EFFECT OF TOTAL PRODUCTIVE MAINTENANCE PRACTICES ON THERMAL POWER PLANT PRODUCTIVITY: A CASE STUDY OF KIPEVU II POWER PLANT

BY

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DECLARATION

This project is my original work and has not been submitted for an award of any degree in any other university

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ABBREVIATIONS AND ACRONYMS

CMMS – Computerized Maintenance Management Systems

EAPP – Eastern Africa Power Pool

FDI – Foreign Direct Investment

GWh – Gigawatt hour

HFO – Heavy Fuel Oil

KPI – Key Performance Indicators

Ksh – Kenya shilling

MW – Megawatt

NCC – National Control Council

NEMA – Nation Environmental Management Authority

OEE – Overall Equipment Efficiency

PEIC – Power Engineering Industries Com

TPCL – Tsavo Power Company Limited

TPM –Total Productive Maintenance

UK – United Kingdom

VIF – Variable Inflation Factor

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DEDICATION

This project is a dedication to my mother, brothers, sister, and colleagues at Kipevu II power plant.

ABSTRACT

This study focused on the effect of total productive maintenance implementation on productivity at Kipevu II thermal power plant. According to this study the TPM practices considered were safety, training, quality maintenance, planned maintenance and autonomous maintenance. While productivity was represented by equipment availability, dispatch compliance, scrap material production, customer satisfaction rating and rate of meeting operations objectives. Kipevu II power plant has resulted to TPM as a measure of survival in a very competitive electricity generation industry. This research employed a longitudinal case study design, where secondary data was used. Multiple linear regression analysis has been used to analyze data collected from the record for Kipevu II power plant covering a period of sixteen and a half years. The data was then discussed. It was found that there exist a strong relationship between TPM implementation and productivity. Planned maintenance had the greatest effect on productivity. It was recommended that thermal power plant should focus attention on improving the TPM practice of planned maintenance, in order to improve their productivity. Future research can look at the effect of TPM practices on electricity generating companies using renewable sources of power.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

The productivity of an organization is largely dependent on the maintenance policies being adopted. The best policy is that which focuses on maximizing the productivity of each and every resource in the entire organization, since an organization is as strong as its weakest link. High productivity results in increased outputs from a small measure of inputs, leading to a reduction in the cost of production. This enables the company to compete on cost leadership thus increased profitability. Total productive maintenance (TPM) seems to be the most appropriate maintenance policy because; it focuses on the organization as a whole, it enables organizations to utilize the available resources optimally by focusing on improving overall equipment efficiency (Nakajima, 1988). TPM has a multifaceted approach brought to life by its eight pillars, which are; continuous improvements, autonomous maintenance, planned maintenance, quality maintenance, education and training, office TPM, 5S and safety health and environment and (Ahuja & Khamba, 2008).

This research was anchored on the resource-based view and the theory of constraint. According to the proponents of resource-based view, a firm can formulate a strategy on the basis of the resources it controls (Penrose, 1959). This theory is relevant because, power plants own resources, competencies and capabilities that are unique. In keeping with this theory, the ownership, and management of this resources can determine how profitable an organization will be. Concepts like total productive maintenance can be adopted for effective resource management that will eventually lead to an increase in organization's productivity. The second theory that hypothesizes the TPM-productivity relationship is the theory of constraints. It's based on the proposition; the rate of goal achievement in a goal oriented system is limited by at least one constraint. According to Goldratt and Cox (1986), once a system has been relieved of its constraints, it will lead to an increased throughput.

Electric generating power plant technology has rapidly advanced. Power plants running on renewable energy sources have undergone numerous developments over the years, with each upgrade, performing better than the last and being more cost effective to maintain. This has rendered Kipevu II power plant running on non-renewable energy source expensive to operate thus less productive. Kipevu II thermal power plants is thus under pressure to reduce costs in order to meet the targets on its key performance indicators like availability, dispatch compliance, reliability, capacity factor, mean time between failures and operating effectiveness. Kipevu II power plant has thus resulted to freezing employment and cutting training budget in an effort to cut cost, which has left the employees demotivated. Inspite of the measures that Kipevu II power plant has taken, productivity has continued to decline due to the rapidly changing demand environment. This situation has led to the execution of TPM practices that focus on improving equipment productivity, necessitated by the need to reinstate the high productivity (Saint-Paul, 2008).

1.1.1 Total Productive Maintenance

The word "total" in total productive maintenance has three meanings. Total employee involvement, total maintenance and total effectiveness (Wakaru, 1988). Productive maintenance refers to maintenance focused on boosting equipment output per every unit of resource input, with no negative impacts on its quality. The productivity perspective is aimed at increasing equipment output by reducing the cost of its inputs

(Ahuja & Khamba, 2008). As stated by Van der WalD (2002), TPM is a program for maintenance activity improvement, by the participation of all employees. This definition does not relate TPM with productivity and equipment efficiency. Sharma, Kumar and Kumar (2006) argue that TPM involves optimizing the usage of equipment to establishing an intensive approach towards the maintenance of equipment in its lifetime. This definition fails to insist on the involvement of all employees. According to Bamber, Sharp and Hides (1999), TPM is an output focused maintenance that depends on the participation of all employees. This definition is quite shallow in the sense that it’s not clear on the ultimate objective of TPM.

Raouf (1994) defines TPM as a cost efficient, cross-functional, interdepartmental and labor-intensive system of preventive maintenance for optimizing equipment effectiveness. This definition does not show how the employees organize themselves during TPM activities. Nakajima (1988), reports that (TPM) is a cross-departmental and all employee productive maintenance activity, organized in small groups with the aim of optimizing overall equipment effectiveness, for the equipment entire life span. This definition clearly indicates the need for inter-departmental interaction, the participation of all employees who are organized in small groups, it's evident that the aim is to optimize the overall equipment efficiency, though this definition failed to bring out clearly the aim of cost efficiency. The definition also does not stress the need to view this concept as a process that is continuous in nature rather than an event practiced once in a while in the life of the equipment (Ireland & Dale, 2001).

Total productive maintenance is a daily maintenance process cutting across all departments, functions and management levels that rely on participation of all employees, organized in small groups that are tasked with the mandate of maximizing, overall equipment efficiency in the most sustainable and cost-efficient manner possible, its ultimate goal is to achieve a perfect production system, where there are zero equipment break down, zero defects and zero accidents and achieve maximum customer satisfaction. TPM is important to thermal power plant because it will lead to lower maintenance cost, in the long run, reduces accidents, increase labor productivity and staff motivation due to the effect of job enrichment. It also enables the operators to be multi-skilled (Ahuja & Khamba, 2008). Thermal power plant stands to gain from TPM implementation by increased equipment reliability, maintainability, and availability. TPM also leads to the production of quality services and products (Narayan, 2012).

1.1.2 Productivity

Raouf (1994) describes capital productivity as the rent earned from an invested capital. This definition is very general. Freeman (2008) defines productivity as the ratio of a process output to its corresponding measure of input. Both definitions fail to show the reasons why productivity is important to an organization. According to Ahuja and Khamba (2008), productivity is the reduction of unplanned plant interruption due to stoppage and breakdown by customizing the equipment to allow quick changeover, resulting in increased capacity and enhance equipment availability. The definition by Ahuja and Khamba (2008) is extensive and very particular to capital productivity. Productivity can be further categorized under labour and capital productivity, both of which are quantifiable. Productivity is the ratio of results produced to resources used in the production of such results. All production processes target to maximize productivity, by producing maximum output with least resources. This is made possible by improving the condition of equipment using a promising maintenance practices, like TPM. The condition of the equipment can be a constraint to productivity if the following losses are not addressed, equipment breakdown, long adjustment time, equipment loading loses, long equipment idling time, derating and planned downtime losses (Narayan, 2012). Efficiently maintained equipment must meet it capital productivity target (Raouf, 1994).

Productivity can be measured by assessing equipment availability. The other measure of productivity is dispatch compliance. Dispatch compliance of a power plant refers to the ability to supply the national grid with electricity as per national control council (NCC) request. Equipment breakdown is a major cause of the failure to honor the request from NCC. Scrap production rate is another good indicator of productivity. The source of the scrap is normally broken spare parts. With a high rate of spare parts replacement, the output per resources input goes down, resulting in poor productivity. According to Ireland and Dale (2001), customer satisfaction rating is another independent indicator of productivity. If the productivity of the power plant is low it will reflect on the type of service the organization offers the customers and as a result, the customer will rate the organization poorly, due to the poor services offered. The rate of meeting operations objectives (these objectives is equipment reliability) of the power plant, is a reflection of the level of the productivity attained. Therefore, if the objectives are met halfway the productivity will increase by only 50% (Venkatesh, 2007).

1.1.3 Total Productive Maintenance and Productivity

Traditionally production costs were minimized by increasing the mean time between failures of the production equipment on one hand and by minimizing maintenance costs on the other. TPM advocates for the improvement of production equipment effectiveness and quality. Productivity is the financial well-being of an organization brought about by the efficient utilization and management of resources. There exist numerous ways of resource utilization and management. TPM being one of them, it ensures the reduced occurrence of unexpected machine breakdowns that disrupt production leading to losses. TPM employs overall equipment effectiveness (OEE) methodology which inculcates metrics from all equipment manufacturing states guidelines into a measurement system that helps maintenance and operations teams improve equipment performance thus reducing equipment cost of ownership (Ahuja & Khamba, 2008).

According to Vorne (2013), equipment efficiency is determined by its availability, performance and the quality of its products, these values are also used in determination of equipment productivity. The overall goal of TPM is to raise the overall equipment effectiveness (OEE). TPM employs OEE as a quantitative metric for measuring the performance of a productive system (Jeong & Phillips, 2001). TPM practices aim to improve equipment and labor productivity, and eventually to secure zero equipment failure, zero defects and rework and zero industrial accidents (Shirose, 1999). TPM practices enable improvement of the performance of production facilities by continuously and systematically addressing the sources of major losses and wastes inherent in the production systems (Gupta, Sonwalkar &Chitale, 2001). TPM implementation can significantly contribute towards improvement in organizational behavior in the manufacturing enterprises leading to world-class competitiveness (Ahuja, Khamba,&Choudhary, 2006).

1.1.4 Thermal Power Stations in Kenya

In Kenya thermal power station use fossil fuel to run an internal combustion engine, which is mechanically coupled to an alternator rotor, the rotation of the rotor results in the generation of electric power. Table 1.1 shows the structure of the seven thermal power plant companies situated in Kenya and their respective electricity generation capacity.

Table 1.1: Licensed Thermal Power Plants in Kenya

Company	**Capacity(MW)**
KENGEN	275.5
IBERAFRICA	108.8
TSAVO POWER	74
RABAI POWER	90
THIKA POWER	87
TRIUMPH POWER	83
GULF POWER	80

Source: Energy Regulatory Commission of Kenya.(2016).

The thermal power plants have been beneficial in maintaining grid stability due to their flexible nature. They have benefited the community by providing employment. They attract less initial cost outlay as compared to other electricity generating plants, they can be installed at any place irrespective of the existence of fuel, as long as the fuel can be transported to the plants, they require less space as compared to hydroelectric power plants. The main disadvantages of the thermal power plants include the pollution of the environment by emitting large volumes of smoke and fumes, and the relatively high operating cost when compared to hydroelectric plants. Alternative sources of electricity include: hydroelectric plants, which utilizes the energy of the falling water to drive the turbine, which in turn runs the generator to produce electricity; solar power which converts the sun rays into electric energy by the photovoltaic cells; geothermal power plants which taps pressurized steam from the earth's core and use it to generate electricity; wind turbine which uses the rotor blades to harness the wind energy that is used to generate electricity (Electrical4u, 2016). Table 1.2 shows the generating capacity of each power source as well as its potential.

Table 1.2 Power Generation Mix in Kenya

Source of power	**Capacity**	**Potential**
Hydropower	820.6 MW	3,200 MW
Fossil fuel	798.3 MW	-
Geothermal	588 MW	10,000 MW
Cogeneration using sugarcane bagasse	26 MW	300 MW
Solar	0.47 MW	-
Wind power	25.5 MW	1,000 MW
Coal power plant	-	900 MW
Total	**2,258.37 MW**	**15,400 MW**

Source: Ministry of energy (2016),

1.1.4.2 Kipevu II Power Plant

Kipevu II power plant is also referred to as Tsavo Power Company Limited (TPCL), it has an operation and maintenance contract with Wartsila Eastern Africa Limited. Kipevu II power plant is owned by a consortium of international power developers and financiers. The electricity generated is sold to Kenya Power. (Actis Capital, 2016). The raw material for the power plant is Heavy Fuel Oil (HFO). The power company started operations in the year 2000. At the time Kenya`s electricity generating system was largely hydro based and in the past, severe drought had caused great shortfalls in electricity supply, in 1997 the supply shortfall had hit 750 GWh. Electricity demand over the last fifteen years has averaged a growth rate of 4.6 per cent, and during the same period the annual growth rate has ranged from between 2.8 per cent and 5.7 per cent, it was clear that electricity generation had therefore not kept pace with demand, there was a need to boost power supply. It was time to also improve the balance between thermal and hydropower capacity in order to make the generation system increasingly less vulnerable to weather influences (Power Engineering International Com, 1999). On these grounds, Kipevu II power plant was constructed.

Since the construction of Kipevu II power plant to date, eight more thermal power plants have been constructed. Kipevu II power plant capacity is 74MW, and its market share is 3.3%. Kipevu II power plant has been used by upcoming thermal power plants as a benchmark on grounds of health, environmental and safety practices, and employee development programs. To the community around it has helped them to access social amenities like water and electricity. It has helped in the beefing up of security of the estates near Kipevu II power plant by virtue of frequent police patrols. Through its numerous corporate social responsibilities, it has managed to support learning institutions by equipping them with learning materials (PEIC, 1999).

To the economy it has created employment opportunities, directly and indirectly, it has contributed to technology transfer between Kenya and the country supplying the equipments, it has also led to a drastic reduction in electricity supply shortfall. It has reduced the excessive dependence on the hydroelectric power plants which are prone to drought. It has stabilized the grid voltage and frequency. It has also acted as a learning and support partner for other thermal power plants in Kenya. Being the first thermal power plant its technology has become obsolete, so it is being faced with a high cost of upgrading entire systems rather than replacing of single parts, this has ended up raising Its maintenance cost. It's clearly not as efficient as modern thermal power plant running on current technology. With continued tightening of air quality legislation locally and globally it's becoming difficult to meet the required targets. With the high cost of upgrading, the power plant runs a risk of being penalized (Kenya Gazette Supplement, 2014)

The other challenge facing Kipevu II power plant is the reduction in dispatch allocated to thermal power plants from 38% to 13%. This has been occasioned by the high cost of buying power from thermal power plants. Herbling (2016) reported that fossil fuel thermal power plant price the electricity they generate at between Ksh. (50-20) per KWh depending on the level of refinement of the fossil fuel. At Ksh. 50 is the refined diesel also used by cars while at Ksh. 20 is the heavy fuel oil (HFO). Hydroelectric power plants at Ksh. 3 per KWh, Mumias cogeneration at Ksh. 6 per KWh, geothermal at Ksh. 7 per KWh, Biojoule's at Ksh. 10 per KWh and finally Strathmore University's solar power at Ksh. 12 per KWh. According to Castellano, Kendall, Nikomarov and Swemmer (2015), geothermal cost Ksh. 5.6 per KWh, hydro Ksh. 9.1 per KWh and thermal power plants Ksh. 35-44 per KWh. The challenges facing Kipevu II power plant paint a discouraging picture of what the future holds for its employees. There is a need to motivate the employee in order to change the situation (Narayan, 2012).

Total productive maintenance could easily be used to address these challenges through its emphasis on training. Instead of upgrading entire systems, trained maintenance staff could be engaged to conduct planned maintenance and continuous improvement activities on plant equipment. Making them handle and perform as well as the modern equipment in the market using current technology. According to

Venkatesh (2007), by involving the operators in maintenance it helps to motivate them because it's an opportunity to acquire multiple skills and it's job enrichment. At the same time it also acts as a cost-cutting measure because it may lead to the reduction of redundant maintenance employees by attrition. Alternatively cost reduction might be achieved through increased employee efficiency and experience. Increased training and continuous improvement on equipment are among the core pillars of TPM (Narayan, 2012).

1.2 Research Problem

Total productive maintenance is a concept that focuses on boosting the productivity of an organizations resource. TPM has to increase manufacturing productivity, by implementing the eight pillars of total productive maintenance to minimize input and maximize output (Rajan & Sajumon, 2013). TPM is an operational strategy that aims at overcoming the production losses caused by equipment inefficiency. By ensuring that the strategy is well cascaded to the functional level, TPM stand a better chance of promoting organization productivity. TPM provides better quality and quantity at a reduced cost and in a timely manner, with a guarantee of safety (Nakajima, 1988). Productivity being the ratio of output to input, It means then, that by improving productivity production cost per unit reduces, resulting in an increase in the competitiveness of the products and services. Increase in products competing power increases its sales and subsequently organizations profits. For this productivity to be sustained it must be anchored on supportive practices. This study believes that TPM practices offer organizations a chance of sustained productivity. According to Stainer (1995) harmony between management and labour is crucial for any productivity to be realized and sustained. He also articulated that the realized returns from productivity must be shared equitably and finally productivity leads to increase in employment. From this, we can see the challenges that productivity could solve and the obstacles that can hinder the implementation of TPM.

With the privatization of government-run power plants, the market has created room for cartels to manage the market, thereby making small and medium sized industries operate at losses, as demonstrated in a research by Simplice and Asongu (2015). The government plans of joining the Eastern Africa power pool (EAPP) will extend interconnectivity, power plants which generate from cheaper sources stand to benefit most because they will appeal more to buyers. Fossil fuel power plant cost of power is subject to the ever-fluctuating fuel prices, it's generally expensive as well when compared to power from renewable sources. Strict regulation by the financiers (World Bank) and government agencies (NEMA) to meet challenging emission target in order to conserve the environment will hinder growth in the sector. Technological advances in power generations, more so in the renewable energy sector is increasing this has made them more reliable and dependable as a result encouraging the shift from non-renewable to renewable sources of energy. Old thermal power plants have been left to generate during peak duration when the demand is more than the efficient power plants can supply. The geothermal and hydroelectric power plants are much cheaper than thermal power plants (Herbling, 2016). With the current investment in wind power plant, the power generation from thermal is likely to diminish even further. Other challenges facing thermal power plants include demotivation of the employee by the low profits, which translates to meager pay, leading to low labor productivity, lack of operators confidence on equipment maintenance due to lack of exposure on maintenance activities raise in maintenance cost, due to recurring replacement of faulty expensive spare parts, low customer satisfaction due to the high cost of operation and maintenance, forcing the price of a unit of electricity relatively high compared to the other alternative sources of electricity (PEIC, 1999). By employing TPM the organization will witness an increase in overall equipment efficiency (Ngugi, 2015). Kipevu II power plant will also benefit from a reduction in the cost of maintenance if TPM practices are fully implemented. TPM has proven to be a reliable technique for improving employee skills and know how thereby motivating its employees (Narayan, 2012).

The following studies have been done on TPM. Venkatesh (2007), researched on the direct benefits of TPM implementation. Raouf (2004) did a study on the relationship between safety and TPM maintenance activities. Raouf (1994), researched on improving capital productivity through maintenance. He established that the use of production equipment effectiveness (PEE) methodology would yield capital productivity. Ahuja and Khamba (2008) focused on seeking the success factors for eliminating barriers to TPM implementation and found out that the success factor included the establishment of an elaborate TPM support system. According to Ireland and Dale (2001) study on the implementation of TPM in three companies, It emerged that, it’s possible for a business facing difficulty to survive because of a successful implementation of TPM. Masjuki and Taha (2004) conducted a survey study in Malaysia seeking to find the extent of TPM implementation among small and medium size industries. The study revealed that the extent of TPM implementation in Malaysia was low. Shaaban and Awni (2014) researched on the reason why TPM deployment was successful in Egyptian fast moving consumer goods companies. Aspinwall and Elgharib (2013), research on how TPM has been implemented in large and medium size organizations in the United Kingdom. It was found that culture was the main obstacle to the successful implementation of TPM in the UK large and medium size manufacturing companies.

A number of scholars have researched on TPM practices in Kenyan firms. Ngugi (2015) study explored the relationship between the implementation of TPM practices and the equipment effectiveness. He adopted a longitudinal, case study research design of Bamburi cement. Ateka (2013) conducted a research on the adoption of TPM practices in large manufacturing firms located in Mombasa County. Induswe (2013) conducted a study to investigate the challenges, success factors, and benefits of TPM implementation in large manufacturing firms in Kenya. The methodology adopted by Raouf (2004) was a crossectional research design. Raouf (1994), focused on TPM and its effect on safety but the context of this study was vague, Masjuki and Taha (2004), conducted a study on TPM implementation in Malaysian context. Ahuja and Khamba (2008), Ireland and Dale (2001), Shaaban and Awni (2014), research focus was on TPM implementation but not in relation to productivity. Aspinwall and Elgharib (2013), researched on how TPM has been implemented in large and medium size organizations in the United Kingdom context. Ngugi (2015), focused on a cement factory. Ateka (2013), and Induswe (2013), used a crossectional research method. Studies conducted on Kipevu II power plant context are scarce. In view of this research gap and the critical importance of TPM in thermal power plants, more so on Kipevu II power plant, this study seeks to answer the following question; does TPM implementation affect the productivity of Kipevu II thermal power plant?

1.3 Research Objective

The general objective of this study is to establish the relationship between TPM implementation and productivity in Kipevu II thermal power plants. The specific objective was to investigate the relationship between:

(i) TPM practices and equipment availability at Kipevu II thermal power plant.

(ii) TPM practices and dispatch compliance at Kipevu II thermal power plant.

(iii) TPM practices and scrap production at Kipevu II thermal power plant.

(iv) TPM practices and customer satisfaction rating at Kipevu II thermal power plant.

(v) TPM practices and rate of meeting operations objectives at Kipevu II thermal power plant.

1.4 Value of this Study

This study will act as a guide to managers on how they allocate resources when implementing TPM. It will also help in strategy formulation so as not to have a conflict in strategy implementation. It will help the manager to better organize their resources, and the sort of control measures to implement for a successful implementation of TPM. By conducting this study the managers will understand how TPM impacts on productivity and in a detailed sense the degree of influence TPM has on the various measure of productivity.

When the TPM practices have been fully appreciated the management will experience a paradigm shift, from the practice of freezing employment, reduction of buffer stocks without improving the efficiency of the supply chain, reduction of training budget and discouraging job rotation across department and facilities to focusing on making the resources available more productive. This is by encouraging continuous improvement, standardizing and sustaining 5S concept, improving flexibility and adaptability among employees, motivating employees by tying rewards to labour productivity, improving the communication line by using small group to address upcoming issues (Nakajima, 1988), equipping employees with modern skills and techniques on accurate equipment troubleshooting and problem solving to address the challenge of frequent replacement of spare part as well as reduce response time in addressing equipment failure, this study is hoping to help managers in the reduction in near miss and incidents, (Raouf, 2004). This research will also help managers to better know how to increase equipment availability and dispatch compliance of the power plants, reduce scrap material production rate and also build on improving customer satisfaction rating. This study will help manager know how to improve on the rate of meeting operations objectives of the power plant.

To the researchers and scholars, this study will make clear to them the kind of impact TPM has on productivity in Kenyan thermal Power plants. It will also act as an eye opener creating a need for deeper research into the impact of TPM to other less researched sectors of the economy as far as TPM is concerned. It will also assist researches seeking to find out the gaps in the TPM’s effect on productivity. This study will give researchers the inferred effect of TPM on productivity to other power plants besides kipevu II. It will also inspire more research on productivity of organization using other practices.

To government and policy makers it will be used to advise the legislations in the energy and power generation sector of the economy. It will also guide the government on the key factors to address so as to attract investment in the power generation sector. It will assist the policy makers determine the area to focus their facilitation attempt so that their efforts can have a greatest impact on the power plants productivity. This study will encourage policy makers to align the TPM practices with legislation in the Energy and power generation sector of the economy.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

It will cover the theoretical foundation of the study, then the theories that hypothesize TPM and productivity relationship. The study will then elaborate more on the TPM practices followed by an empirical review of past related researches, this will lead to the stating of the research gap and finally, discuss the conceptual framework.

2.2 Theoretical Foundation of the Study

Over the years maintenance practices have changed from breakdown maintenance (Wireman, 1990a), which led to enormous losses occasioned by long equipment downtime. It also led to high cost of repairs (Telang, 1998). Preventive maintenance was introduced to curb this losses, this is where maintenance activities are undertaken after a specified period of time or amount of machine running hours (Herbaty, 1990). It is split further into periodic maintenance and condition base maintenance (Vanzile and Otis, 1992). Corrective maintenance followed, with a purpose to modify the equipment to eliminate design weaknesses (Ahuja & Khamba, 2008). It was the followed by maintenance prevention concept, whose target was to make equipment maintenance free. Reliability Centered Maintenance then emerged (Ahuja & Khamba, 2008). This paved way for the development of TPM. With continued advancement in maintenance and with the adoption of computers in maintenance, computerized maintenance management systems (CMMS) was developed to better manage maintenance data (Hannan &Keyport, 1991; Singer, 1999).

2.2.1 Resource Based View

This research is anchored on the resource-based view. According to its proponent, the resource-based view is based on the concept of economic rent Penrose (1959). It considers a firm as a collection of resources competencies and capabilities that need to be mixed appropriately in order to deliver competitive advanced (Willmott, 1994). The resources within a firm can be used as the basis for strategy formulation and as a result yield maximum economic rent by exploiting these unique capabilities, competencies and resource in line with market needs and wants. These recourses need to be valuable, inimitable, rare and non-substitutable, for the competitive advantage to be sustained thus making the firm profitable (wernerfelt 1984). The study views unique maintenance and operations department resources, competencies and capabilities within a power plant and the way in which they are managed using concepts like TPM as possibility for the creation of competitive advantage. By ensuring that these resources remain valuable inimitable, rare and non-substitutable guarantees the power plant continued productivity.

2.2.2 Theory of Constraints

The second theory that supports the TPM, productivity relationship is the theory of constraints. It's bases on the argument that, the rate of goal achievement in a goal oriented system like in project management (where it was originally applied) is limited by at least one constraint. Every production system entails resources passing through various processes, before being a final product ready for the market. In the process stage, there is a bottleneck that limits the system throughput from attaining its goal of maximization. The most critical constraint that will produce the biggest and quickest benefit should be identified, and sequentially optimized to maximize system throughput. According to Goldratt and Cox (1986), once a system has been relieved of its constraints it will lead to an increased throughput.

The theory relates throughput with constraints. In any maintenance system there exist bottlenecks that could limit power plant productivity. This includes poorly trained employees or equipment design weakness, just to name but a few. Because of the relationship between constraints and productivity as suggested by Goldratt and Cox (1986), it, therefore, means that if the training and equipment issues could be addressed the power plant throughput will increase by increasing the availability of the equipment. With TPM being focused on the whole organization its best suited to relieve the organization of these constraints through its practice of continuous improvement (Venkatesh, 2007).

2.3 Total Productive Maintenance Practices

Total productive maintenance is a concept practiced with the aim of productivity maximization, it views maintenance as an opportunity to give the plant a competitive advantage over its competitors, productivity rather than reliability is the main purpose of TPM. Alot of focus on reliability results in over-engineering that shifts the focus from the production of goods and services to maintaining the equipment, eventually the cost of maintenance spiral out of control leading to the processes being unproductive. This concept is supported by the following eight pillars (Ahuja & Khamba, 2008).

2.3.1 Autonomous Maintenance

Robinson and Ginder (1995), states that it’s through this practice of autonomous maintenance that operators undertake to split maintenance responsibilities with maintenance staff, these is aimed at sustaining equipment level of productivity. Autonomous maintenance entail making operators have the sense of ownership and responsibility for performing the daily light equipment maintenance of inspecting, cleaning, lubricating, retightening loose connections and making minor adjustments on the equipment. This aids in facilitating and maintaining equipment superior (Ahuja & Khamba, 2008).

Venkatesh (2007), stress that this practice makes oil consumption by equipment decrease at the same time process time increased thus contributing to the productivity of the equipment. Owing to this practice the lifespan of the equipment will be longer than usual, while maintaining high productivity (Patra, Tripathy & Choudhary, 2005). Autonomous maintenance is the bedrock of Office TPM practice. This explains shows how TPM practices depend on each other. This study measured autonomous maintenance as the number of hours spent by operations employee performing maintenance related tasks.

2.3.2 Office Total Productive Maintenance

Office total productive maintenance is the replication of TPM concept in all operations within the organization to create synergy among different functions. It encourages the cross-functional aspect and the total participation aspect of TPM, Its aim is to foster a sense of job ownership among employees, It also targets a reduction in wastage thus improvement in resource effectiveness, Office TPM promote a better organization culture and creates a conducive environment for optimizing employee productivity (Patra, Tripathy & Choudhary, 2005).

2.3.3 Planned Maintenance

Planned maintenance is made possible by scheduling maintenance activities efficiently and effective It’s a practice that stands to yield increased equipment availability, increased mean time between failures and zero accidents caused by fatigue. It also prevents the coinciding of two or more major maintenance activities. This saves the organization from the financial strain of incurring a sudden high expense on spares (Ahuja & Khamba, 2008). According to Venkatesh (2007), it also enhances equipment reliability and maintainability. With effective planned maintenance, it's possible for an equipment to record zero breakdowns and zero equipment failure cases.

According to Moore (2001) analysis of critical success factors in the maintenance for the top-performing companies, it was realized that their unplanned maintenance stood at 10% compared to 50% for the average performer, he also sought the correlation between availability rate and unplanned maintenance and found out that, with the latter dropping by 2-3% the former increases by 10%.

2.3.4 Quality Maintenance

Effective total productive maintenance implementation can result in zero customer complaints (Venkatesh, 2007). This can be interpreted to mean that the customer is satisfied. Traditionally productivity has been measured against cost and quality, product-centric service operating environment use customer satisfaction as a measure of productivity (Morris & Johnson, 1987; Lewis, 2004; Gebauer & Friedli, 2005) (Ayeni, Ball & Baines, 2016). Venkatesh (2007), also states that organization that implement TPM successfully can reduce the cost of quality by 50%. Power plants have been generating large amounts of scrap material (defective products or materials that cannot be repaired, sold or reused) this is an internal failure cost, which shows the quality of maintenance performed.

Quality maintenance can be improved to the point of having zero scrap material through the adoption of TPM where defective parts are studies and once the root cause of the failure is identified it's re-designed with the intention of elimination the previous design weakness (Ahuja & Khamba, 2008).

2.3.5 Education and Training

Training the employee equips them with the confidence to perform the autonomous maintenance, it also acts as a motivation since it gives the employee new skills on how to perform some tasks. It helps in aligning the employee to organizations objectives. It also improves safety according to Duffuaa, Raouf and Campbell (1998), employee skills and the number of near misses has a strong negative correlation, to build on that study, Heinrich (1959) stated that for every 300 near misses one of them will result in an accident that will result in one or more injuries. Therefore it's clear that training makes employees safer.

2.3.6 Safety, Health, and Environment

A safe workplace motivates the employees. Safety also enhances the productivity of the workforce due to minimal employee absenteeism occasioned by work-related injuries. It is evident that for maximizing plant operation effectiveness, an adequate and integrative approach to maintenance and safety is necessary. (Raouf 2004) It's also expense to operate a power plant which does not care about employee safety due to legal battle between the injured and the company for compensations for the injuries.

The premiums paid to the insurance companies will end up being high if the organization safety standards are low. Besides keeping the people safe it's also important to keep the environment and equipment safe from pollution and damage respectively, thus avoiding the repeat of safety disasters such as BP Texas City, Piper Alpha, Bhopal and Sayano Shusenskaya (Narayan, 2011). For the sake of this study, safety will be measured by the number of permits raised.

2.3.7 5S: Sort, Shine, Set, Standardize and Sustain

The 5S stand for sort, shine, set, standardize then sustain. Sort is where items are categorized according to the frequency of usage. Shine is the act of practicing good housekeeping which helps to keep the workplace free of dust, grease, oil and scrap material (Venkatesh, 2007) thus ensuring employee safety. Set means locating an item in a convenient location. Frequently used items are located at points nearer to the workplace to increase accessibility and eliminate time wasted when accessing these items. The rarely used items are located away from the workplace to minimize clutter at the workplace (Ahuja & Khamba, 2008). Then the items are arranged on the location neatly to create order. The procedure is then standardized by institutionalizing the 5S practice through procedures .Finally, the fifth S which stands for sustaining, means, putting measures in place to ensure that the 5S concept is practiced. The 5S concept should be frequently audited to check on the implementation of this concept.

5S make the identification of gaps and problems at the work place possible. It cuts on time wastage while waiting for the store keeper to look for a spare (Womack & Jones, 1996). 5S eliminates the seven wastes as identified by Ohno (1988). It helps improve employee productivity. With the successful implementation of 5S, production process faults are evident and clearly identifiable, this speeds up the process of taking a corrective action (Ayeni, Ball & Baines, 2016).

2.3.8 Continuous Improvement

Bhadury (1988) argues that continuous improvement is a gradual process where small improvements are made on a daily basis with the aim of increasing system productivity. There is a need for a process appraisal from time to time to check if the KPI have been met. After getting a clear view of the state of affairs, identify opportunities for improvement, is done using tools like process mapping, flow charting, force field analysis, cause analysis, brainstorming, pareto analysis, statistical process control charts, check sheets, bar charts, scatter diagrams, matrixes analysis, histogram, six sigma, tally charts, then continuous improvement is conducted, prioritization is based on return and criticality.

Patra,Tripathy, and Choudhary (2005) argues that the critical determinant of staying competitive today is the successful execution of important improvements on the organization which could be as a result of innovative ideas or gradual and continuous improvements.

2.4 Empirical Review

The following studies have been done on TPM. Venkatesh (2007) study on the direct benefits of TPM implementation on productivity and overall equipment efficiency (OEE), found that TPM was responsible for the reduction in customer complaints, manufacturing cost by 30%, and accidents. Raouf (2004) research on relationship between safety and TPM maintenance activities, found that integration of safety and maintenance is important for strategy development of the organization. He went on to recommend the treatment of safety and maintenance as an integrated subsystem of production. Raouf (1994) did a study on improving capital productivity through maintenance, and found out that traditional means of evaluating maintenance management do not yield high capital productivity thus recommending the use of production equipment effectiveness (PEE) methodology. Ahuja and Khamba (2008) study on TPM practices adoption found out that TPM can be used to gain competitive advantage. They also focused on seeking the success factors for eliminating barriers to TPM implementation this study revealed that success factor was the establishment of an elaborate TPM support system. Ahuja and Khamba (2008) highly recommended the adoption of TPM. According to Ireland and Dale (2001), through their study on the implementation of TPM in three companies, he found that, it's possible for a business facing difficulty to survive because of a successful implementation of TPM. Masjuki and Taha (2004) conducted a survey study in Malaysia seeking to find the extent of TPM implementation among small and medium size industries. The study revealed that the extent of TPM implementation in Malaysia was low.

Shaaban and Awni (2014), researched on the reason why TPM deployment was successful in Egyptian fast moving consumer goods companies. The research findings showed that leadership style, management commitment organization culture, the level of knowledge and experience benchmarking practices and clear vision were the critical success factors. Aspinwall and Elgharib (2013), research on how TPM has been implemented in large and medium size organizations in the United Kingdom. The researcher adopted a case study methodology. It was found that culture was the main obstacle to the successful implementation of TPM in the UK large and medium size manufacturing companies.

A number of scholars have researched on TPM practices in Kenyan firms, Ngugi (2015), study was to explore the relationship between the implementation of TPM practices and the equipment effectiveness of a typical large scale manufacturing company in Kenya, the research was a case study of Bamburi cement, the methodology adopted was a longitudinal case study. The preliminary results of the analysis showed that the implementation of TPM practices caused a significant increase in the equipment effectiveness in the organization with autonomous maintenance having the biggest role. The study recommended the implementation of autonomous maintenance in manufacturing companies. Ateka (2013) conducted a research on the adoption of TPM practices in large manufacturing firms ocated in Mombasa County. The study found that TPM implementation resulted in high productivity as well as an increase in quality. The study results also showed that the most important critical success factors of TPM is cooperation and involvement of both the operators and the maintenance workers. The methodology used by the researcher was a cross-sectional survey. Induswe (2013) conducted a study to investigate the challenges, success factors, and benefits of TPM implementation in large manufacturing firms in Kenya. This research revealed that the benefits of implementing TPM was the elimination of waste and losses, reduction of equipment breakdown, reduction of maintenance costs, optimization of equipment reliability, improvement of operator skills and boosting the morale of employees.

2.5 Summary and Knowledge Gap

From the collection of studies discussed in section 2.4, it’s clear that none used Kipevu II power plant context. Raouf (2004) relates productivity with safety though his methodology was a cross-sectional survey. Raouf (1994), in his study of how to improve productivity through maintenance, focused was on safety. Ahuja and Khamba (2008), study on the review of TPM literature had a vague context. Ngugi (2015) has a slightly related focus and methodology but the context is a cement factory.

Ateka (2013) conducted a research on the adoption of TPM practices in large manufacturing firms located in Mombasa County. This study used cross-sectional while this study used a longitudinal case study research design. The research by Venkatesh (2007) looked at the benefit of TPM implementation. Ateka (2013) used a cross-sectional survey. Based upon these studies, research on the effect of TPM practices on productivity are scarce, in view of this revelation there exist a gap that the researcher seeks to fill by adopting a case study research design and exploring the effect of TPM on Kipevu II thermal power plant. The electricity generation industry is believed to be unique due to the nature of its product and the mode of operation adopted. The units used to measure productivity are also unique to this industry. By conducting this study the TPM concept will be better understood by the practitioners in this industry.

2.6 Conceptual Framework

This section outlines the conceptual framework for the study. It shows the conceptual model that will explain the relationship between the independent variable and dependent variable.

Figure 2.1: Conceptual Framework

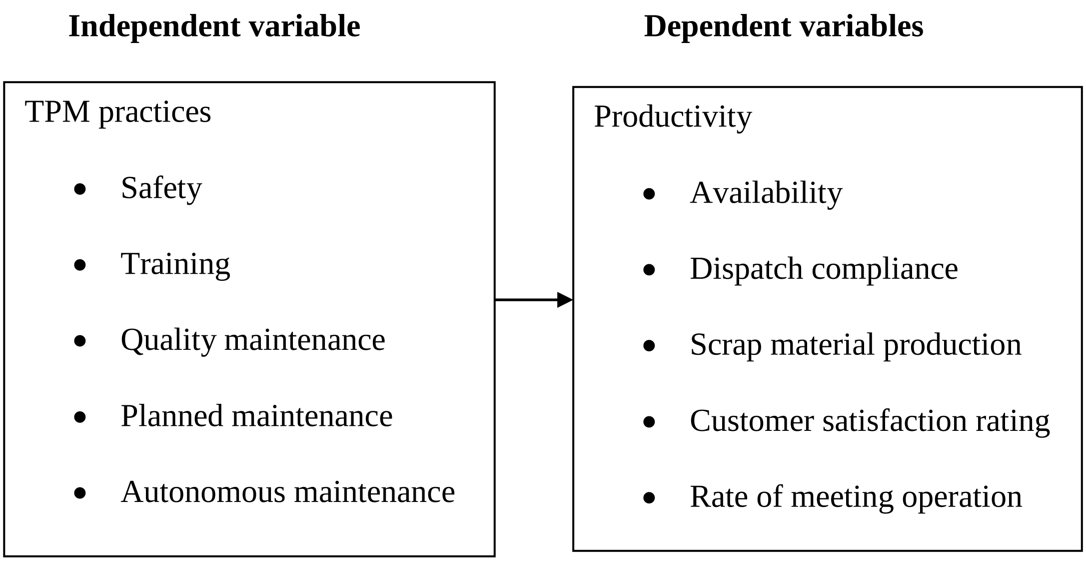

Figure 2.1 illustrates the conceptual argument for this study showing the relationship between the independent variable which are the TPM practices which the researcher will manipulate in order to determine their effect on the dependent variable which is productivity.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter will discuss the design of the research, outline the methodology of the study, explain the procedure that was carried out in order to conduct the study, and justify the reason why this case study, methodology, and research design was preferred by the researcher. Data collection procedure will be discussed followed by the operationalization of the study variables, and finally, the data analysis techniques will be discussed.

3.2 Research Design

This research employed descriptive, longitudinal case study research design. Longitudinal design involves conducting a study on a subject by using data that has been accumulated over a period of time on the subject being researched on. According to Gratton and Jones (2004), longitudinal study is a kind of a correlation research that takes a closer look at variables over certain duration of time. The goal of correlation research is to determine if an alteration in a variable influence a change in another variable. Such a study helps the researcher to quantify the degree to which the independent variables influence the dependent variable. When this relationship is established it is then possible to control the independent variable in order to get the desired dependent variable (Kuula & Putkiranta, 2012).

The benefit of a longitudinal study is that it’s better placed to show the changes in the variables over time. These changes are normally very clear and they follow a certain pattern (Pettigrew, 1990). This kind of study allows the research to conduct an exhaustive and thorough study in a particular subject (Trochim, 2006). This research has taken a case study approach. A case study is an empirical quest into the contemporary phenomenon within its real-life context especially when the boundaries between the phenomenon and the context are not clearly evident (Yin, 2003). As shown by Table 1.1 (list of thermal power plants in Kenya), Conducting a survey of the seven thermal power plant in Kenya is a very small number to allow the researcher to arrive at credible research results after using the multiple linear regression method of data analysis. This research was empirical, by adopting this research design the researcher believe that research question was adequately answered (Crotty, 1998).

3.3 Case Selection

Thermal power plants are an integral industry in any economy, this is due to their vital role is an electricity generation. According to a study done by Alam (2013) on the impact of electric power consumption and economic growth, an empirical evidence for India covering a period of 1975- 2008 indicated a long run relationship between electric energy consumption and foreign direct investment (FDI) which in turn influence economic growth, thermal power plants have been very vital in protecting the nation grid from load surges by stabilizing the grid. The other crucial element of the thermal power plants has been in their ability to caution the national grid from adverse influence of the weather (PEIC, 1999). For a country with a relatively stable weather pattern and well-managed grid system, the thermal power plants risk losing due to the low sales. Kipevu II is the oldest thermal power plant in Kenya, Mombasa County. It runs on expensive fossil fuel, the technology it has employed and the degree of automation is not at par with modern thermal power plants. The cost of upgrading to the new technology is enormous (Herbling, 2016).

Despite the hostile economic environment within which Kipevu II power plant is operating. Its chances of survival cannot be ruled out if the power plant implements TPM fully. Ireland and Dale (2001) study showed that, the survival of struggling companies is possible by virtue of implementing the TPM practices. This industry was singled out due to its key role in economic growth. Kipevu II power plant was selected as the subject of research due to its vulnerability, based on its utilization of some obsolete technologies and the relatively high cost of electricity per KWh.

3.4 Operationalization of Study Variables

Independent variables for the sake of this study were, safety which was measured by number of permits raised (Australian Standard, 1990).There is no training that does not need an education that's why a new employee must meet some entry level education before being recruited by an organization. Education is also needed in cases where new policies are being introduced. The training process takes different forms, with the most common being apprenticeship training for new employees and job rotation for the not so new employees. Training the employee equips them with the confidence to perform the task while being unsupervised. It also acts as a source of motivation since it gives the employee new skills on how to perform some tasks. It helps in aligning the employee to organizations objectives. It also improves safety according to Duffuaa, Raouf and Campbell (1998). In this study was measuring training by the hours spend on training employees.

Autonomous Maintenance is the core practice for the success of manufacturing industry in Kenya (Ngugi, 2015). This practice has contributed to the longevity of equipment while maintaining high productivity (Patra, Tripathy & Choudhary 2005). Autonomous maintenance is the bedrock of Office TPM practice. This goes a long way in explaining how this TPM practices depend on each other. This study measured autonomous maintenance by the number of hours spent by operations employee performing maintenance related tasks. Planned maintenance is an essential TPM practice. With effective planned maintenance it's possible for an equipment to record zero breakdowns and zero equipment failure cases, hence reduced costs (Mirghani, 2001). In this study planned maintenance was measured by the number of equipment unplanned maintenance.

According to Garvin’s (1984, 1987) eight product quality dimensions, reliability is one of the measures of quality. By improving quality the reliability of the products will end up being improved. Effective TPM implementation can also result in a reduction of customer complaints to zero. This can be interpreted to mean the customer is satisfied. According to Venkatesh (2007), quality maintenance can be improved to the point of having zero scrap material. In the case of this study quality will be measured by the percentage of down time as a result of a break down to the down time allowance.

Dependent variable for this research was productivity. Power plant productivity was measured by assessing equipment availability (Venkatesh, 2007). Productivity was also measured by, dispatch compliance. Equipment breakdown is the major cause of the failure to honor the request from NCC (Stainer, 1995). According to Venkatesh (2007), scrap production rate is a good indicator of productivity, the same author also claims that customer satisfaction rating is another independent indicator of productivity. The rate of meeting operations objectives which is reflected as equipment reliability of the power plant, is a reflection of the level of the productivity attained (Venkatesh, 2007).

Table 3.1: Operationalization of TPM Practices and Measures of Productivity

Variable	Subconstruct	Indicators	Sources
TPM practices Independent variable	Safety	Number of permits raised	(Australian Standard, 1990)
	Training	Training hours	(Nakajima,1988)
	Quality maintenance	Forced outage hours	(Ahuja &, Khamba, 2008)
	Planned maintenance	Number of equipment unplanned outages	(Venkatesh, 2007)
	Autonomous maintenance	Operators number of hours spent doing maintenance task	(Nakajima,1988)
Productivity Dependent variable	Availability	Equipment utilizable capacity (%)	(Venkatesh, 2007)
	Dispatch compliance	Ratio of power generated to dispatch assigned (%)	(Stainer, 1995).
	Scrap material production	Scrap metal produced in tones	(Venkatesh, 2007)
	Customer satisfaction rating	Customer survey results as a percentage	(Venkatesh, 2007)
	Rate of meeting operation objectives	Equipment reliability as a percentage	(Venkatesh, 2007)

3.5 Data Collection

This study used secondary data. The data was obtained from records of Kipevu II power plants for a period of sixteen and a half years (January 2000 to July 2016). The data was semi-annual and included the number of permits raised, forced outage hours as a percentage of the allowed number of forced outage hours. Data on equipment unplanned outage hours spent on training the employees and the number of hours spent by operations employee performing maintenance related tasks was collected. For the dependent variables, productivity was measured by the equipment availability, equipment dispatch compliance, scrap metal produced, the rate of meeting operations objectives this is a measure of equipment reliability and finally customer satisfaction rating. This information is as shown on the data collection form in appendix1.

3.6 Data Analysis

The study focused on understanding the relationship between TPM implementation and productivity at Kipevu II thermal power plant. it further explored the relationship between TPM and equipment availability, dispatch compliance, scrap production, customer satisfaction rating, and rate of operation of meeting operation objectives. Multiple linear regression analysis was used to analyze the effect of implementation of the TPM practices on equipment productivity. The Multiple linear regression models took the forms:

$$y_1 = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mathcal{E}$$

$$y_2 = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mathcal{E}$$

$$y_3 = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mathcal{E}$$

$$y_4 = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mathcal{E}$$

$$y_5 = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mathcal{E}$$

Where: β_o = constant,

$\beta_1 - \beta_5$ = Regression coefficients,

y_1 = Availability measured by the equipment utilizable capacity (%),

y_2 = Dispatch compliance measured by ratio of power generated to dispatch assigned (%),

y_3 = Scrap material production measured by scrap metal produced in tonnes,

y_4 = Customer satisfaction rating measured by customer survey results (%),

y_5 = Rate of meeting operation objectives measured by equipment reliability (%),

x_1 = Safety measured by number of permits raised,

x_2 = Training measured by training hours,

x_3 = Quality maintenance measured by forced outage (%),

x_4 = Planned maintenance measured by number of equipment unplanned outages,

x_5 = Autonomous maintenance measured by operators number of hours spent doing maintenance task,

ε = error term.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

This chapter starts by testing assumptions for multiple linear regression then analysis of the correlation coefficient and its significance test. The F-test and T-test will be conducted, followed by their significance tests. Finally, present the finding followed by interpretations that links the findings to the objectives of the study.

4.2 Implementation of Total Productive Maintenance Practices and Productivity

Semi-annual data was collected from the records of Kipevu II power plant for a duration of sixteen and a half years, and summarized as shown in Table 4.1.

Where:

y_1 = Availability measured by the equipment utilizable capacity (%),

y_2 = Dispatch compliance measured by ratio of power generated to dispatch assigned (%),

y_3 = Scrap material production measured by scrap metal produced in tones,

y_4 = Customer satisfaction rating measured by customer survey results (%),

y_5 = Rate of meeting operation objectives measured by equipment reliability (%),

x_1 = Safety measured by number of permits raised,

x_2 = Training measured by training hours,

x_3 = Quality maintenance measured by forced outage hour,

x_4 = Planned maintenance measured by number of equipment unplanned outages,

x_5 = Autonomous maintenance measured by operators number of hours spent doing maintenance task.

Table 4.1: Total Productive Maintenance Practices and Productivity Data

Sno	Period	y_1	y_2	y_3	y_4	y_5	x_1	x_2	x_3	x_4	x_5
1	Jan-Jun 2000	95.00	78.00	67.00	78.00	98.10	99.00	88.00	55.00	89.00	99.00
2	Jul-Dec 2000	94.00	85.00	78.00	75.00	97.90	78.00	90.00	35.00	78.00	78.00
3	Jan-Jun 2001	97.00	87.00	81.00	85.00	89.00	86.00	103.00	40.00	65.00	67.00
4	Jul-Dec 2001	97.00	88.00	83.00	80.00	89.00	90.00	104.00	36.00	70.00	78.00
5	Jan-Jun 2002	97.10	80.00	91.00	78.00	87.00	89.00	110.00	45.00	71.00	89.00
6	Jul-Dec 2002	91.70	81.00	90.00	80.00	78.00	77.00	157.00	46.00	72.00	76.00
7	Jan-Jun 2003	89.50	83.00	92.00	86.00	88.00	76.00	139.00	38.00	76.00	77.00
8	Jul-Dec 2003	92.50	81.00	89.00	84.00	87.00	75.00	79.00	45.00	80.00	31.00
9	Jan-Jun 2004	96.80	85.00	93.00	84.00	86.00	79.00	65.00	32.00	98.00	79.00
10	Jul-Dec 2004	94.50	86.00	91.00	81.00	89.00	78.00	56.00	37.00	90.00	87.00
11	Jan-Jun 2005	89.30	87.00	94.00	79.00	90.00	86.00	50.00	39.00	78.00	86.00
12	Jul-Dec 2005	91.50	89.00	98.00	97.00	91.00	87.00	68.00	50.00	83.00	88.00
13	Jan-Jun 2006	93.10	86.00	99.00	97.00	89.00	89.00	68.00	45.00	80.00	78.00
14	Jul-Dec 2006	92.60	88.00	81.00	99.00	90.00	90.00	68.00	23.00	78.00	78.00
15	Jan-Jun 2007	89.70	90.00	83.00	93.00	92.00	89.00	54.00	45.00	77.00	81.00
16	Jul-Dec 2007	93.00	91.00	78.00	97.00	89.00	89.00	54.00	50.00	63.00	83.00
17	Jan-Jun 2008	88.80	90.00	79.00	96.00	87.00	91.00	95.00	54.00	70.00	80.00
18	Jul-Dec 2008	91.20	91.00	73.00	94.00	87.00	95.00	91.00	44.00	40.00	82.00
19	Jan-Jun 2009	91.10	92.00	71.00	86.00	89.00	54.00	89.00	41.00	67.00	79.00
20	Jul-Dec 2009	91.60	93.00	69.00	85.00	93.00	54.00	89.00	37.00	66.00	78.00
21	Jan-Jun 2010	87.30	96.00	64.00	97.00	95.00	68.00	90.00	34.00	68.00	85.00
22	Jul-Dec 2010	93.00	96.00	63.00	80.00	91.00	68.00	89.00	31.00	64.00	83.00
23	Jan-Jun 2011	95.00	95.00	66.00	80.00	90.00	50.00	87.00	29.00	62.00	86.00
24	Jul-Dec 2011	94.10	97.00	70.00	95.00	94.00	56.00	86.00	27.00	57.00	89.00
25	Jan-Jun 2012	95.00	98.00	63.00	99.00	95.00	65.00	78.00	21.00	60.00	90.00
26	Jul-Dec 2012	92.00	98.00	61.00	95.00	96.00	79.00	79.00	20.00	59.00	97.00
27	Jan-Jun 2013	98.80	97.00	57.00	91.00	95.00	139.00	75.00	17.00	45.00	96.00
28	Jul-Dec 2013	95.80	96.00	53.00	100.00	96.00	157.00	76.00	12.00	43.00	95.00
29	Jan-Jun 2014	95.70	97.00	45.00	100.00	94.00	110.00	77.00	22.00	39.00	94.00
30	Jul-Dec 2014	98.30	99.00	42.00	99.00	95.00	104.00	89.00	13.00	36.00	99.00
31	Jan-Jun 2015	98.60	99.00	35.00	99.00	99.00	103.00	90.00	19.00	27.00	91.00
32	Jul-Dec 2015	97.10	100.00	30.00	100.00	98.70	103.00	86.00	18.00	36.00	90.00
33	Jan-Jun 2016	99.60	100.00	25.00	100.00	99.80	88.00	78.00	10.00	40.00	92.00

4.2.1 Total Productive Maintenance Practices and Availability

To test for multicollinearity assumption between the variable the study used variable inflation factor (VIF) as shown in Table 4.5, if VIF is less than 5 it means multicollinearity does not exist.

This study has used Durbin Wartson test to test autocorrelation assumption on the variables. From Table 4.3. $d\ calculated\ (d_c)$=1.521

If d_c<d_L reject H_o : ρ = 0 thus autocorrelation exist,

If d_c>d_U reject H_1 : ρ ≠ 0 thus autocorrelation does not exist,

If d_L<d_c<d_U test is inconclusive.

From the Durbin-Watson table $d_L =$ 1.127 and $d_U =$1.813 therefore the test is inconclusive. Pearson's correlation analysis was run to determine the nature of the relationship between the implementation of the TPM practices of safety, training, quality maintenance, planned maintenance and autonomous maintenance and equipment availability. The results are summarized in Table 4.2.

Table 4.2: Correlations between Total Productive Maintenance Practices and Availability

Correlations

		Availability (%)	Permits Raised	Training (hours)	Forced Outage (hours)	Unplanned Maintenance	Autonomous Maintenance
Availability (%)	Pearson Correlation	1					
	Sig. (2-tailed)						
Permits Raised	Pearson Correlation	.409*	1				
	Sig. (2-tailed)	.018					
Training (hours)	Pearson Correlation	-.028	-.152	1			
	Sig. (2-tailed)	.875	.398				
Forced Outage (hours)	Pearson Correlation	-.570**	-.323	.120	1		
	Sig. (2-tailed)	.001	.067	.507			
Unplanned Maintenance	Pearson Correlation	-.445**	-.414*	-.090	.668**	1	
	Sig. (2-tailed)	.009	.017	.618	.000		
Autonomous Maintenance	Pearson Correlation	.300	.346*	-.138	-.433*	-.406*	1
	Sig. (2-tailed)	.090	.049	.444	.012	.019	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

From Table 4.2 it is observed that there is a weak, positive and insignificant relationship between autonomous maintenance and equipment availability (r = 0.3, p = 0.09). It is also observed that there is a weak, negative and insignificant relationship between training hours and equipment availability (r = -0.028, p = 0.875). A medium strength, positive and significant relationship exist between number of permits raised and equipment availability (r = 0.409, p = 0.018). It is also evident that there is a medium strength, negative and significant relationship between unplanned maintenance and equipment availability (r = -0.445, p = 0.009). It is observed that there is a strong, negative and significant relationship between forced outage and equipment availability (r = -0.57, p = 0.001).

A Multiple linear regression analysis was performed to determine the relationship between the implementation of the TPM Practices and Kipevu II power plant equipment availability. The results were summarized in Table 4.3 to 4.5.

Table 4.3: Model Summary Regression Results of Total Productive Maintenance Practices and the Availability

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.622[a]	.387	.273	2.7181	1.521

a. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance
b. Dependent Variable: Availability (%)

Table 4.4: ANOVA Regression Results of Total Productive Maintenance Practices and the Availability

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	125.681	5	25.136	3.402	.016[b]
	Residual	199.480	27	7.388		
	Total	325.161	32			

a. Dependent Variable: Availability (%)
b. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance

Table 4.5: Coefficients Regression Results of Total Productive Maintenance Practices and Equipment Availability

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	93.733	6.150		15.241	.000		
	Permits Raised	.037	.025	.259	1.502	.145	.767	1.305
	Training (hours)	.010	.023	.071	.442	.662	.886	1.128
	Forced Outage (hours)	-.123	.053	-.491	-2.306	.029	.501	1.997
	Unplanned Maintenance	.000	.040	-.001	-.004	.997	.462	2.165
	Autonomous Maintenance	.002	.046	.008	.044	.966	.747	1.339

a. Dependent Variable: Availability (%)

From Table 4.3, the significance of R was tested using the t distribution

The null hypothesis H_o : r = 0 (the correlation coefficient is not significant) The alternative hypothesis H_1 : r ≠ 0 (the correlation coefficient is significant)

The decision rule would therefore be to reject $H_o$if the computed t value (t_c)is either less than -2.040 of greater than 2.040. This is a two tailed test at 0.05 level of significance. Degrees of freedom = (sample size-2) = ($n-2$) = 33 – 2 = 31

$\left|t_c\right| = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$ where the sample correlation coefficient (strength of the relationship between the sample variables) (r) =0.622,

$\left|t_c\right| = \frac{0.622}{\sqrt{1-0.387}} \times \sqrt{(33-2)}$ =4.422

From the t distribution table the tabulated t value (t_t) at (n-2) degrees of freedom using 5% level of significance is $t_t = 2.040$. Since, computed t falls in the rejection region that is less than 2.040 reject H_o thus the correlation between TPM practices and availability is significant. 27.3% of the total variability in equipment availability can be attributed to the changes in TPM practices implementated by Kipevu II power plant (adjusted R^2=0.273). From Table 4.4, the P value of the F-test is 0.016, since the analysis was conducted at 5% significance level, reject the H_o: The model has no explanatory power. Therefore the model that is generated by this regression is significant. The model took the form:

$$y_1=93.733 + 0.037x_1 + 0.01x_2 - 0.123x_3 + 0x_4 + 0.002x_5$$

This model means that when one more permit is raised the equipment availability increases by 0.037% provided that all other TPM practices are held constant, when one more hour is spent training employees, availability increases by 0.01% provided that all other TPM practices are held constant, when one more hour of forced outage is avoided, availability increases by 0.123% provided that all other TPM practices are held constant. Availability is not affected by the lack of planning for maintenance if all other TPM practices are held constant. When an operator spends one hour more doing maintenance-related task availability increases by 0.002% provided that all other TPM practices are held constant.

The P-values for the t-statistics show that only forced outage at p= 0.029 thus < 0.05 is significant at 5% significance level. So reject H_o: forced outage has no predictive ability over equipment availability. Therefore, forced outage can be used to predict availability for the population.

4.2.2 Total Productive Maintenance Practices and Dispatch Compliance

VIF is less than 5 which means multicollinearity does not exist. This study has used Durbin-Watson test to test for autocorrelation$dcalculated\ (d_c)$=1.988.

From the Durbin-Watson table $d_L = 1.127$ and d_U =1.988 therefore autocorrelation does not exist. Pearson's correlation analysis was run to determine the nature of the relationship between the implementation of the TPM practices and dispatch compliance. The results are summarized in Table 4.6.

Table 4.6: Correlations between Total Productive Maintenance Practices and Dispatch Compliance

Correlations

		Dispatch Compliance (%)	Permits Raised	Training (hours)	Forced Outage (hours)	Unplanned Maintenance	Autonomous Maintenance
Dispatch Compliance (%)	Pearson Correlation	1					
	Sig. (2-tailed)						
Permits Raised	Pearson Correlation	.139	1				
	Sig. (2-tailed)	.440					
Training (hours)	Pearson Correlation	-.249	-.152	1			
	Sig. (2-tailed)	.162	.398				
Forced Outage (hours)	Pearson Correlation	-.756**	-.323	.120	1		
	Sig. (2-tailed)	.000	.067	.507			
Unplanned Maintenance	Pearson Correlation	-.783**	-.414*	-.090	.668**	1	
	Sig. (2-tailed)	.000	.017	.618	.000		
Autonomous Maintenance	Pearson Correlation	.494**	.346*	-.138	-.433*	-.406*	1
	Sig. (2-tailed)	.004	.049	.444	.012	.019	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From the analysis in Table 4.6 it is observed that there is a weak, positive and insignificant relationship between number of permits raised and dispatch compliance (r = 0.139, p = 0.440). A medium strength, positive and significant relationship exist between autonomous maintenance and dispatch compliance (r = 0.494, p = 0.004). There is a strong, negative and significant relationship between outage and dispatch compliance (r = -0.756, p = 0.000). The same relationship exist between unplanned maintenance and dispatch compliance (r = -0.783, p = 0.000). A Multiple linear regression analysis was performed to further explore the relationship between the implementation of the TPM Practices and dispatch compliance at Kipevu II power plant. The results were summarized in Table 4.7 to 4.9.

Table 4.7: Model Summary Regression Results of Total Productive Maintenance Practices and the Dispatch Compliance

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.934[a]	.873	.849	2.496	1.988

a. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance
b. Dependent Variable: Dispatch Compliance (%)

Table 4.8: ANOVA Regression Results of Total Productive Maintenance Practices and the Dispatch Compliance

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1155.249	5	231.050	37.074	.000[b]
	Residual	168.266	27	6.232		
	Total	1323.515	32			

a. Dependent Variable: Dispatch Compliance (%)

b. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance

Table 4.9: Coefficients Regression Results of Total Productive Maintenance Practices and the Dispatch Compliance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	121.130	5.649		21.445	.000		
	Permits Raised	-.100	.023	-.344	-4.387	.000	.767	1.305
	Training (hours)	-.089	.021	-.305	-4.180	.000	.886	1.128
	Forced Outage (hours)	-.154	.049	-.305	-3.144	.004	.501	1.997
	Unplanned Maintenance	-.248	.037	-.683	-6.769	.000	.462	2.165
	Autonomous Maintenance	.085	.042	.161	2.024	.053	.747	1.339

a. Dependent Variable: Dispatch Compliance (%)

From Table 4.9, the significance of R was tested using the t distribution.

The null hypothesis H_o : r = 0 (the correlation coefficient is not significant)

The alternative hypothesis H_1 : r ≠ 0 (the correlation coefficient is significant)

The decision rule would therefore be to reject $H_o$if the computed t value (t_c) is either less than -2.040 of greater than 2.040. This is a two tailed test at 0.05 level of significance. Degrees of freedom = (sample size-2) = ($n - 2$) = 33 – 2 = 31

$\left|t_c\right| = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$ where the sample correlation coefficient (strength of the relationship between the sample variables) (r) = 0.934,

$\left|t_c\right| = \frac{0.934}{\sqrt{1-0.873}} \times \sqrt{(33-2)}$ =14.556

From the t distribution table the tabulated t value (t_t) at (n-2) degrees of freedom using 5% level of significance is t_t =2.040. Since, computed t falls in the rejection region that is less than 2.040 reject H_o thus the correlation between TPM practices and dispatch compliance is significant. 84.9% of total variability in dispatch compliance can be explained by the changes in TPM practices implemented by Kipevu II power plant (adjusted R^2=0.849). From Table 4.8, the P value of the F-test is 0.000, since the analysis has been conducted with a 5% significance level the H_o: The model has no explanatory power was rejected. Therefore, the model that was be generated by this regression was significant and was used in explaining how dispatch compliance changed with change in TPM practices. The model took the form:

$$y_1=121.130 - 0.1x_1 - 0.089x_2 - 0.154x_3 - 0.248x_4 + 0.085x_5$$

This model means when one more permit is raised the dispatch compliance decreases by 0.1% provided that all other TPM practices are held constant, when one more hour is spent training employees to dispatch compliance decreases by 0.089% provided that all other TPM practices are held constant, when one more hour of forced outage is avoided dispatch compliance increases by 0.154% provided that all other TPM practices are held constant. When unplanned maintenance drops by one percent dispatch compliance increases by 0.248% provided that all other TPM practices are held constant. When an operator spends one hour more doing maintenance-related task dispatch compliance increases by 0.085% provided that all other TPM practices are held constant.

The P-values for the t-statistics show that only autonomous maintenance at p= 0.053 thus > 0.05 is insignificant at 5% significance level. So refuse to reject H_o: autonomous maintenance has no predictive ability over dispatch compliance, therefore autonomous maintenance cannot be used to predict availability for the population.

4.2.3 Total Productive Maintenance Practices and Scrap Material Production

To test for the assumptions of multicollinearity VIF was calculated. From Table 4.13. VIF is less than 5 which means multicollinearity does not exist. Pearson's correlation analysis was run to determine the nature of the relationship between the implementation of the TPM practices and scrap material production. The results are summarized in Table 4.10.

Table 4.10: Correlations between Total Productive Maintenance Practices and Scrap Material Production

Correlations

		Scrap Metal (tonnes)	Permits Raised	Training (hours)	Forced Outage (hours)	Unplanned Maintenance	Autonomous Maintenance
Scrap Metal (tonnes)	Pearson Correlation	1					
	Sig. (2-tailed)						
Permits Raised	Pearson Correlation	-.316	1				
	Sig. (2-tailed)	.073					
Training (hours)	Pearson Correlation	.031	-.152	1			
	Sig. (2-tailed)	.866	.398				
Forced Outage (hours)	Pearson Correlation	.751**	-.323	.120	1		
	Sig. (2-tailed)	.000	.067	.507			
Unplanned Maintenance	Pearson Correlation	.846**	-.414*	-.090	.668**	1	
	Sig. (2-tailed)	.000	.017	.618	.000		
Autonomous Maintenance	Pearson Correlation	-.494**	.346*	-.138	-.433*	-.406*	1
	Sig. (2-tailed)	.003	.049	.444	.012	.019	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From Table 4.10 a weak, positive and insignificant relationship exist between training hours and scrap metal produced (r = 0.031, p = 0.866). It is observed that there is a weak, negative and insignificant relationship between number of permits raised and tonnes of scrap metal produced (r = -0.316, p = 0.073). It is also evident that there is a medium strength, negative and significant relationship between autonomous maintenance and tonnes of scrap metal produced (r = -0.494, p = 0.003). From the analysis, it is observed that there is a strong, positive and significant relationship between forced outage and scrap metal produced (r = 0..751, p = 0.000). The same relationship exit between unplanned maintenance and tonnes of scrap metal produced (r = 0.846, p = 0.000). A multiple linear regression analysis was performed to determine the relationship between the implementation of the TPM Practices and scrap material production at Kipevu II power plant. The results were summarized in Table 4.11 to 4.13.

Table 4.11: Model Summary Regression Results of Total Productive Maintenance Practices and Scrap Material Production

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.894[a]	.798	.761	9.683	.994

a. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance
b. Dependent Variable: Scrap Metal (tonnes)

Table 4.12: ANOVA Regression Results of Total Productive Maintenance Practices and Scrap Material Production

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10023.992	5	2004.798	21.384	.000[b]
	Residual	2531.341	27	93.753		
	Total	12555.333	32			

a. Dependent Variable: Scrap Metal (tonnes)

b. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance

Table 4.13: Coefficients Regression Results of Total Productive Maintenance Practices and Scrap Material Production

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	16.811	21.908		.767	.450		
	Permits Raised	.088	.089	.098	.989	.331	.767	1.305
	Training (hours)	.046	.083	.050	.550	.587	.886	1.128
	Forced Outage (hours)	.447	.190	.288	2.361	.026	.501	1.997
	Unplanned Maintenance	.720	.142	.644	5.065	.000	.462	2.165
	Autonomous Maintenance	-.219	.163	-.134	-1.344	.190	.747	1.339

a. Dependent Variable: Scrap Metal (tonnes)

From Table 4,11 the significance of R was tested using the t distribution

The null hypothesis H_o : r = 0 (the correlation coefficient is not significant) The alternative hypothesis H_1 : r ≠ 0 (the correlation coefficient is significant)

The decision rule would therefore be to reject H_o if the computed t value (t_c)is either less than -2.040 of greater than 2.040. This is a two tailed test at 0.05 level of significance. Degrees of freedom = (sample size-2) = ($n-2$) = 33 – 2 = 31

$|t_c| = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$ where the sample correlation coefficient (strength of the relationship between the sample variables) (r) = 0.894,

$|t_c| = \frac{0.894}{\sqrt{1-0.798}} \times \sqrt{(33-2)}$ =11.109

From the t distribution table the tabulated t value (t_t) at (n-2) degrees of freedom using 5% level of significance is t_t =2.040. Since, computed t falls in the rejection region that is less than 2.040 reject H_o thus the correlation between TPM practices and scrap material production is significant. 76.1% of total variability in dispatch compliance can be explained by the changes in TPM practices implemented by Kipevu II power plant (adjusted R^2=0.761). From Table 4.12, the P value of the F-test is 0.000, since the analysis was conducted with a 5% significance level reject the H_o: The model has no explanatory power. Therefore the model that was generated by this regression was significant and was used in explaining how dispatch compliance changed with change in TPM practices. The model took the form:

$$y_1=16.811 + 0.088x_1 + 0.046x_2 + 0.447x_3 + 0.720x_4 - 0.219x_5$$

This model means that when one more hour of forced outage is avoided scrap metal will decrease by 447 kilograms provided that all other TPM practices are held constant. When unplanned maintenance drops by one percent scrap metal will decrease by 720 kilograms provided that all other TPM practices are held constant. When an operator spends one hour more doing maintenance-related task scrap metal will decrease by 219 kilograms provided that all other TPM practices are held constant. The P-values for the t-statistics show that only forced outage and unplanned maintenance at p= 0.0026 and p=0.000 respectively thus < 0.05 are significant at 5% significance level. So reject H_o: Forced outage and unplanned maintenance have predictive ability over scrap metal production, therefore Forced outage and unplanned maintenance can be used to predict availability for the population.

4.2.4 Total Productive Maintenance Practices and Customer Satisfaction Rating

To test for the assumptions of multicollinearity VIF was calculated. From Table 4.17 VIF is less than 5 which means multicollinearity does not exist. To test for autocorrelation Durbin-Watson test was conducted. From Table4.15 $d\ calculated(d_c)$=1.551. From the Durbin-Watson table $d_L = 1.127$ and d_U =1.813 therefore the test is inconclusive.

Pearson's correlation analysis was run to determine the nature of the relationship between the implementation of the TPM practices and customer satisfaction rating. The results were summarized in Table 4.14.

Table 4.14: Correlations between Total Productive Maintenance Practices and Customer Satisfaction Rating

Correlations

		Customer Satisfaction (%)	Permits Raised	Training (hours)	Forced Outage (hours)	Unplanned Maintenance	Autonomous Maintenance
Customer Satisfaction (%)	Pearson Correlation	1					
	Sig. (2-tailed)						
Permits Raised	Pearson Correlation	.367*	1				
	Sig. (2-tailed)	.036					
Training (hours)	Pearson Correlation	-.294	-.152	1			
	Sig. (2-tailed)	.096	.398				
Forced Outage (hours)	Pearson Correlation	-.460**	-.323	.120	1		
	Sig. (2-tailed)	.007	.067	.507			
Unplanned Maintenance	Pearson Correlation	-.579**	-.414*	-.090	.668**	1	
	Sig. (2-tailed)	.000	.017	.618	.000		
Autonomous Maintenance	Pearson Correlation	.315	.346*	-.138	-.433*	-.406*	1
	Sig. (2-tailed)	.075	.049	.444	.012	.019	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

It was observed from Table 4.14 that a weak, positive and insignificant relationship exist between autonomous maintenance and customer satisfaction (r = 0.315, p = 0.075). It is also clear that there is a weak, positive and significant relationship between number of permits raised and customer satisfaction (r = 0.367, p = 0.036). It is also observed that there is a weak, negative and insignificant relationship between training hours and customer satisfaction (r = -0.294, p = 0.096). It is evident that there is a medium strength, negative and significant relationship between forced outage and customer satisfaction (r = -0.46, p = 0.007), there is a strong, negative and significant relationship between unplanned maintenance and customer satisfaction (r = -0.579, p = 0.000). A multiple linear regression analysis was performed to determine the relationship between the implementation of the TPM practices and customer satisfaction rating at Kipevu II power plant. The results are summarized in Table 4.15 to 4.17.

Table 4.15: Model Summary Regression Results of Total Productive Maintenance Practices and Customer satisfaction

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.679[a]	.462	.362	6.774	1.551

a. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance
b. Dependent Variable: Customer Satisfaction (%)

Table 4.16: ANOVA Regression Results of Total Productive Maintenance Practices and Customer satisfaction

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1061.948	5	212.390	4.628	.004[b]
	Residual	1239.022	27	45.890		
	Total	2300.970	32			

a. Dependent Variable: Customer Satisfaction (%)

b. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance

Table 4.17: Coefficients Regression Results of Total Productive Maintenance Practices and Customer satisfaction

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	115.707	15.328		7.549	.000		
	Permits Raised	.029	.062	.076	.469	.643	.767	1.305
	Training (hours)	-.128	.058	-.331	-2.206	.036	.886	1.128
	Forced Outage (hours)	-.011	.133	-.016	-.081	.936	.501	1.997
	Unplanned Maintenance	-.270	.099	-.564	-2.716	.011	.462	2.165
	Autonomous Maintenance	.004	.114	.006	.039	.969	.747	1.339

a. Dependent Variable: Customer Satisfaction (%)

From table 4.15, the significance of R was tested using the t distribution

The null hypothesis H_o : r = 0 (the correlation coefficient is not significant) The alternative hypothesis H_1 : r ≠ 0 (the correlation coefficient is significant)

The decision rule would therefore be to reject H_o if the computed t value (t_c) is either less than -2.040 of greater than 2.040. This is a two tailed test at 0.05 level of significance. Degrees of freedom = (sample size-2) = ($n-2$) = 33 – 2 = 31

$|t_c| = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$ where the sample correlation coefficient (strength of the relationship between the sample variables) (r) =0.679,

$|t_c| = \frac{0.679}{\sqrt{1-0.462}} \times \sqrt{(33-2)}$ =5.1496

From the t distribution table the tabulated t value (t_t) at (n-2) degrees of freedom using 5% level of significance is t_t =2.040. Since, computed t falls in the rejection region that is less than 2.040 reject H_o thus the correlation between TPM practices and customer satisfaction is significant. 36.2% of total variability in customer satisfaction can be attributed to the changes in TPM practices implemented by Kipevu

II power plant (adjusted R^2=0.362). From Table 4.16, the P value of the F-test is 0.004, since the analysis has been conducted with a 5% significance level reject the H_o: The model has no explanatory power. Therefore the model that was generated by this regression was significant and was used in explaining how customer satisfaction rating changed with change in TPM practices. The model took the form:

$$y_1=115.707 + 0.029x_1 - 0.128x_2 - 0.011x_3 - 0.270x_4 + 0.004x_5$$

This model means when one more permit is raised the customer satisfaction rating increases by 0.029% provided that all other TPM practices are held constant, when one percentage more of forced outage is avoided customer satisfaction rating increases by 0.011% provided that all other TPM practices are held constant. When one unplanned maintenance is avoided, customer satisfaction rating increases by 0.27% provided that all other TPM practices are held constant. If an operator spends one hour more doing maintenance-related task customer satisfaction rating increases by 0.004% provided that all other TPM practices are held constant.

The P-values for the t-statistics show that only forced outage and autonomous maintenance at p= 0.036 and p=0.011 respectively thus < 0.05 are significant at 5% significance level. So reject the H_o: Forced outage and autonomous maintenance have a predictive ability over customer satisfaction rating, therefore Forced outage and autonomous maintenance can be used to predict customer satisfaction for the population.

4.2.5 Total Productive Maintenance Practices and Equipment Reliability

To test for the assumptions of multicollinearity VIF was calculated. From Table 4.21 VIF is less than 5 which means multicollinearity does not exist. Pearson's correlation analysis was run to determine the nature of the relationship between the implementation of the TPM practices of safety, training, quality maintenance, planned maintenance and autonomous maintenance and equipment reliability. The results are summarized in Table 4.18.

Table 4.18: Correlations between Total Productive Maintenance Practices and Equipment Reliability

Correlations

		Equipment Reliability (%)	Permits Raised	Training (hours)	Forced Outage (hours)	Unplanned Maintenance	Autonomous Maintenance
Equipment Reliability (%)	Pearson Correlation	1					
	Sig. (2-tailed)						
Permits Raised	Pearson Correlation	.281	1				
	Sig. (2-tailed)	.113					
Training (hours)	Pearson Correlation	-.338	-.152	1			
	Sig. (2-tailed)	.055	.398				
Forced Outage (hours)	Pearson Correlation	-.600**	-.323	.120	1		
	Sig. (2-tailed)	.000	.067	.507			
Unplanned Maintenance	Pearson Correlation	-.490**	-.414*	-.090	.668**	1	
	Sig. (2-tailed)	.004	.017	.618	.000		
Autonomous Maintenance	Pearson Correlation	.524**	.346*	-.138	-.433*	-.406*	1
	Sig. (2-tailed)	.002	.049	.444	.012	.019	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From Table 4.18 it is evident that a weak, positive and insignificant relationship exist between number of permits raised and Equipment reliability(r = 0.281, p = 0.113). It is observed that there is a weak, negative and insignificant relationship between training hours and equipment reliability (r = -0.338, p = 0.055). It’s also evident that there is a medium strength, negative and significant relationship between unplanned maintenance and equipment reliability (r = -0.49, p = 0.004). It is observed that there is a strong, positive and significant relationship between autonomous maintenance and equipment reliability (r = 0.524, p = 0.002). There is a strong, negative and significant relationship between forced outage and equipment reliability (r = -0.6, p = 0.000).

A Multiple linear regression analysis was performed to determine the relationship between the implementation of the TPM practices and equipment reliability at Kipevu II power plant. The results are summarized in table 4.19 to 4.21.

Table 4.19: Model Summary Regression Results of Total Productive Maintenance Practices and Equipment Reliability

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.724[a]	.524	.436	3.5529	1.011

a. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance
b. Dependent Variable: Equipment Reliability (%)

Table 4.20: ANOVA Regression Results of Total Productive Maintenance Practices and Equipment Reliability

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	374.925	5	74.985	5.940	.001[b]
	Residual	340.818	27	12.623		
	Total	715.742	32			

a. Dependent Variable: Equipment Reliability (%)
b. Predictors: (Constant), Autonomous Maintenance, Training (hours), Permits Raised, Forced Outage (hours), Unplanned Maintenance

Table 4.21: Coefficients Regression Results of Total Productive Maintenance Practices and Equipment Reliability

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	96.354	8.039		11.986	.000		
	Permits Raised	-.010	.033	-.048	-.315	.755	.767	1.305
	Training (hours)	-.062	.030	-.287	-2.032	.052	.886	1.128
	Forced Outage (hours)	-.120	.070	-.324	-1.724	.096	.501	1.997
	Unplanned Maintenance	-.055	.052	-.207	-1.059	.299	.462	2.165
	Autonomous Maintenance	.108	.060	.277	1.801	.083	.747	1.339

a. Dependent Variable: Equipment Reliability (%)

From Table 4.19, the significance of R was tested using the t distribution

The null hypothesis H_o : r = 0 (the correlation coefficient is not significant)

The alternative hypothesis H_1 : r ≠ 0 (the correlation coefficient is significant)

The decision rule would therefore be to reject $H_o$if the computed t value $(t_c)$is either less than -2.040 of greater than 2.040. This is a two tailed test at 0.05 level of significance. Degrees of freedom = (sample size-2)= $(n-2)$ = 33 – 2 = 31

$|t_c| = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$ where the sample correlation coefficient (strength of the relationship between the sample variables) (r) = 0.724

$|t_c| = \frac{0.724}{\sqrt{1-0.524}} \times \sqrt{(33-2)}$ =4.2309

From the t distribution table the tabulated t value (t_t) at (n-2) degrees of freedom using 5% level of significance is t_t =2.040. Since, computed t falls in the rejection region that is less than 2.040 reject H_o thus the correlation between TPM practices and equipment reliability is significant. 43.6% of total variability in equipment reliability can be explained by the changes in TPM practices implemented by Kipevu

II power plant (adjusted R^2=0.436). From Table 4.20, the P value of the F-test is 0.001, since the analysis was conducted with a 5% significance level reject the H_o: The model has no explanatory power. Therefore the model that was generated by this regression was significant and was used in explaining how equipment reliability rating changed with change in TPM practices. The model took the form:

$$y_1=96.354 - 0.01x_1 - 0.062x_2 - 0.12x_3 - 0.055x_4 + 0.108x_5$$

This model means when one more permit is raised the equipment reliability decreases by 0.01% provided that all other TPM practices are held constant. When one forced outage is avoided equipment reliability increases by 0.12% provided that all other TPM practices are held constant. If one unplanned maintenance is avoided equipment reliability increases by 0.055% provided that all other TPM practices are held constant. When an operator spends one hour more doing maintenance-related task equipment reliability increases by 0.108% provided that all other TPM practices are held constant.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the findings of the research, thus answering the research questions. It presents conclusions and recommendations drawn from the study. It also gives suggestions for the research gaps that can be addressed in future research and finally limitations of the study.

5.2 Summary of the Findings of the Study

The study established that the implementation of various TPM practices at Kipevu II power plant had a significant effect on equipment availability, dispatch compliance, scrap metal production, customer satisfaction and last but not least the rate of meeting operations objectives. It has also led to the decrease of scrap metal produced by 37% between 2003 and 2008, signifying a reduction in waste arising from low-quality maintenance. It has also led to the increase in customer satisfaction rating to 99% in 2013, an increase in equipment reliability from 78% in 2002 to 98% in 2012. Quality maintenance practice of preventing forced outage has had the most impact in as far as improving equipment reliability is concerned, when one more hour of forced outage is avoided equipment reliability increases by 0.12%, if all other TPM practices were held constant The same TPM practice has the highest contribution on improving availability, when one more hour of forced outage is avoided availability increases by 0.123% provided that all other TPM practices are held constant.

Planned maintenance has proved to be the most effect TPM practice at Kipevu II power plant when it comes to increasing customer satisfaction rating. Since, when one unplanned maintenance is avoided customer satisfaction rating increases by 0.27%

provided that all other TPM practices are held constant. This practice also assists in cutting down on scrap metal production by the biggest margin. When unplanned maintenance drops by one percent, scrap metal decreases by 720 kilograms provided that all other TPM practices are held constant. Unplanned maintenance is still significant in helping Kipevu II power plant to comply with the dispatch assigned since it's the TPM practice having the biggest contribution toward dispatch compliance, when unplanned maintenance drops by one percent dispatch compliance increases by 0.248% provided that all other TPM practices are held constant.

5.3 Conclusions

This research concludes that there is a significant relationship between the implementation of total productive maintenance (TPM) practices at Kipevu II power plant from the year 2000 to 2016 and productivity the former is also related to the improvement in the equipment availability, dispatch compliance, scrap metal production, customer satisfaction, and equipment reliability. Out of the five TPM practices considered, planned maintenance of thermal power plant equipment was found to have the biggest effect on the productivity of Kipevu II thermal power plant, followed by the quality maintenance. The findings of this study agree with the findings of Ngugi (2015) who performed a study on the effect of TPM on equipment effectiveness and established that TPM practices enable improvement in the equipment availability, performance, and quality rate at Bamburi cement factory. Ngugi (2015) used three TPM practices namely, autonomous maintenance, planned maintenance and elimination of lost equipment time.

This study also agrees with the research by Venkatesh (2007) which showed that TPM practice of planned maintenance would make the equipment reliability improve by 50% while quality maintenance would make the cost of quality reduce by 50%. According to Venkatesh (2007), the cost of quality includes the rework and scrap. The findings of this study are also in agreement with the findings of Ateka (2013) who explored the adoption of TPM practices in large manufacturing firms located in Mombasa County. In his study he found that TPM implementation resulted in high productivity as well as an increase in quality. The study results also showed that the most important critical success factors of TPM is cooperation and involvement of both the operators and the maintenance workers.

5.4 Recommendations

In order for an organization to maximize productivity based on the level of implementing planned maintenance, thermal power plants should focus investing on a system that improves maintenance planning. This could be by employing modern and effective CMMS as well as training the maintenance planners on the latest techniques of maintenance planning. The thermal power plants can also upgrade the equipment used in monitoring equipment performance. Since it's based on such information that the equipment will be declared unfit for operation thus be availed for maintenance.

The thermal power plant can also boost productivity by improving quality maintenance there by reducing factors that result in forced outages. These factors include conducting maintenance in a way that enhances equipment reliability and completely eliminates chances of equipment failure. Forced outage can be avoided by ensuring that proper equipment operation and maintenance procedures are in place. The level of employee skills and knowledge can also avoid equipment forced outages.

5.5 Limitations of the Study

The methodology being used was longitudinal. The fact that it dated back to 2001 made record retrieval a limitation to this study. The variation in the data collected over time could be affected by many another intervening variable which were not included in this study. The data was limited to quantitative information only leaving out the qualitative information. The time within which the study was conducted was a limitation in the sense that the scope could not be made any wider.

5.6 Suggestions for Further Research

This study focused on five TPM practices and their effect on productivity, perhaps future research could be conducted to establish the effect of office TPM, 5S and continuous improvement on productivity. A broader study, focusing on the entire county would be more appropriate. Focusing on productivity only was a narrow view, perhaps future research should focus on broader subjects. This study was a case study of a thermal power plant, future studies can focus on companies generating electricity from renewable sources of electricity. This research recommends a study on TPM implementation on service industry to see if its impacts resembles what has been witnessed in the manufacturing industries.

REFERENCES

Actis Capital (2016), *Tsavo: A solution to a power problem. London: Actis Capital (AC). Retrieved 1 April 2016.*

Ahuja I.P.S. & Khamba J.S. (2008). Total productive maintenance: literature review and directions. *International Journal of Quality & Reliability Management, 25*(7), 709 – 756.

Alam, A. (2013). Electric power consumption, foreign direct investment and economic growth: A comparative study of India and Pakistan. *World Journal of Science, Technology and Sustainable Development*, *10*(1), 55-65.

Ateka, N. (2013). *Adoption of total productive maintenance practices among large manufacturing firms in Mombasa County, Kenya* (Unpublished MBA Thesis).University of Nairobi, Kenya.

Australian Standard (1885.1– 1990), *Australian standard:Workplace Injury and Disease Recording Standard*, Australian Standard.

Bamber, C.J., Sharp, J.M., & Hides, M.T. (1999). Factors affecting successful implementation oftotal productive maintenance – a UK manufacturing case study perspective. *Journal of Quality in Maintenance Engineering, 5*(3), 162-81.

Bhadury, B. (2000). Management of productivity through TPM. *Productivity, 41*(2), 240-51.

Bhadury, B. (1988). *Total Productive Maintenance*. Allied Publishers Limited, New Delhi.

Castellano, A., Kendall, A., Nikomarov, M., & Swemmer, T. (2015). Brighter Africa: The growth potential of the sub-Saharan electricity sector. *McKinsey Report.http://www.mckinsey.com/insights/energy_resources_materials/powering_africa*.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage.

Duffuaa, O.S., Raouf, A. & Campbell, J. (1998). *Planning and control of maintenance systems*.Wiley, New york, NY.

Elaine, A., & Maged E. (2013). TPM implementation in large and medium size organisations. *Journal of Manufacturing Technology Management*, *24*(5), 688 – 710.

Electrical4u. (2016). *Wind power*. Retrived from. http://www.electrical4u.com/search.php?searchkey=wind+power

Emiliani, M.L. (1998), Lean behaviors, *Management Decision*. 36 (9), 615 – 631

Energy Regulatory Commission of Kenya. (2016). *Licensed power plants in Kenya.* Retrived from http://www.erc.go.ke/

Freeman, R. (2008). *Labour productivity indicators . OECD* pp.1

Garvin, D. A. (1984).*What does product quality Really Mean?* Sloan management review, 25.

Garvin, D. A. (1987). Competing on the 8 dimensions of quality. *Harvard Business Review*, *65*(6), 101-109.

Goldratt, E. M.,& Cox, J. (1986). *The goal: a process of ongoing improvement*. North River Press NY.

Gratton, C., & Jones, I. (2004). *Research methods for sports studies*. London: Routledge.

Gupta, R. C., Sonwalkar, J., & Chitale, A. K. (2001). Overall equipment effectiveness through total productive maintenance. *Prestige Journal of management and Research*. *5*(1), 61-72.

Heinrich, H.W. (1959). *Industrial Accident Prevention*, (4th ed.). McGraw-Hill, New York, NY.

Herbling, D. (2016, October 4). Why more steam power will not drive down fuel charges.*The Daily nation Smart Company*, p.4.

Hurn, J. B. (2013). Response of managers to the challenges of globalisation, *Industrial and Commercial Training*. *45*(6), 336 - 342

Induswe, J. (2013). *Implementation of Total Productive Maintenance In LargeManufacturing Firms In Kenya* (Unpublished MBA Thesis). University ofNairobi, Kenya.

Ireland, F. & Dale, B. G. (2001). A study of total productive maintenance implementation. *Journal of Quality in Maintenance Engineering*, *7*(3), 183 – 192

Jeong, K. Y., & Phillips, D. T. (2001). Operational efficiency and effectiveness measurement. *International Journal of Operations & Production Management*, *21* (11), 1404-1416.

Kenya Gazette Supplement. (2014). *The environmental management and co-ordination (AirQuality) Regulations 2014.No.4*. Retrieved from http://kenyalaw.org/kl/fileadmin/pdfdownloads/LegalNotices/34

Kumarasiri J., & Jubb C. (2016).Carbon emission risks and management accounting: Australian evidence. *Accounting Research Journal*, *29* (2), 37 – 153.

Kuula, M., & Putkiranta, A. (2012). Longitudinal benchmarking studies in operations management: lessons learned, Benchmarking. *An International Journal, 19*(3), 358 – 373.

Ministry of energy. (2016). *Projects.* Retrived from http://www.energy.go.ke/index.php/projects/on-going-projects.html.

Mirghani, M.A. (2001). A framework for costing planned maintenance. *Journal of Quality in Maintenance Engineering*, *7* (3), 170 – 182.

Moore, R. (2001). *Making Common Sense Common Practice*. Butterworth-Heinemann, Burlington: MA.

Moubray, J. (1997). *Reliability Centered Maintenance*, (2nd ed.). Industrial Press, New York, NY.

Mohamed, S.S.A.H.A. (2014). Critical success factors for total productive manufacturing (TPM) deployment at Egyptian FMCG companies, *Journal of Manufacturing Technology Management. 25* (3), 393 – 414

Nakajima, S. (1988). *Introduction to TPM, Total Productivity Maintenance*. Productivity Press, Cambridge, MA.

Narayan, V. (2012). Business performance and maintenance. *Journal of Quality in Maintenance Engineering, 18* (2),183 – 195.

Ngugi, K. (2015). *Total productive maintenance practices and equipment effectiveness: a case study of Bamburi cement limited, Kenya* (Unpublished MBA Thesis). University of Nairobi, Kenya.

Ohno, T. (1988). *Toyota Production System: Beyond Large-Scale Production*. Productivity Press, Portland, OR.

Patra, N.K, Tripathy, J.K. & Choudhary, B. K. (2005). Implementing the office total productive maintenance (“office TPM”) program: a library case study. *Library Review*, *54* (7), 415 -424.

PEIC. (1999). *Kipevu II: A Balancing Act*. Retrieved from http://kpowerengineeringint.com (PEIC).

Penrose, E. (1959) *The theory of the growth of the firm*. Oxford, UK: Blackwell.

Peter, A., Peter, B., & Tim, B. (2016). Towards the strategic adoption of Lean in aviation Maintenance Repair and Overhaul (MRO) industry. *Journal of Manufacturing TechnologyManagement. 27* (1), 38 – 61.

Pettigrew, A. M. (1990). Longitudinal field research on change: Theory and practice. *Organization science*, *1*(3), 267-292.

Rajan, R. & Sajumon, K. T. (2013). Evaluation of the contributors of OEE (Overall Equipment Effectiveness) using Shapley value: A Case Study. *International Journal of Innovative Research in Science, Engineering and Technology*. *2*(1). 2347 - 6710.

Raouf, A.S.I., (2004). *Productivity enhancement using safety and maintenance integration*, Kybernetes, 33 (7) 1116 – 1126.

Raouf, A.S.I. (1994). Improving Capital Productivity through Maintenance, *International Journal of Operations & Production Management, 14* (7), 44 – 52.

Raouf, A., & Dhillon, B. S. (1993). *Safety assessment: A quantitative approach*. Lewis Publishers.

Robinson, C.J.,& Ginder, A.P. (1995). *Implementing TPM: The North American Experience.* Productivity Press, Portland, OR.

Saint-Paul, G. (2008*). Innovation and inequality: How does technical progress affect workers?.* Princeton, New Jersey: Princeton University Press.

Samanta, B., Sarkar, B., & Mukherjee, S.K. (2001). Reliability centered maintenance (RCM) strategy for heavy earth moving machinery in coal mine. *Industrial Engineering Journal, 30* (5), 15-20.

Shamsuddin, A. M. H. & Hassan, Z. T. (2004). State of implementation of TPM in SMIs: a survey study in Malaysia. *Journal of Quality in Maintenance Engineering, 10* (2) 93 – 106.

Sharma, R.K., Kumar, D., & Kumar, P. (2006). Manufacturing excellence through TPM implementation: a practical analysis. *Industrial Management & Data Systems, 106*(2), 256-80.

Shirose, K. (Ed.). (1999). *TPM: Total Productive Maintenance: New Implementation Program in Fabrication and Assembly Industries*. Japan Institute of Plant Maintenance (JPM), 1999.

Simplice, M. E. B., & Asongu A. (2015). The impact of liberalization policies on income inequality in African countries. *Journal of Economic Studies*, *42* (1),68 – 100.

Stainer, A. (1995). Productivity management: the Japanese experience. *Management Decision*, *33* (8), 4 – 12.

Trochim, W.M.K. (2006). *Time in research. Research Methods Knowledge Base*. *Web Center for Social Research Methods*. Retrieved from http://www.socialresearchmethods.net/kb/timedim.php.

Van der WalD. Lynn, R.W.E (2002). Total productive maintenance in a South African pulp and paper company: a case study, *The TQM Magazine*, *14* (6), 359 – 366.

Vanzile, D., & Otis, I. (1992). *Measuring and controlling machine performance, in Salvendy, G. (Ed.), Handbook of Industrial Engineering,* John Wiley, New York, NY.

Venkatesh, J. (2007). *Plant Maintenance Resource Centre. An Introduction to Total Productive Maintenance (TPM) (online)*. Retrieved from: http://www.plant maintenance.com/articles/tpm. intro.pdf.

Vorne Industries Inc. (2013). *TPM – Total Productive Maintenance.* Retrieved from http://www.leanproduction.com/tpm.html.

Wakaru, Y. (1988). *TPM for Every Operator in JIPM* (Ed.), Productivity Press, Portland, OR.

Wernerflt, B. (1984). A resource based view of the firm. *Strategic management journal*,*5*(2), 171-180.

Willmott, P. (1994, November). TPM's place in the quality scene, *Quality World,* 762-5.

Wireman, T. (1990a). *World Class Maintenance Management*. Industrial Press Inc., New York, NY.

Womack, J.P., Jones, D.T., & Roos, D. (1990). *The Machine That Changed the World*. HarperCollins, New York, NY.

Womack, J.P., & Jones, D.T. (1996). *Lean Thinking*. Simon & Schuster, New York, NY.

Yin, R. K. (2003). Case study research design and methods (3rd Ed.) *Applied social research methods series, 5*.

APPENDICES

Appendix 1: Data Collection Table

Period	y_1	y_2	y_3	y_4	y_5	x_1	x_2	x_3	x_4	x_5
Jan-Jun 2000										
Jul-Dec 2000										
Jan-Jun 2001										
Jul-Dec 2001										
Jan-Jun 2002										
Jul-Dec 2002										
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Jul-Dec 2012										
Jan-Jun 2013										
Jul-Dec 2013										

Jan-Jun 2014										
Jul-Dec 2014										
Jan-Jun 2015										
Jul-Dec 2015										
Jan-Jun 2016										

Where:

y_1= Availability
x_1 = Safety

y_2= Dispatch compliance
x_2= Training

y_3 = Scrap material production
x_3= Quality maintenance

y_4 = Customer satisfaction rating
x_4= Planned maintenance

y_5 =Rate of meeting operation objectives
x_5= Autonomous maintenance

Appendix 2: Formulas for Calculating Availability and Equipment Reliability

Availability %: the time that the engines are running or would be able to run (stand-by) out of the total amount of hours during the month.

$$\text{Availability [\%]} = \frac{\text{Running hours + Standby hours}}{\text{Running hrs+ Standby hrs + Planned Maintenance hrs + Forced Outage hrs}}$$

Reliability %: the time that the engines are running or would be able to run (stand-by) or are under planned maintenance out of the total amount of hours during the month.

$$\text{Reliability [\%]} = \frac{\text{Running hours + Standby hours+ Planned Maintenance hours}}{\text{Running hrs+ Standby hrs + Planned Maintenance hrs + Forced Outage hrs}}$$