your plant, where;

1. =Strongly Disagree 2. = Disagree 3. = Neutral 4. =Agree 5. =Strongly Agree

	1	**2**	**3**	**4**	**5**
a. The firm has a well-established framework for scheduling process.					
b. The firm has computer based monitoring system for your plant.					
c. The firm use Gantt Charts in maintenance scheduling.					
d. The firm plan for lowest skill required for each task.					
e. The firm measure maintenance performance based on schedule compliance.					
f. Supervisors handle day's work without necessarily following scheduled program.					
g. The firm schedule work from highest skills available.					
h. The firm gives priority to critical tasks.					
i. The firm utilize all available man hours.					

8. Which maintenance practice does your organization prefer?

    i. Breakdown Maintenance (   );

    ii. Conditioned Based Maintenance (   );

iii. Time Based Maintenance ( );

iv. Reliability Based Maintenance ( );

v. Others ………………………………………………………….. ( ).

9. How frequently do you stop generation to carry out Plant Scheduled Maintenance?

i. Monthly ( );

ii. Quarterly ( );

iii. Annually ( );

iv. Semiannually ( );

v. Two years ( );

vi. Between two and five years ( );

vii. Above five years ( ).

10. How many times are you called in a month to attend to unscheduled work?

i. 0 -2 ( ).

ii. 3-5 ( ).

iii. 6-7 ( ).

iv. Above 8.

11. How many unscheduled work(s) in 11 above result in plant outage in a month?

i. 0 ( ).

ii. 1-3 ( ).

iii. 4-6 ( ).

iv. Above 6 ( ).

SECTION C: Operations Performance

12. To what extent has your firm performed in the following areas: Please use a tick (√) to rate extent of achievement in relation to your plant, where;

a) What was your annual average plant availability last year?

i) Below 60% ( )

ii) 60% - 65% ( )

iii) 65% - 70% ( )

iv) 75% - 80% ( )

iv) 80% - 85% ( )

v) 85% - 90% ( )

vi) 90% - 95% ( )

vii) Above 95% ( )

b) What are the units rated net output (MWH)

i) Unit 1………………;

ii) Unit 2………………;

iii) Unit 3 ………………;

iv) Unit 4………………;

v) Unit 5 ………………;

vi) Unit 6………………;

vii) Unit 7 ……………….

c) What were the annual unitssold last year? …………………..(GW)

d) How many outages did you experience last month?

i) Forced outages …………..;

ii) Planned outages ……………

e) How many machines and systems related accidents were reported last year?

i) None ( ).

ii) 1-3 ( ).

iii) 4-6 ( ).

iv) Above 6 ( ).

f) What was your average operation and maintenance cost per KWh last year?

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