

**UNIVERSITY OF NAIROBI  
SCHOOL OF BUSINESS**

**HOW MAINTENANCE PRACTICES INFLUENCE  
MANUFACTURING PERFORMANCE IN KTDA  
MANAGED FACTORIES**

**BY  
NG'ERA SAMUEL MBUGUA  
D61/62902/2011**

This research project is submitted in partial fulfilment of the requirements for the award of degree of Master of Business Administration of the University of Nairobi.

**November 2013**

**DECLARATION**

I hereby Declare that the work content in this project report is my original work and has not been presented either in part or in its entirety to the University of Nairobi or any other University. Where the works of other authors has been used, this has been cited appropriately.

Signature .....

Date .....

**Ng'era Samuel Mbugua**

**D61/62902/2011**

This research project has been submitted for examination with my approval as university of Nairobi supervisor.

Signature.....

Date.....

**Dr Owino Okwiri**  
**Department of Management Science**  
**School of Business, University of Nairobi**

## **DEDICATION**

To my lovely Wife, Agnes and Children, Njeri, Wambui, Wakarima and Ng'era for making it worthwhile.

## **ACKNOWLEDGEMENTS**

I would like to appreciate several individuals who have contributed to this study by way of materials, guidance and motivation

My appreciation to my supervisor Dr Owino Okwiri for his guidance and support

I also appreciate the KTDA Production Managers who were accommodative and supportive in giving me information on their manufacturing operations and performance and issues . I also appreciate regional Engineers who provided invaluable information on maintenance performance measurements.

My appreciation to my wife who gave me emotional support. My daughters Njeri and Wambui -your determination motivated me, my nephew George for throwing in the challenge, my class mates – mafans- for suffering without bitterness.

Last but not least, my friends; Jeff Arodi and Rugendo (Modiglian) who kept on encouraging and inspiring me .

**THANK YOU GOD FOR SEEING ME THIS FAR**

## **TABLE OF CONTENTS**

<b>Declaration</b>	<b>ii</b>
<b>Dedication</b>	<b>iii</b>
<b>Acknowledgements</b>	<b>iv</b>
<b>Table of Contents</b>	<b>v</b>
<b>List of tables</b>	<b>viii</b>
<b>List of figures</b>	<b>ix</b>
<b>Abbreviations and accronames</b>	<b>xi</b>
<b>Abstract</b>	<b>xii</b>
<b>1.0 CHAPTER – INTRODUCTION</b>	<b>1</b>
<b>1.1 Background of the study</b>	<b>1</b>
<b>1.1.1 Maintenance Management Practices and Maintenance Performance</b>	<b>1</b>
<b>1.1.2 The Tea Industry in Kenya and KTDA Role</b>	<b>3</b>
<b>1.2 Statement of the Research Problem</b>	<b>4</b>
<b>1.3 Objective of the Study</b>	<b>5</b>
<b>1.4 Value of the study</b>	<b>6</b>
<b>2.0 CHAPTER 2- LITERATURE REVIEW</b>	<b>7</b>
<b>2.1 Introduction</b>	<b>7</b>
<b>2.2 Maintenance Approaches</b>	<b>7</b>
<b>2.3 Maintenance Performance Measurement System</b>	<b>9</b>
<b>2.4 Summary and Conceptual Framework</b>	<b>11</b>

<b>3.0</b>	<b>CHAPTER 3- RESEARCH METHOD</b>	<b>13</b>
<b>3.1</b>	<b>Introduction</b>	<b>13</b>
<b>3.2</b>	<b>Research Design</b>	<b>13</b>
<b>3.3</b>	<b>Research Sample</b>	<b>13</b>
<b>3.4</b>	<b>Data Collection Method</b>	<b>14</b>
<b>3.5</b>	<b>Data Analysis</b>	<b>14</b>
<b>4.0</b>	<b>CHAPTER 4- DATA ANALYSIS AND PRESENTATION OF FINDINGS</b>	<b>16</b>
	<b>4.1 Introduction</b>	<b>16</b>
	<b>4.2 Data Analysis and presentation of results</b>	<b>16</b>
	<b>4.2.1 Maintenance Practices</b>	<b>16</b>
	<b>4.2.2 Maintenance Practices influence on Maintenance Performance</b>	<b>17</b>
	<b>4.2.4 Factors affecting maintenance performance</b>	<b>18</b>
	<b>4.2.5 Influence of Maintenance Performance on manufacturing performance</b>	<b>19</b>
	<b>4.2.6 Preferred options to handle production disruptions</b>	<b>34</b>
<b>4.3</b>	<b>Summary and interpretation of the findings</b>	<b>34</b>

<b>5.0</b>	<b>CHAPTER 5 – SUMMARY CONCLUSIONS AND</b>	<b>36</b>
	<b>RECOMMENDATIONS</b>	
<b>5.1</b>	<b>Introduction</b>	<b>36</b>
<b>5.2</b>	<b>Summary of the findings</b>	<b>36</b>
<b>5.3</b>	<b>Conclusions</b>	<b>36</b>
<b>5.4</b>	<b>Policy Recommendation</b>	<b>37</b>
<b>5.5</b>	<b>Limitation of the study</b>	<b>37</b>
<b>5.6</b>	<b>Recommendation for further research</b>	<b>37</b>
	<b>References</b>	<b>39</b>
	<b>Introduction letter</b>	<b>41a</b>
	<b>Appendix 1 – Survey Instruments</b>	<b>41</b>
	<b>Appendix 2– Summary of Research Data</b>	<b>38</b>

## LIST OF TABLES

- Table 1: Summary of Maintenance and manufacturing performance - Pg 19.
- Table 2: Spearman's rank correlation for plant availability against other manufacturing performance measures region 1 – pg 21
- Table 3: Spearman's rank correlation for plant availability against other manufacturing performance measures region 2 – pg 23
- Table 4: Spearman's rank correlation for plant availability against other manufacturing performance measures region 3 - pg 25
- Table 5: Spearman's rank correlation for plant availability against other manufacturing performance measures region 4 – pg 27
- Table 6: Spearman's rank correlation for plant availability against other manufacturing performance measures region 5 – pg 29
- Table 7: Spearman's rank correlation for plant availability against other manufacturing performance measures region 6 – pg 31
- Table 8: Spearman's rank correlation for plant availability against other manufacturing performance measures region 7 – pg 33
- Table 9: Spearman correlation between Maintenance Practice and Plant availability- pg 50

## LIST OF FIGURES

- Figure 1: Pie Chart-representing Maintenance Practices – pg 16.
- Figure 2: Scatter graph representing maintenance practices and plant availability – pg 17
- Figure 3: Line graph – for factors affecting maintenance performance – pg 18
- Figure 4: Scatter graph – region 1- for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 20
- Figure 5: Scatter graph – Region 1 – for KGMT/CUMF, Average auction Prices and plant availability - 20
- Figure 6: Scatter graph – region 2- for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 22
- Figure 7: Scatter graph – Region 2 – for KGMT/CUMF, Average auction Prices and plant availability – pg 22
- Figure 8: Scatter graph – region 3 for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability –pg 24
- Figure9: Scatter graph – Region 3 – for KGMT/CUMF, Average auction Prices and plant availability – pg 24
- Figure 10: Scatter graph – region 4- for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 26
- Figure 11: Scatter graph – Region 4 – for KGMT/CUMF, Average auction Prices and Plant Availability- pg 26
- Figure 12: Scatter graph – Region 5 – for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 28
- Figure 13: Scatter graph – Region 5 – for KGMT/CUMF, Average auction Prices and  
Plant availability – pg 28
- Figure 14: Scatter graph – Region 6 for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 30
- Figure 15: Scatter graph – Region 6 – for KGMT/CUMF, Average auction Prices and plant availability- pg 30

- Figure 16: Scatter graph – Region 7 – for MJ/KGMT, Energy cost KSH/KGMT, KWH/KGMT and Plant Availability – pg 32
- Figure 17: Scatter graph – Region 7– for KGMT/CUMF, Average auction Prices and plant availability – pg 32
- Figure 18: Line Graph – Representing Preferred options to overcoming production disruption –pg 34

## **ABBREVIATIONS AND ACCRONAMES**

CUMF	Cubic Metre of Firewood
GDP	Gross Domestic Produce
KAM	Kenya Association Of Manufacturers
KGGL	Kilogram of Green Leaf
KGMT	Kilogram of Made Tea
KTDA	Kenya Tea Development Agency
KWH	Kilo Watt Hour
LCC	Life Cycle Costing
MJ	Mega Joules
MPM	Maintenance Performance Measurement
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
OEE	Overall Equipment Effectiveness
RCM	Reliability Centered Maintenance
TPM	Total Productive Maintenance

## **ABSTRACT**

The purpose of this study was to investigate how maintenance practices influence maintenance performance which in turn influence manufacturing performance in KTDA Managed factories. The study was guided by determining the maintenance practices, determining the level of plant availability and determining the relationship between plant availability and manufacturing performance.

A census was done in all 65 KTDA factories. Spearman's rank correlation was used to establish if there are any relationship between maintenance practice and maintenance performance and whether maintenance performance affects manufacturing performance. Findings revealed that there was a positive relationship between the level of preventive maintenance carried out and plant availability. The findings also revealed that there is a negative correlation between the level of breakdown maintenance carried out and plant availability. The findings also revealed that there is positive correlation between plant availability and auction prices and also firewood consumption in KGMT/CUMF. The research also concluded that there is negative correlation between plant availability and energy consumption in MJ/KGMT and in KWH/KGMT and also energy cost in Ksh/KGMT.

It was recommended that KTDA factories monitor and aim to improve the Preventive maintenance strategies in order to improve maintenance performance through plant availability which will in turn improve manufacturing performance.

# **1 CHAPTER 1- INTRODUCTION**

## **1.1 Background of the Study**

Maintenance is defined as a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (BSI, 1984; Pintelon and VanPuyvelde, 2006). The purpose of maintenance is to maximize the production system availability at minimum costs, by reducing the probability of equipment or system breakdowns (Crespo Márquez, A 2007).

According to Pinjala et al., (2006). To ensure the plant operates at the required condition while meeting its production targets at an optimal cost, maintenance management has to make conscious decisions regarding the maintenance objectives and strategies that need to be pursued. Good maintenance assumes that maintenance objectives and strategies are not determined in isolation, but are in some way derived from factors such as company policy, manufacturing policy and other potentially conflicting demands and constraints in the company ( Johnsson and Lesshamar, 1999; Swanson 2001) Maintenance resources are utilised so that the manufacturing equipments are in good condition, the plant achieves its design life, the safety standards are met, the energy use and raw material consumption are optimised among other factors (Dekker, 1996).

### **1.1.1 Maintenance Management Practices and Maintenance Performance**

Maintenance management is the direction and organization of resources in order to control the availability and performance of industrial plant to some specified level (Parida, A. & Kumar, U. 2006). Maintenance management involves planning, scheduling, organizing, controlling maintenance activities. This involves a mixture of policies and techniques which varies from facility to facility According to Al- Najjar (2000) maintenance strategy depends on several factors, these are, the goals of maintenance, the nature of facility or equipment to be maintained, work flow patterns and the work environment.

Maintenance action can either be preventive Maintenance (PM) , ie replacing components are a pre-specified time using prognostic/diagnostic based on historical failure data. It can also be condition based maintenance (CBM) based on data from monitoring the condition of the component using the condition monitoring (CM) techniques.

According to Kelly (2006) maintenance strategy involves the identification, researching and execution of many repairs, replacement and inspection decisions. It is concerned with formulating the best life plan for each unit of the plant, and formulating the optimal maintenance schedule for the plant, in coordination with production and other functions concerned. Maintenance strategy describes what events (e.g. failure, passing of time, condition) trigger what type of maintenance (inspection, repair or replacement). This according to , Al-Najjar (1997) involves of a mix of policies/techniques, which varies from facility to facility depending on several factors such as the goals of maintenance, the nature of the facility or the equipment to be maintained, work flow patterns and the work environment. The identification and implementation of the appropriate maintenance policy will enable managers to avoid premature replacement costs, maintain stable production capabilities and prevent the deterioration of the system and its component parts, (Madu. 2000).

There are two aspects of performance when considering maintenance management practices. These are manufacturing performance and maintenance performance. While assessing manufacturing performance we are concerned with speed, flexibility, quality and cost. (Slack et al. 2004). Speed considers such factors considered as fast and on time delivery. Flexibility considers factors such as design adjustments, broad product line ability to rapidly change product mix and volume. Cost considers factors such as low production cost, low energy cost. Quality considers factors such as low defect rate, performance quality, product durability and environmental aspects.

Maintenance performance is concerned with Maintenance effectiveness and the results of the maintenance efforts with aims at minimizing the maintenance cost and enhancing production reliability, cost and quality. According to Parida, (2006), Some of the measures of maintenance performances are availability, mean time between failures (MTTF), failure/breakdown frequency, mean time to repair (MTTR) and

production rate index. Maintenance productivity indicators measure the usage of resources, like; labour, materials, contractors, tools and equipment. These components also form various cost indicators, such as man power utilization and efficiency, material usage and work order. Control of maintenance productivity (MP) ensures that the budgeted levels of maintenance efforts are being sustained and that required plant output is achieved (Kelly, 1997).

Hansen (2002) proposes Overall Equipment Effectiveness (OEE) is a measurement method that aids in understanding the performance of the manufacturing area, but also to identify possible limitations. OEE calculates the percentage effectiveness of the manufacturing process. OEE is further a function consisting of the three factors, availability, performance efficiency and quality.

### **1.1.2 The Tea industry in Kenya and KTDA'S Role**

The tea industry comprises of small scale holders and plantations. According to Tea Board (2011), the small scale tea farmers account for 66% of the production while 34% is produced by the plantations. According to KNBS 2012) agriculture contributes 24% of the GDP of which Tea sector contributes 68.4%. Kenya Tea Development Agency (KTDA) Ltd manages the small scale Tea Farmers. KTDA Ltd was established on 30th June 2000 after privatization of the then parastatal, the Kenya Tea Development Authority (KTDA). KTDA Ltd is the managing agent of 65 tea-processing factories and serve over 580,000 smallholder tea growers cultivating over 115,000 hectares of tea spread in 16 tea growing counties of Kenya. These counties are Kiambu, Murang'a, Nyeri, Kirinyaga, Embu, Tharaka-Nithi Meru, Kericho, Bomet, Nakuru, Kisii, Nyamira, Nandi, Kakamega, Vihiga and Trans Nzoia. KTDA has divided these tea growing counties into seven regions for ease of management.

According to Tea Board of Kenya (May 2013), In 2012, Kenya produced 399m kg of Tea. The local consumption stands at 5% of the production while 95% is exported. The major destinations of Kenyan tea are Egypt, Pakistan, United Kingdom, Afghanistan, Sudan and UAE. The major import commodities for KTDA Managed Factories are machineries and fertilizer. Machineries are mainly imported from India, south Africa and United Kingdom. They account for 50% of the capital budget.

Labour is still relatively cheap. According to KNBS, economic survey (2012), the average wage for manufacturing industry was at Ksh 881/day for manufacturing sector in 2012. This is a modest increase from Ksh 846/day in 2007. This is very low compared to average daily rate in UK GBP 50/day- ksh6750/day.

The Tea Industry faces diverse challenges that includes over production, increasing production costs, high labour costs, high energy costs, un-favourable exchange rates, reducing marginal returns, poor infrastructure, and competition from other beverages, old technologies and environmental degradation. Energy cost particularly pose a serious challenge that threaten to kill the industry. Furnace oil prices have gone from a low of ksh 20 per litre in 2003 to Ksh 90 per litre. This has forced the industry to revert to firewood. There is all likelihood that the firewood if not used prudently and replanted it will be depleted in the next few years. Electricity price has also risen from Ksh 5/KWH in 2003 to ksh 17/kwh. It is therefore important for the Tea Factories to be efficient in their manufacturing operations if they are to remain competitive in the domestic and export market.

## **1.2 Statement of the Research Problem**

There is interdependence between equipment maintenance and manufacturing performance. Equipment breakdown bring about production disturbances which affect operational performance in product quality, production speed, production cost, plant availability, work conditions, environment, safety (Bellgran and Säfssten, 2010). It is argued that Maintenance practices influences a manufacturing performance through their effect on quality, speed, cost and efficiency. A change in Maintenance practice can have an effect on these outcome measures and manufacturing performance. The major driver of cost is productivity.

A review of manufacturing performance for KTDA Factories for maintenance KPI, auction prices and payment to farmers show a wide range in performance. Energy consumption range from 22mj/kgmt to 47mj/kgmt, fire wood consumption range from a high 380kgmt/cumf to a low of 179 kgmt/cum, electrical consumption range from 1kwh/kgmt to 0.6kwh/kgmt, bonus payment range from Ksh 22 to ksh 41 per kg of green leaf. Since KTDA Factories are managed under a common platform it is expected that there would be little variance in their performance. Bellgran and Säfssten

(2010) suggest there is a strong link between productivity and manufacturing performance. Productivity is an important requirement for success in manufacturing. Low productivity could be due to issues such as skills, technology, management effectiveness, planning or environmental related factors. Some of these factors could also have an effect on maintenance management.

There is little research on how maintenance practices influence manufacturing performance. There are studies that have focused on establishing maintenance performance framework. Parida (2007) evaluated the role of condition monitoring and performance measurement in asset productivity enhancement. Crespo Márquez, and Gupta( 2007)proposes that the maintenance function must integrate five major factors in order to achieve optimum costs for upkeep and repair, and provide production reliability; these are People, Policies, equipment, practices and performance evaluation. Liyanage and Kumar (2003) also argues on the same line and proposes a maintenance management system where logistics, people related issues and production needs are the input and cost effectiveness, safety and reliability are the outputs

The aim of this research is to investigate this framework in the KTDA Managed factories context. The study seeks to determine the optimal mix of maintenance factors. It will answer the question, “Can optimization of maintenance practices bring about improved manufacturing performance?” In order to answer the question the following specific objectives are to be achieved.

### **1.3 Objective of the study**

The specific objectives of the research work were

- a) Determine the maintenance practices employed in the KTDA Managed factories
- b) Determine the level of Plant availability in KTDA Managed factories
- c) Determine the relationship between Plant Availability and manufacturing performance in KTDA Managed Factories.

#### **1.4 Value of the study**

The study provides Key answers for KTDA Managed Factories to the factors affecting manufacturing performance. These factors when addressed will lead to efficiency and effectiveness of the Tea factories and thus improved productivity which could translate to higher prices and payment to farmers The study is also useful to academics and researchers in that it forms the basis for further research work in Maintenance practice for Tea industries In Kenya. The study also provides other Tea industry players in Kenya with a framework to develop a maintenance management framework through which they can implement suitable maintenance strategies that will contribute towards improvement of manufacturing productivity and contribute towards business success.

## **2 CHAPTER 2 – LITERATURE REVIEW**

### **2.1 Introduction**

In this chapter literature is reviewed along two areas. Section (2.2) discusses general maintenance practices applied so as to gain insight into the maintenance frameworks. Section (2.3) reviews literature on maintenance management performance measurement and how they relate to manufacturing performance. The chapter also discusses, “Overall Equipment effectiveness OEE”, and its role in Maintenance and Manufacturing performance. Section (2.4) summarizes the literature studied and the research Hypothesis.

### **2.2 Maintenance Approaches**

Mobley (2004) discusses the various approaches to Maintenance. According to Mobley (2004) there are two types of maintenance management that are typically utilized by industrial and process plants; corrective maintenance and preventive maintenance.

Corrective maintenance is carried out after fault recognition and is intended to put equipments into a state in which it can perform a required production function. This management approach is , “fix it when it breaks” (Mobley, 2004). The maintenance type is emergency, repair, unscheduled and remedial tasks (Mobley, 2004). Though this method has been a major part of the maintenance operations it is also the most expensive one due to high machine downtime, low production availability, high overtime labor costs and high spare parts inventory cost (Mobley, 2004). Analyses has indicated, according to Mobley (2004), that this corrective approach of maintenance cost in average three times more than the same repair in a preventive approach.

Preventive Maintenance means replacing components or overhauling items at fixed intervals (Mobley, 2004) to prevent unscheduled downtime that would result in repair or corrective activities. This approach to maintenance management is time-driven where tasks are performed to maintain acceptable levels of availability and reliability (Mobley, 2004). Preventive maintenance can, according to (Mobley, 2004). be divided into three divisions:

Scheduled Maintenance is a form of Preventive maintenance carried out in accordance with an established time schedule or established number of units of use. Predetermined Maintenance is Preventive maintenance carried out without previously condition investigations and in accordance with established intervals of time or number of units of use. Condition Based Maintenance is Preventive maintenance consisting of performance and parameter monitoring and the subsequent actions. The performance and parameter monitoring may be scheduled, on request or continuously. Machine rebuilds and repairs are in preventive maintenance scheduled based on MTTF statistic or the bathtub curve (Mobley, 2004).

Mobley (2004), also discusses various techniques for optimizing maintenance function like Total Productive maintenance (TPM), Reliability Centred Maintenance (RCM), Life cycle costing and Computerized Maintenance Management Systems (CMMS).

Ahuja, I.P.S. and Khamba, J.S. (2007), discuss Total productive Maintenance PM implementation initiatives in an Indian manufacturing enterprise”, According to Ahuja et al (2007) Total Productive Maintenance (TPM) is designed to maximize equipment effectiveness by establishing a comprehensive productive maintenance system covering the entire life of the equipment spanning all equipment related field (planning, use and maintenance) and with participation of all employees from top management down to shop floor workers to promote productive maintenance through motivation management or voluntary small group activities .TPM involves a total participation of at all levels of the organization. The strength of the concept is the integration of production, maintenance and quality issues into addressing the, six big losses of useful capacity. These losses are breakdown, set up and adjustment, small stops, reduced speed, start up reject and production rejects.

Mobley (2004) and Ahuja et al (2007) both concur that the development of maintenance starts with corrective maintenance, then develops to preventive maintenance before introducing more integrated techniques like tpm, rcm, lcc. These fully integrated maintenance system then incorporate a Decision support system like Computerized Maintenance Management system (CMMS)

### **2.3 Maintenance Performance Measurement System**

Parida A (2006) argues that Maintenance performance measurement (MPM) is required for measuring value created by the maintenance, justifying the investment made and revising resource, allocation, taking care of customers, health, safety and environmental issues adapting to new trends in operation and maintenance strategy and organizational structural changes. Therefore, he argues that MPM can be defined as “the multi-disciplinary process of measuring and justifying the value created by maintenance investment, and taking care of the organization’s stakeholders’ requirements viewed strategically from the overall business perspective.”

Parida (2006) demonstrated that performance indicators are not defined in isolation, but should be the result of a careful analysis of the interaction of the maintenance function with other organisational functions, most evidently with the production function. In this paper, a conceptual framework that provides guidelines for choosing maintenance function performance indicators is proposed. It seeks to align maintenance objectives with manufacturing and corporate objectives, and provides a link between the maintenance objectives, maintenance process/efforts and maintenance results. Based on this conceptual framework, performance indicators of the maintenance process and maintenance results are identified for each category. Parida (2006) and Swanson (2001) argue that maintenance performance can be divided into leading and lagging indicators and Cost performance.

According to Swanson (2001) the maintenance leading indicators monitor whether the tasks are being performed well so that the desired production results can be attained. The maintenance process is addressed through: work identification (based on maintenance objectives and performance gaps), work planning, work scheduling, and work execution. In Work identification we measure % of proactive, reactive and improvement works and we also measure the work request response rate. In work planning we measure planning intensity, quality of planning and planning responsiveness. In work scheduling we measure quality of scheduling and scheduling realization rat and in Work execution we measure schedule compliance, MTTR (Mean time to repair), Man power utilization, man power efficiency and work order turnover.

According to Parida (2006) and Swanson (2001), the results of the maintenance process (lagging indicators) can be summarized as reliability, availability and operability of the technical systems. In these we measure the No of failures, their frequency, MTBF (mean time between failures), availability and Overall equipment effectiveness.

According to Parida (2006) and Swanson (2001), Maintenance cost is many times influenced by the effectiveness and efficiency in which maintenance is performed. The measures of cost performance are direct maintenance cost, breakdown severity, maintenance intensity, maintenance stock turnover, % cost of personnel, % cost of supplies

Hansen, (2002), in his study, “Overall Equipment Effectiveness: A Powerful Production/Maintenance Tool for Increased Profit”, carried out in New York describes OEE is a measurement method that aids in understanding the performance of the manufacturing area, but also to identify possible limitations. OEE calculates the percentage effectiveness of the manufacturing process. OEE is further a function consisting of the three factors, availability, performance efficiency and quality.

$$OEE = Availability \times Performance\ Efficiency \times Quality \quad (1)$$

Availability measures how long time an asset is running out of the total time available. Performance efficiency is the amount of products produced within a given time compared to the expected amount of products it would have produced. Quality is a measure of the amount of first class product (that do not require rework) against the total production (Hansen, 2002). Thus, following equations describe availability, performance efficiency and quality.

$$Availability = \frac{Planned\ production\ time - Unscheduled\ downtime}{Planned\ production\ time} \quad (2)$$

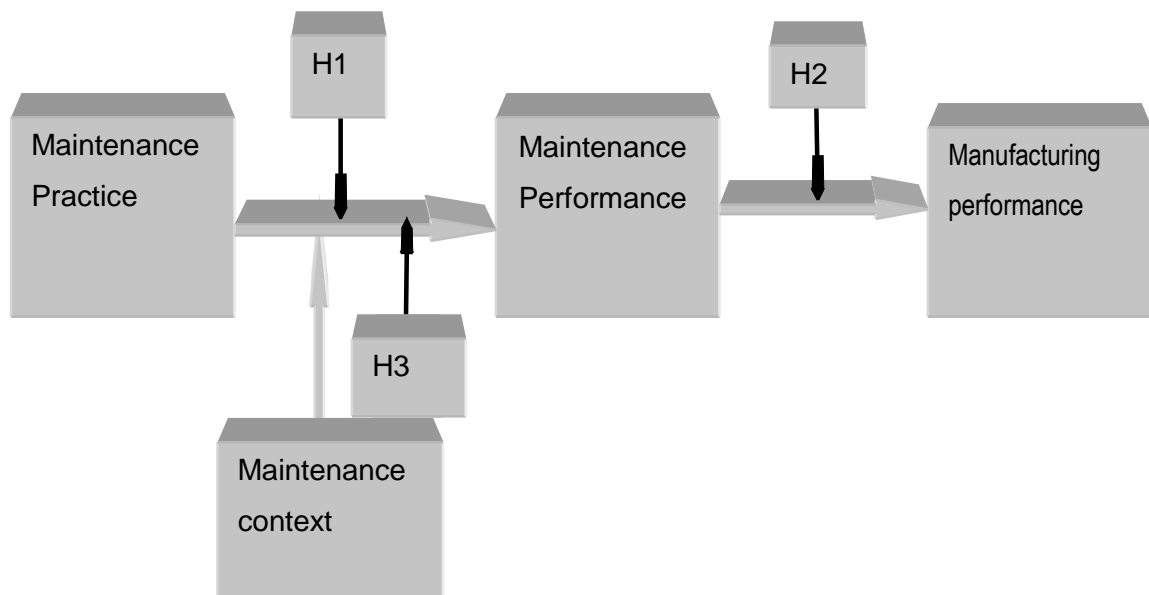
$$Performance\ Efficiency = \frac{Cycle\ time \times Products\ processed}{Production\ time} \quad (3)$$

$$Quality = \frac{Products\ processed - Products\ in\ need\ of\ rework}{Products\ processed} \quad (4)$$

OEE should be applied to bottlenecks or other critical equipment. When driven correctly, as a fact of monitoring and improving the OEE, these areas will make significant improvements to the overall performance of the manufacturing line (Hansen 2002).

## 2.4 Summary and Conceptual Frame Work

The Understanding how the Maintenance practices affect Maintenance performance and the effect on manufacturing performance is critical for the development and successful implementation Maintenance Management system. This is captured in the following conceptual framework.



The primary output of production is the desired product while demand for maintenance would be the secondary output as a result of production activities. This output would act as input for the maintenance function. Maintenance results in restored production capacity which would further act as secondary input to production thus completing the maintenance cycle. Thus production manufactures the product while maintenance produces the capacity for production. The quality of the final product is affected by both the production process and the quality of maintenance work. The way maintenance is performed will influence the availability of production facilities, the volume, quality and cost of production, as well as safety of the operation.

In order to test this in the KTDA Managed Factories the following hypothesis are proposed

H1: The Choice of Maintenance Practice has significant relationship with maintenance performance

H2: Maintenance performance has significant relationship with manufacturing performance.

H3: The relationship between maintenance management practice and maintenance performance is influenced by the maintenance context

## **3 CHAPTER 3 – RESEARCH METHODOLOGY**

### **3.1 Introduction**

In this section the research design, the population and sampling methods are explained. The method of data collection and data analysis is also explained.

### **3.2 Research Design**

The objective of this research was to investigate maintenance practices framework in a specific context in which the context of the study is limited to one or few organizations. According to Yin (2002), This provides opportunity to achieve in-depth contextual analysis. Case studies are considered less desirable form of research than survey or experiment because of lack of rigor and by their nature there is little basis for scientific generalization, Yin (2000). This is mitigated in our case because KTDA has many factories which are managed independently and post varied manufacturing performance and attract different auction prices.

The research was thus an empirical study and was done through a cross section survey of KTDA Factories. The study can further be described as case study because only KTDA factories were targeted in the research.

### **3.3 Research Population**

The research covered all 65 KTDA Managed factories. The focus of the survey was on the production Managers and seven nos KTDA Regional Engineers, This rank was chosen since high ranking informants are considered to be a reliable source of information according to (Saunders 2007). The rank was also chosen as they are the main users of maintenance services.

The unit of sampling was at company level and thus one questionnaire was sent to an individual respondent for each factory and one questionnaire to each region.

### **3.4 Data collection method**

Both primary data and secondary data were collected. Primary data aimed to gather information on level of application of various Maintenance practices in different factories. The primary data also informed on factors affecting maintenance

performance and preferred alternative to handling production disruption. Secondary data was obtained from current maintenance, manufacturing and marketing reports. This data gave information on plant availability, energy use, energy cost and average auction prices

To boost the response rate, questions were made as clear and concise as possible. Closed questions were used, since according to (Saunders 2007), they are quicker and easier to answer, as they require minimal writing. Responses are also easier to compare, as they are predetermined. For the closed questions, lists, ratings and quantity types of questions (Saunders 2007) were used in the questionnaire to acquire the various data required. The respondents were offered anonymity to increase response rate (for those who prefer confidentiality) and to increase veracity of responses.

The first survey instrument established the maintenance practices in use in KTDA Tea Factories. The second instrument established the main factors that affect maintenance performance. The third instrument collected information on various performance data for factories that included Plant Availability, Thermal Energy consumption in MJ/KGMT, Electrical Energy consumption in KWH/KGMT, Firewood consumption in KGMT/CUMF, Total Energy cost in Ksh./KGMT, average auction price Per KGMT. The fourth instrument established how the factories overcome production disruption

### **3.5 Data Analysis**

A total of 26 responses were received from the 65 nos questionnaires that were sent to the production managers. The maintenance and manufacturing data for all 65 factories was obtained from current performance reports for the month of August

The data from the survey was analyzed using quantitative techniques as well as written descriptions to facilitate comparison and the construction of hypotheses. Histogram and pie charts were used to illustrate the contrast between various factors. Spearman's rank correlation was used to test whether there is an association between maintenance practices and overall equipment effectiveness. Spearman's rank correlation was also used to test whether there is correlation between maintenance

practice and plant availability. Correlation was also tested between plant availability and various performance measurement that include MJ/KGMT, KWH/KGMT, Energy cost /KGMT, KWH/KGMT, CUMF/KGMT and Auction price /KGMT

Spearman rho is calculated using the following formula where there are no tied ranks

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where  $d_i$  = difference in paired ranks and  $n$  = number of cases. The formula to use when there are tied ranks is:

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

where  $i$  = paired score.

## 4 CHAPTER FOUR – Data Analysis Results and Discussions

### 4.1 Introduction

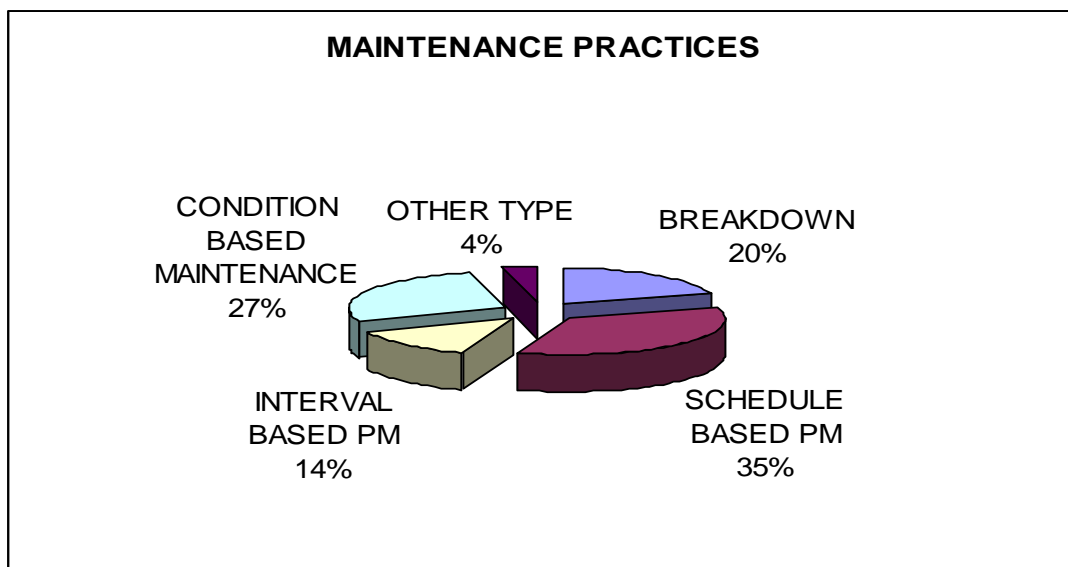
This chapter provides a summary of the data analysis, results of the study and the discussion of the results of the study. The chapter is organized as follows: section 4.2 describes the data presentation, analysis and the results of the study and section 4.3 discusses the implication of findings of the study with regard to the objective of the study which was to establish how maintenance influences manufacturing performance in KTDA Managed factories

### 4.2 Data analysis and Presentation of Results

We obtained data from 26 questionnaires that were received out of the 65 no sent to prospective respondents. We also obtained data for all 65 factories for the current performance data for both manufacturing and maintenance from current management reports. This data has been analyzed as follows.

#### 4.2.1 Maintenance Practices

To gain insight into the maintenance practices employed in the factories the factories the respondents were asked to indicate the percentage of the type of maintenance carried out in their factories.

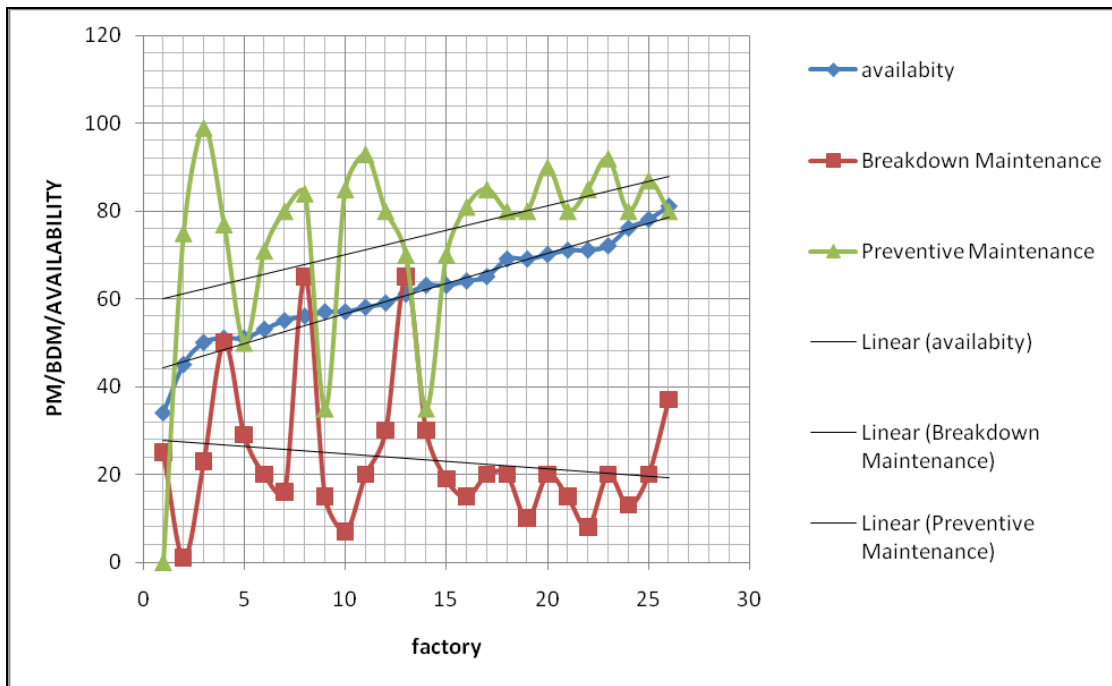


*Figure 1: Maintenance Practices*

From the results, breakdown maintenance takes up 24% while various forms of preventive maintenance take 76%.

#### 4.2.2 Maintenance Practice influence on Maintenance Performance

To check the influence of maintenance practice on Plant availability a scatter graph was drawn for Preventive, breakdown maintenance and Availability.



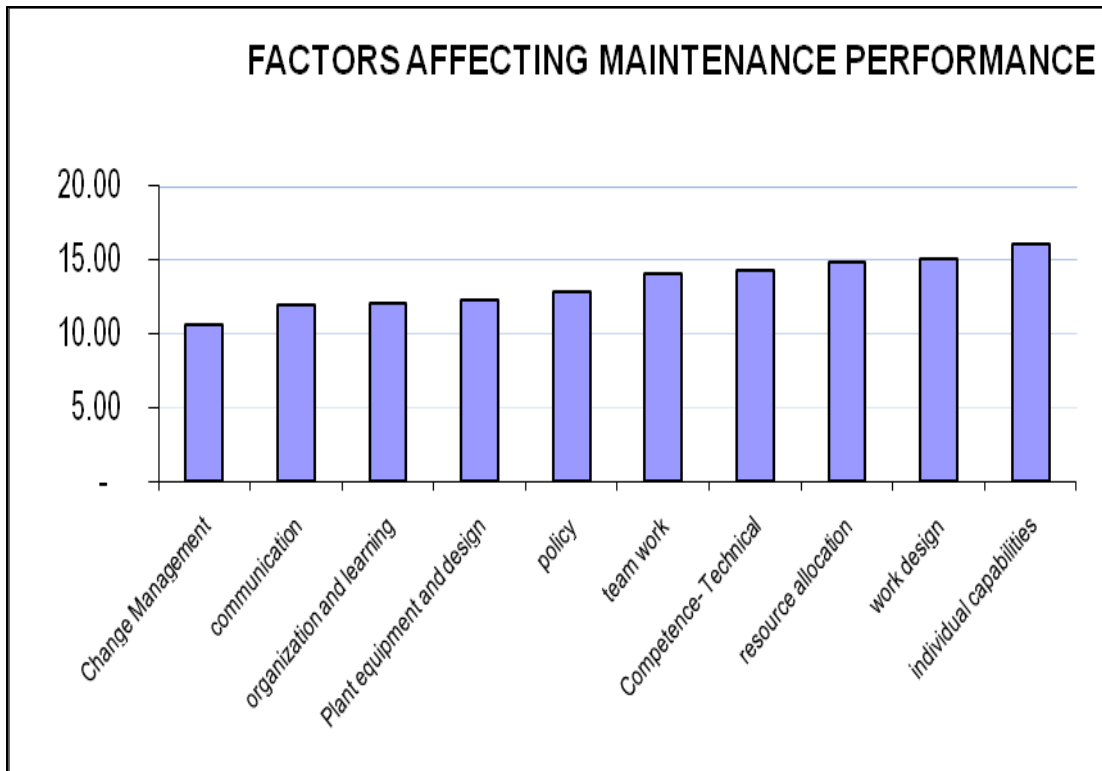
**Figure 2- scatter graph showing relationship between preventive , breakdown Maintenance and availability.**

To further check the influence of preventive maintenance practice on overall equipment effectiveness spearman rank correlation was done. The results showed a positive correlation of 0.18 and a  $P= 0.34$  at  $\alpha=0.05$ . The calculated t –Test was 0.89 against critical t value of 1.711.

The influence of breakdown maintenance practice on overall equipment effectiveness was also checked using spearman’s rank correlation. The results showed a negative correlation of -0.18 and  $P=0.4$  at  $\alpha=0.05$ . The calculated t- Test was -0.898 against critical t value of 1.711.

### 4.2.3 Factors affecting Maintenance Performance

Research question 4 aimed at establishing the highest factors that affect maintenance performance



*Figure 3- Factors affecting Maintenance Performance*

The results showed that individual capabilities, work design, resource allocation and technical competence as the highest factors that affect maintenance.

### 4.2.4 Maintenance and Manufacturing performance.

Secondary data was gathered to establish the current levels of various performance measurements. The data gathered included MJ/KGMT, CUMF/KGMT, KGMT/CUMF, ENERGY COST/KGMT, AUCTION PRICE/KGMT. The average value for each region is tabulated below and the performance per factory is attached in the Table 2

<b>Table 1- SUMMARY TABLE FOR MAINTENANCE AND MANUFACTURING PERFORMANCE</b>						
<b>REGION</b>	<b>ENERGY usage MJ/KgMt</b>	<b>F.wood Usage -KgMt/CUM</b>	<b>ELECTRICITY usage - Kwh/KgMt</b>	<b>COST INTENSITY- ksh/KgMt</b>	<b>Availability</b>	<b>average auction price</b>
<b>TARGET</b>	25	350	0.55	16	0.85	
<b>REGION 1</b>	<b>39.01</b>	<b>222.38</b>	<b>0.80</b>	<b>23.43</b>	<b>0.70</b>	<b>3.26</b>
<b>REGION 2</b>	<b>44.21</b>	<b>192.53</b>	<b>0.90</b>	<b>23.93</b>	<b>0.65</b>	<b>3.27</b>
<b>REGION 3</b>	39.31	223.14	0.69	19.49	0.66	3.34
<b>REGION 4</b>	30.88	282.66	0.90	19.75	0.82	3.27
<b>REGION 5</b>	38.20	220.32	0.61	16.61	0.62	3.06
<b>REGION 6</b>	40.61	209.12	0.70	13.96	0.66	3.14
<b>REGION 7</b>	36.84	232.00	0.85	22.10	0.60	3.06

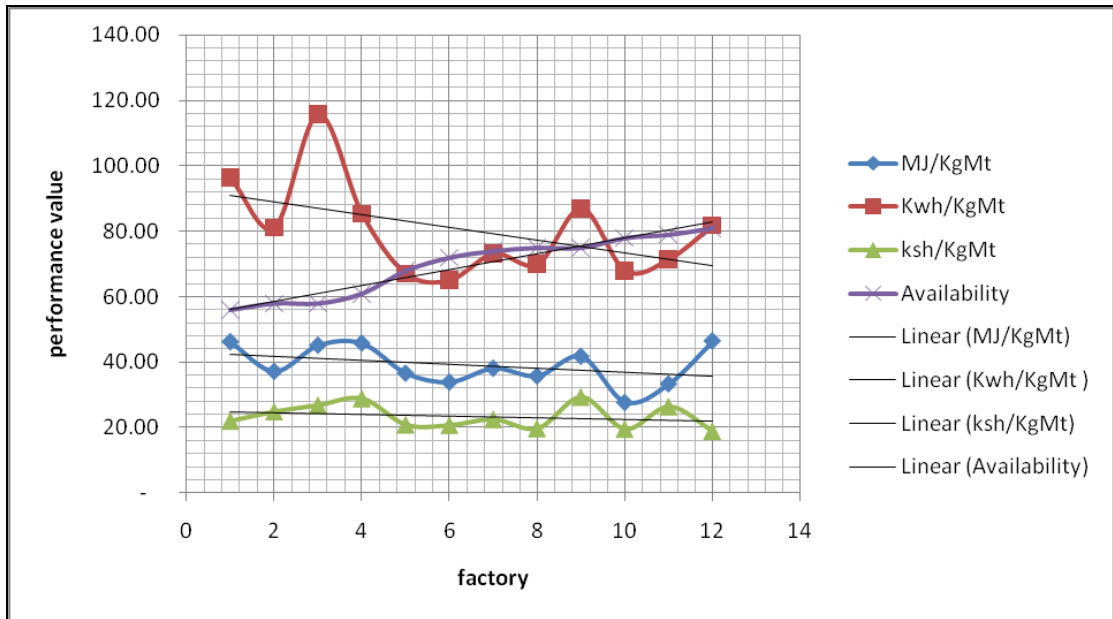
The results show diverse ranges of performance and all invariably below the target.

#### **4.2.5 Influence of Maintenance Performance on Manufacturing Performance.**

To investigate how maintenance- represented by plant availability- influence manufacturing performance, spearman rank correlation was calculated for each regions manufacturing performance represented by MJ/KGMT, KWH/KGMT, ENERGY COST/KGMT, KGMT/CUMF, AVERAGE AUCTION PROCE/KGMT

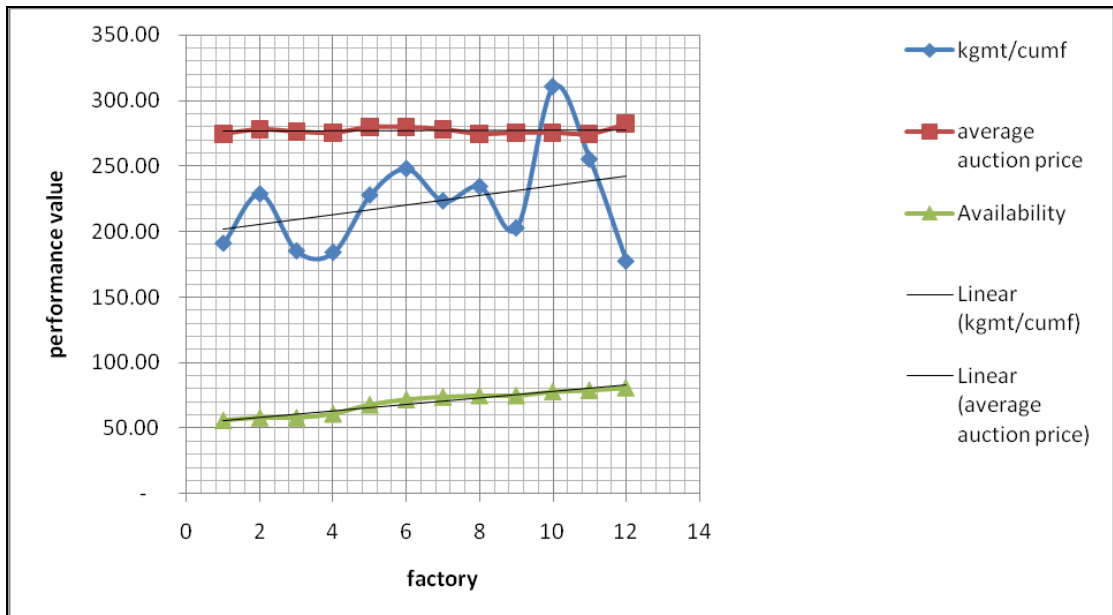
The results for each region are tabulated below.

**Figure 4- REGION 1 SCATTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show as plant availability increases, MJ/KGMT, KWH/KGMT and energy cost Ksh/KGMT decreases.

**Figure 5 - REGION 1 SCATTER GRAPH FOR KGMT, AVERAGE AUCTION PRICES/KGMT AND PLANT AVAILABILITY**



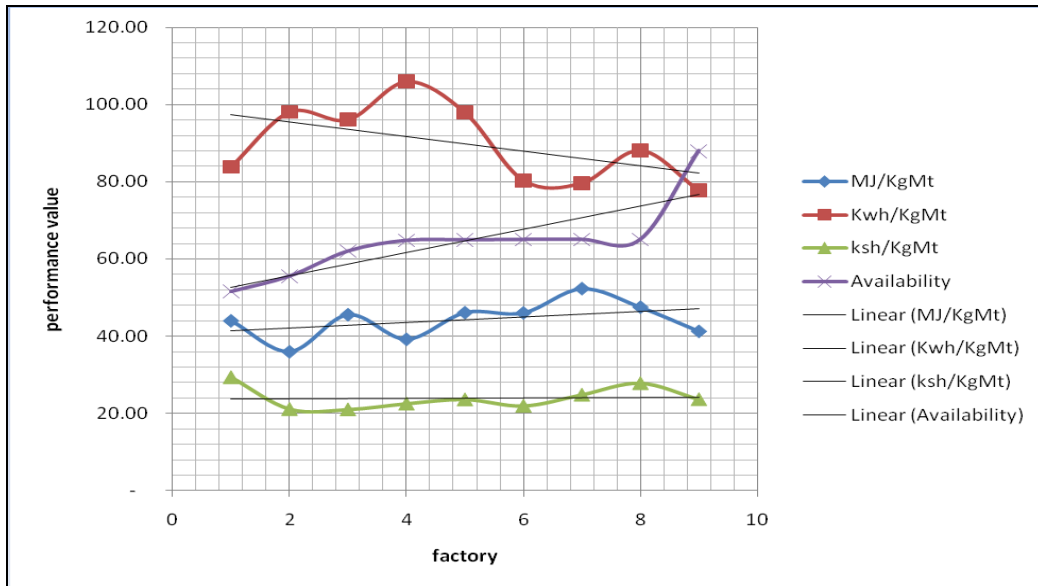
The results show as plant availability increases, fire wood yeild in /CUMF increases while average auction price largely remains constant for the region.

The results are supported by Spearman's rank correlation summarized below.

<b>TABLE 2 SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 1</b>					
OEE VS BONUS PAYMENT	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
Statistic	Value	Value	Value	Value	Value
<a href="#">Correlation (not corrected)</a>	0.050699	(0.71)	(0.59)	0.27	(0.04)
<a href="#">Correlation (corrected)</a>	0.03036	(0.72)	(0.61)	0.27	(0.05)
<a href="#">t-Test (n&gt;10)</a>	0.096052	(3.30)	(2.41)	0.88	(0.14)
Degrees of Freedom	10	10.00	10.00	10.00	10.00
Critical 2-sided T-value (5%)	2.228	2.23	2.23	2.23	2.23
Critical 1-sided T-value (5%)	1.812	1.81	1.81	1.81	1.81
D-square value (calculated)	271.5	489.00	456.00	208.00	298.50
D-square value (expected)	286	286.00	286.00	286.00	286.00
Standard Deviation	86.23225	86.23	86.23	86.23	86.23
<a href="#">z-Test</a>	-0.16815	2.35	1.97	(0.90)	0.14
Probability	0.865	0.02	0.05	0.36	0.88
Observations	12	12.00	12.00	12.00	12.00

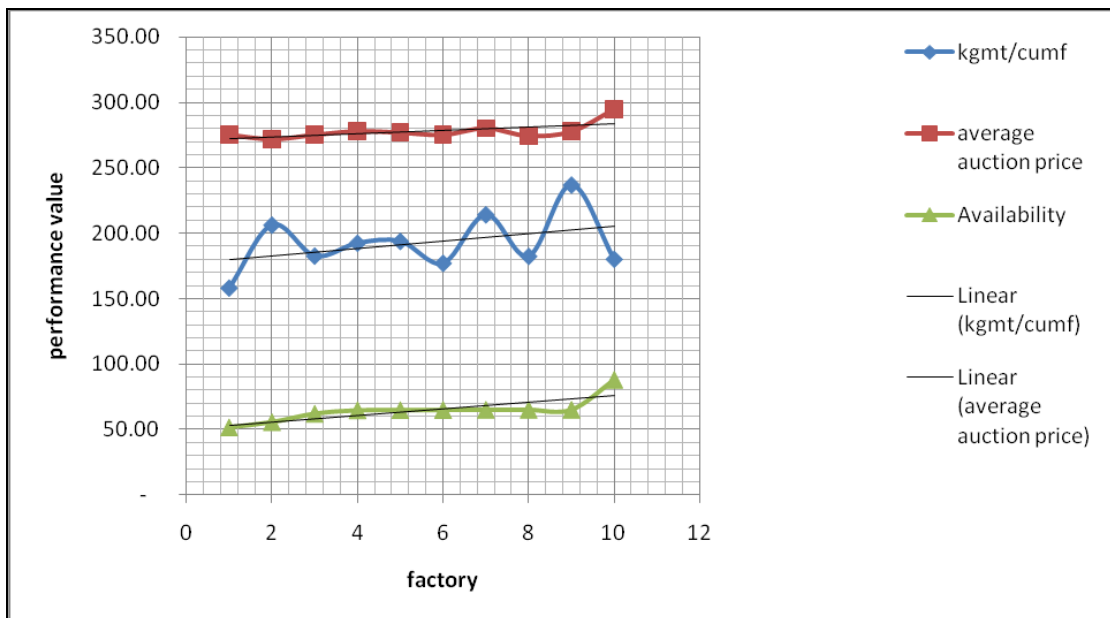
The results for region 1 showed positive correlation between availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 6-REGION 2 SCATTTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show as plant availability increases, kwh/kgmt decreases and cost remains constant and MJ increases.

**FIGURE 7- REGION 2 SCATTTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



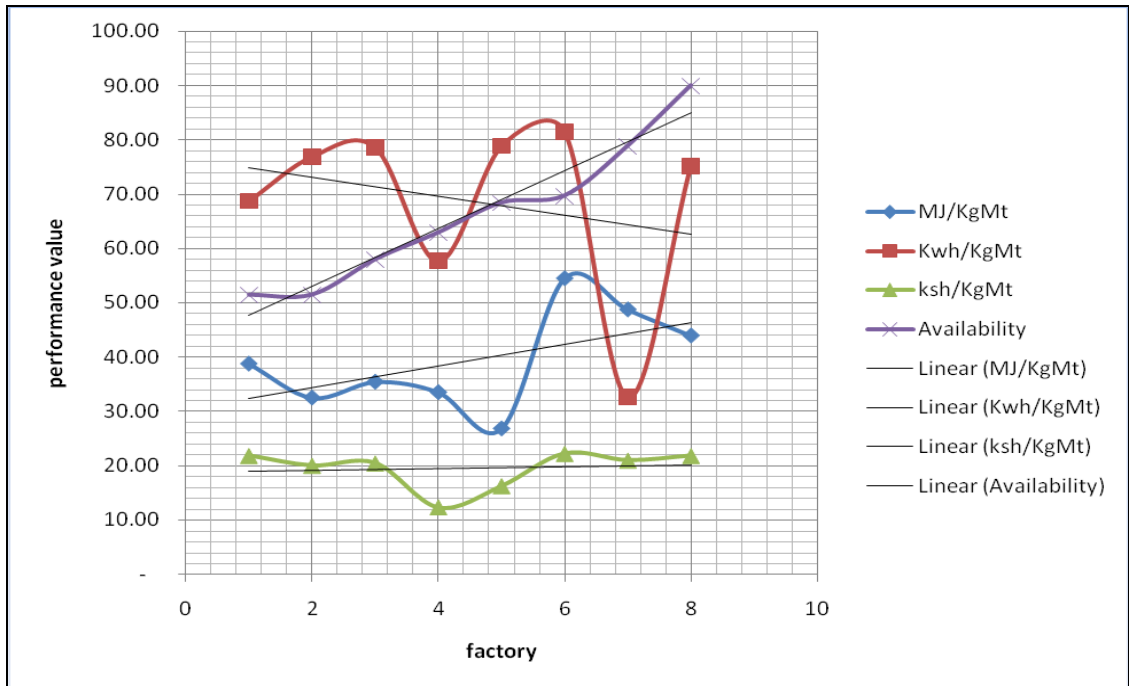
The results show as plant availability increases, the average auction price and firewood yield in KGMT/CUMF increases.

These results are collaborated by the spearman's rank correlation as tabulated below.

<b>TABLE 3- SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 2</b>					
<b>Statistic</b>	<b>AUCTION PRICES VS AVAILABILITY</b>	<b>MJ VS AVAILABILITY</b>	<b>COST VS AVAILABILITY</b>	<b>KGMT/CUMF VS AVAILABILITY</b>	<b>KWHT/KGMT VS AVAILABILITY</b>
<a href="#">Correlation (not corrected)</a>	0.7	(0.22)	-0.29697	0.72	(0.34)
<a href="#">Correlation (corrected)</a>	0.668503	(0.22)	-0.38144	0.71	(0.35)
<a href="#">t-Test (n&gt;10)</a>	2.378205	(0.59)	-1.167116	2.70	(1.00)
Degrees of Freedom	7	7.00	8	7.00	7.00
Critical 2-sided T-value (5%)	2.365	2.37	2.306	2.37	2.37
Critical 1-sided T-value (5%)	1.895	1.90	1.86	1.90	1.90
D-square value (calculated)	36	146.00	214	34.00	161.00
D-square value (expected)	120	120.00	165	120.00	120.00
Standard Deviation	42.42641	42.43	55	42.43	42.43
<a href="#">z-Test</a>	-1.9799	0.61	0.890909	(2.03)	0.97
Probability	0.0478	0.54	0.3682	0.04	0.33
Observations	9	9.00	9.00	9.00	9.00

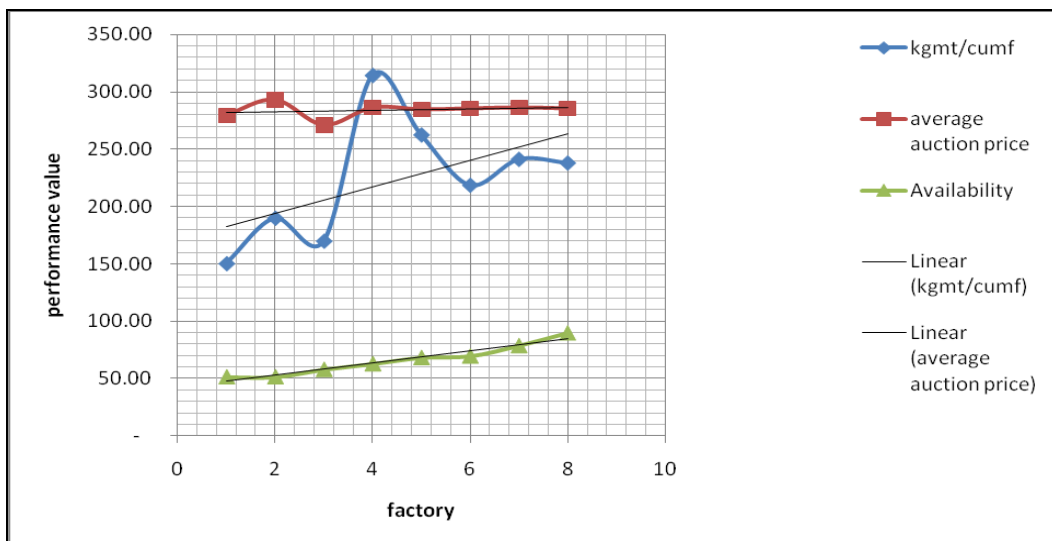
The results for region 2 also showed positive correlation between availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 8- REGION 3 SCATTTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show as plant availability increases, kwh/kgmt decreases and cost remains constant and MJ increases.

**FIGURE 9-REGION 3 SCATTTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



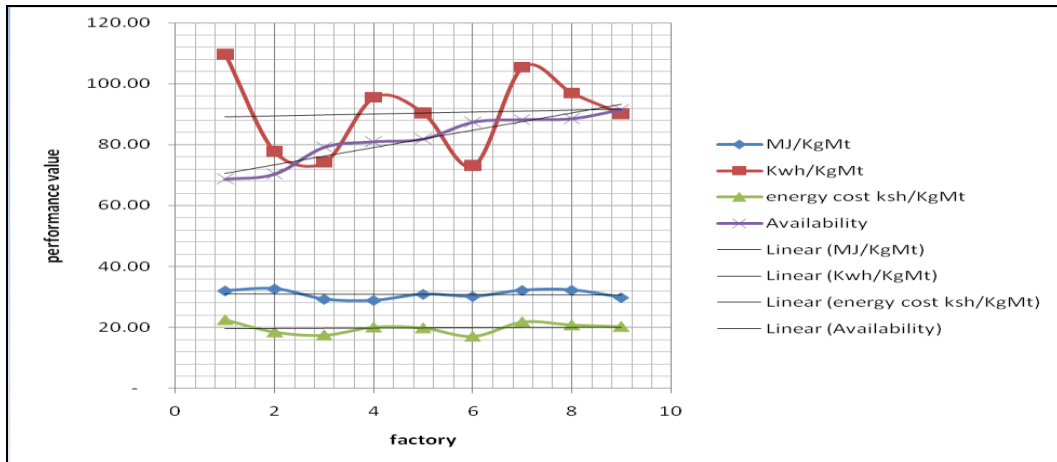
The results showed as plant availability increases KGMT/CUMF increases and average auction price remains constant.

The results were tested further using spearman's rank correlation and are summarized below.

<b>TABLE 4- SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 3</b>					
Statistic	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
<a href="#">Correlation (not corrected)</a>	0.619048	(0.52)	(0.45)	0.52	(0.14)
<a href="#">Correlation (corrected)</a>	0.614502	(0.52)	(0.46)	0.52	(0.14)
<a href="#">t-Test (n&gt;10)</a>	1.907959	(1.51)	(1.25)	1.51	(0.35)
Degrees of Freedom	6	6.00	6.00	6.00	6.00
Critical 2-sided T-value (5%)	2.447	2.45	2.45	2.45	2.45
Critical 1-sided T-value (5%)	1.943	1.94	1.94	1.94	1.94
D-square value (calculated)	32	128.00	121.50	40.00	96.00
D-square value (expected)	84	84.00	84.00	84.00	84.00
Standard Deviation	31.74902	31.75	31.75	31.75	31.75
<a href="#">z-Test</a>	-1.63785	1.39	1.18	(1.39)	0.38
Probability	0.101	0.16	0.23	0.16	0.70
Observations	8	8.00	8.00	8.00	8.00

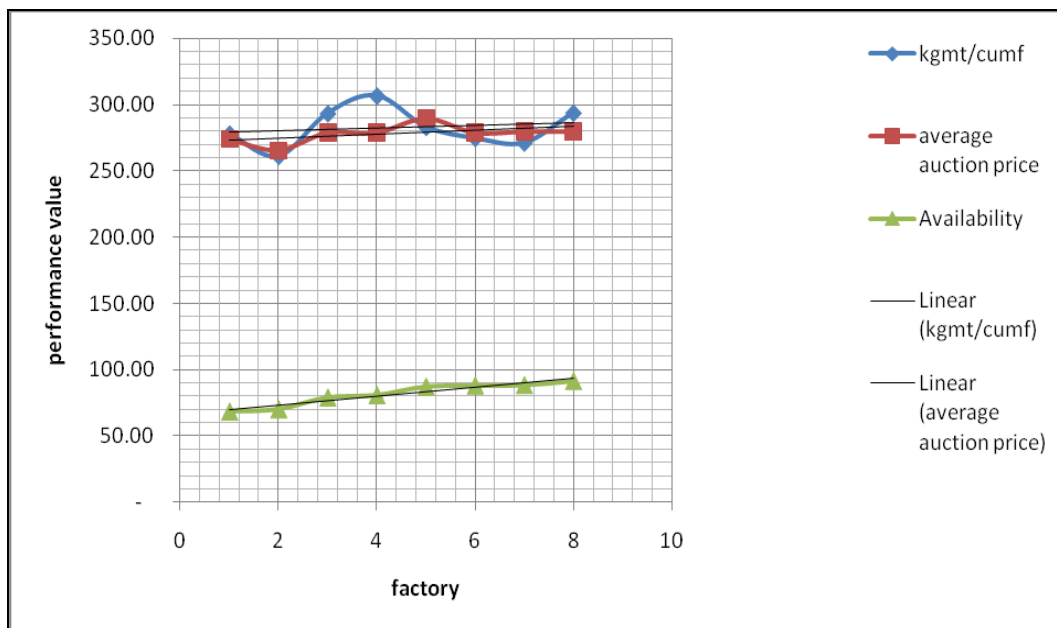
The results for region 3 also showed positive correlation between availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 10 - REGION 4 SCATTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results for the region showed that as plant availability increased, MJ/KGMT and energy cost/kgmt decreased electrical energy showed a slight upward trend.

**FIGURE 11 - REGION 4 SCATTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



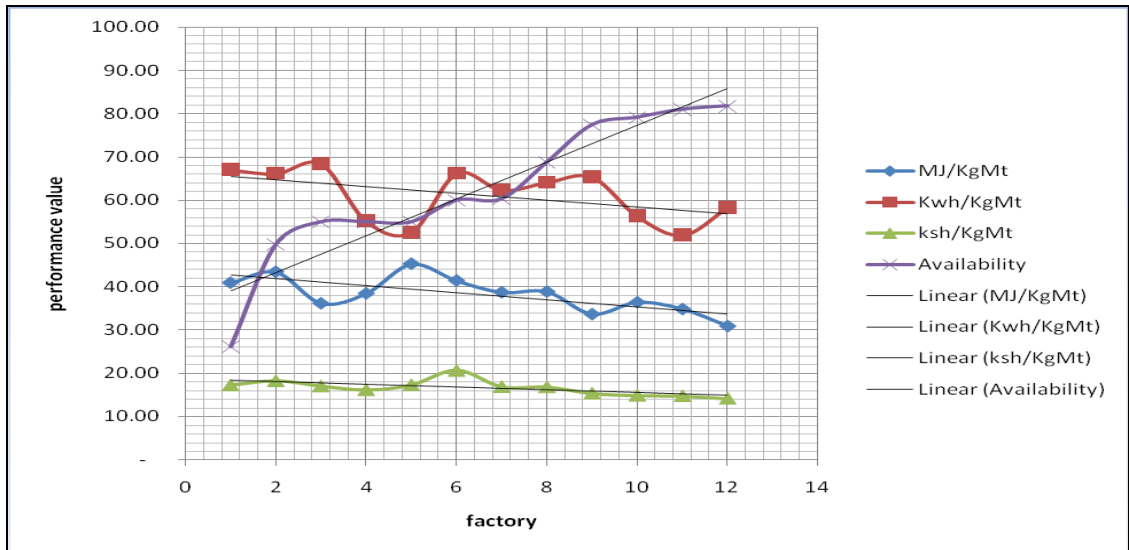
The results for the region showed as plant availability increased both the firewood yeild in KGMT/CUMF and average auction price increased.

The results were tested further using spearman's rank correlation and the outcome is tabulated below.

<b>TABLE 5- SPEARMAN'S RANK COTRRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 4</b>					
Statistic	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
<a href="#">Correlation (not corrected)</a>	0.779762	(0.55)	(0.19)	0.43	(0.43)
<a href="#">Correlation (corrected)</a>	0.77337	(0.55)	(0.19)	0.43	(0.43)
<a href="#">t-Test (n&gt;10)</a>	2.988166	(1.60)	(0.48)	1.16	(1.16)
Degrees of Freedom	6	6.00	6.00	6.00	6.00
Critical 2-sided T-value (5%)	2.447	2.45	2.45	2.45	2.45
Critical 1-sided T-value (5%)	1.943	1.94	1.94	1.94	1.94
D-square value (calculated)	18.5	130.00	100.00	48.00	120.00
D-square value (expected)	84	84.00	84.00	84.00	84.00
Standard Deviation	31.74902	31.75	31.75	31.75	31.75
<a href="#">z-Test</a>	-2.06306	1.45	0.50	(1.13)	1.13
Probability	0.0384	0.15	0.61	0.25	0.25
Observations	8	8.00	8.00	8.00	8.00

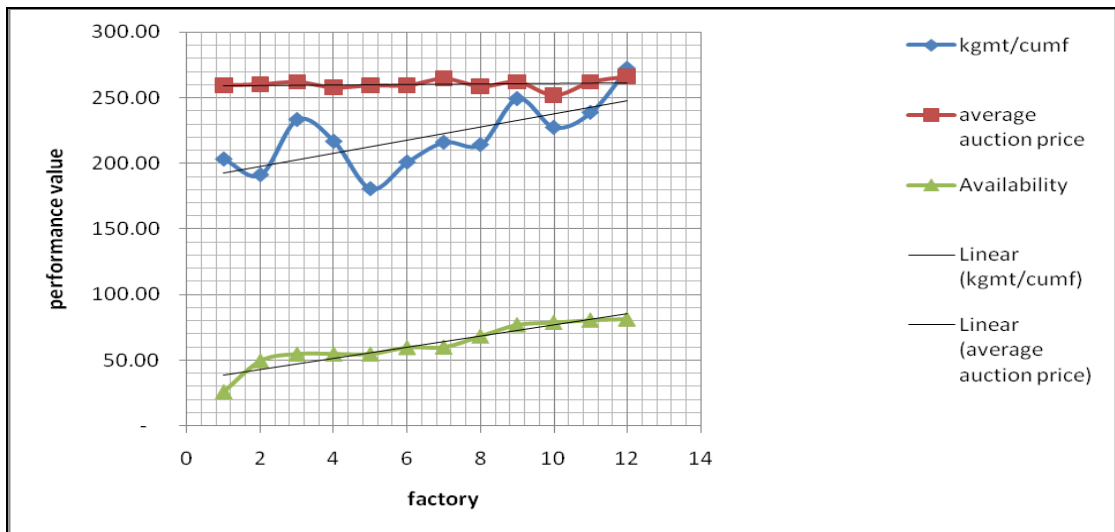
The results for region 4 also showed positive correlation between Plant availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 12 -REGION 5 SCATTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show that as plant availability increases kwh/kgmt, MJ/KGMT, and energy cost in Ksh/KGMT decreases

**FIGURE 13 -REGION 5 SCATTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



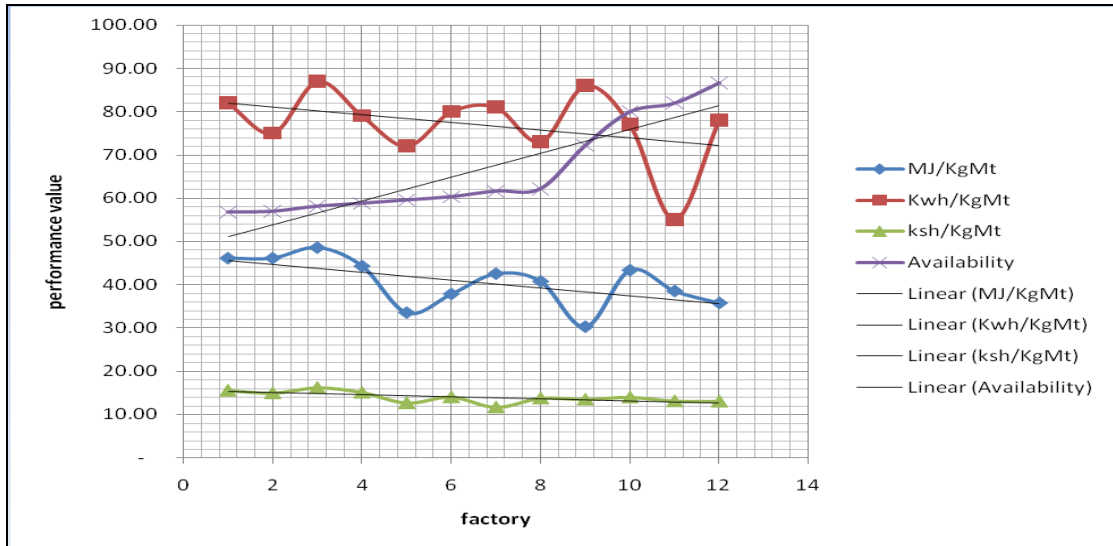
The results show that as plant availability increases auction price per KGMT and firewood yield increases in KGMT/CUMF

Spearman rank correlation also collaborates this result as tabulated in the table below.

TABLE 6 SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 5					
Statistic	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
<u>Correlation (not corrected)</u>	0.288462	(0.05)	(0.20)	0.05	(0.61)
<u>Correlation (corrected)</u>	0.271918	(0.05)	(0.20)	0.05	(0.62)
<u>t-Test (n&gt;10)</u>	0.893549	(0.15)	(0.63)	0.15	(2.52)
Degrees of Freedom	10	10.00	10.00	10.00	10.00
Critical 2-sided T-value (5%)	2.228	2.23	2.23	2.23	2.23
Critical 1-sided T-value (5%)	1.812	1.81	1.81	1.81	1.81
D-square value (calculated)	203.5	300.00	342.00	272.00	461.00
D-square value (expected)	286	286.00	286.00	286.00	286.00
Standard Deviation	86.23225	86.23	86.23	86.23	86.23
<u>z-Test</u>	-0.95672	0.16	0.65	(0.16)	2.03
Probability	0.337	0.87	0.52	0.87	0.04
Observations	12	12.00	12.00	12.00	12.00

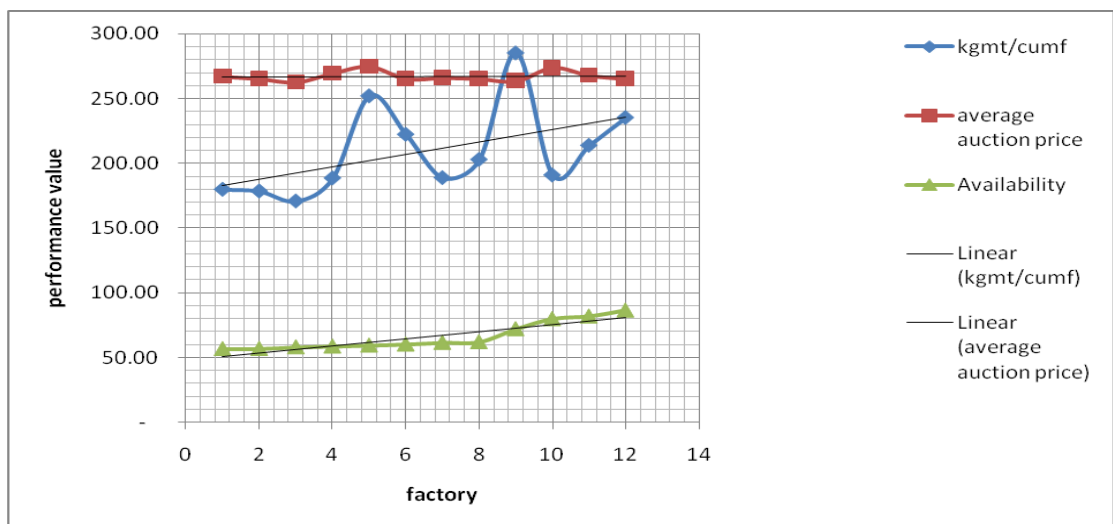
Again the results for region 5 also showed positive correlation between availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 14 - REGION 6 SCATTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show that as plant availability increases kwh/kgmt, MJ/KGMT, and energy cost in Ksh/KGMT decreases

**FIGURE 15- REGION 6 SCATTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



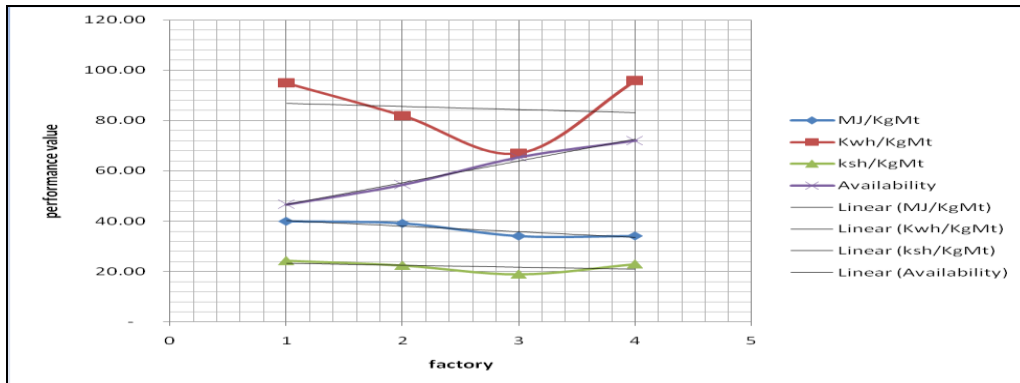
The results show that as plant availability increases auction price per KGMT and firewood yield increases in KGMT/CUMF

Spearman's rank correlation is used to confirm above results the results are tabulated below.

<b>TABLE 7 SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 6</b>					
Statistic	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
<a href="#">Correlation (not corrected)</a>	0.269231	(0.72)	(0.66)	0.76	(0.04)
<a href="#">Correlation (corrected)</a>	0.256268	(0.72)	(0.66)	0.76	(0.05)
<a href="#">t-Test (n&gt;10)</a>	0.838389	(3.28)	(2.76)	3.64	(0.14)
Degrees of Freedom	10	10.00	10.00	10.00	10.00
Critical 2-sided T-value (5%)	2.228	2.23	2.23	2.23	2.23
Critical 1-sided T-value (5%)	1.812	1.81	1.81	1.81	1.81
D-square value (calculated)	209	492.00	474.00	70.00	298.50
D-square value (expected)	286	286.00	286.00	286.00	286.00
Standard Deviation	86.23225	86.23	86.23	86.23	86.23
<a href="#">z-Test</a>	-0.89294	2.39	2.18	(2.50)	0.14
Probability	0.3682	0.02	0.03	0.01	0.88
Observations	12	12.00	12.00	12.00	12.00

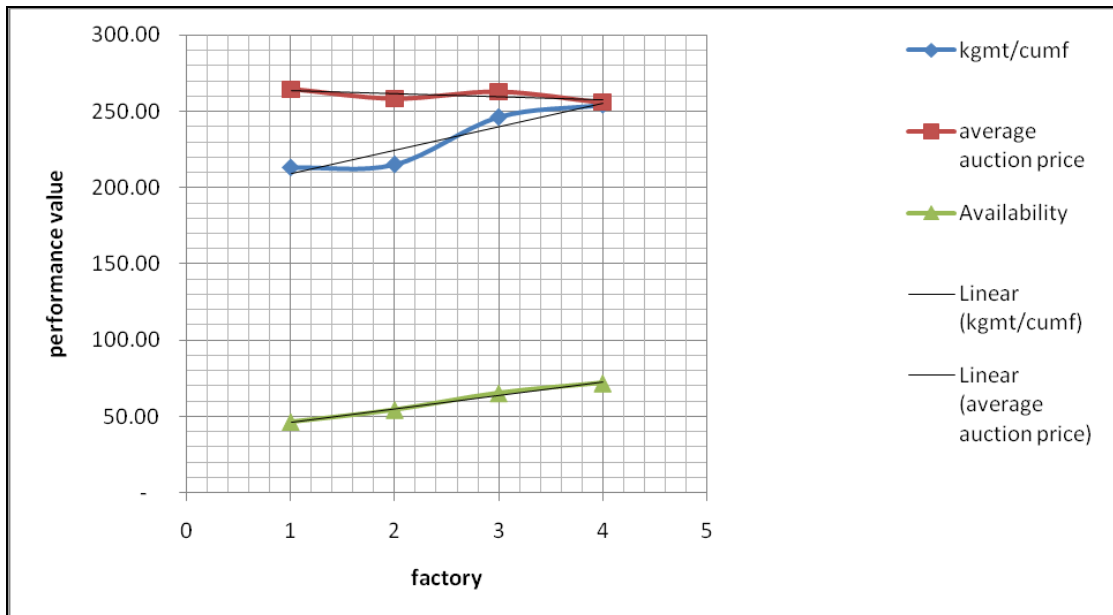
Once again the results for region 6 also showed positive correlation between availability and auction price and also firewood consumption in KGMT/CUMF. The results showed negative correlation between availability and MJ/KGMT, Energy cost Ksh/KGMT and KWH/KGMT.

**FIGURE 16 -REGION 7 SCATTER GRAPH FOR MJ/KGMT, ENERGY COST/KGMT, KWH/KGMT AND PLANT AVAILABILITY**



The results show that as plant availability increases kwh/kgmt, MJ/KGMT, and energy cost in Ksh/KGMT decreases

**FIGURE 17 - REGION 7 SCATTER GRAPH FOR KGMT/CUMF, AVERAGE AUCTION PRICE AND PLANT AVAILABILITY**



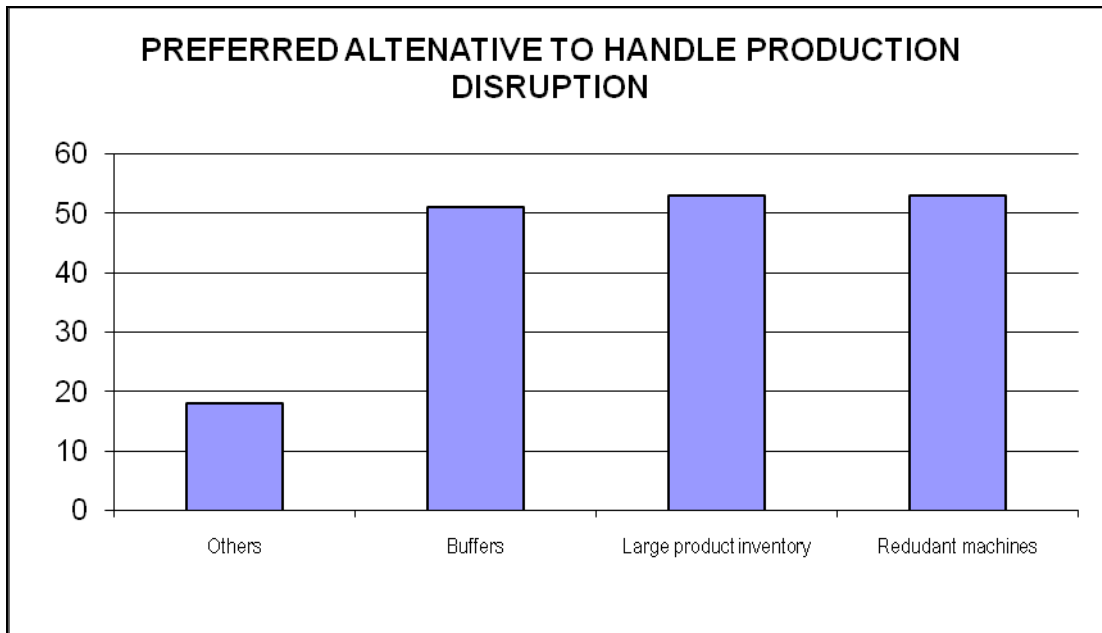
The results show that as plant availability increases auction price per KGMT and firewood yield increases in KGMT/CUMF

<b>TABLE 8- SPEARMAN'S RANK CORRELATIO FOR VARIOUS PERFORMANCE MEASUREMENT AGAINST PLANT AVAILABILITY - REGION 7</b>					
Statistic	AUCTION PRICES VS AVAILABILITY	MJ VS AVAILABILITY	COST VS AVAILABILITY	KGMT/CUMF VS AVAILABILITY	KWHT/KGMT VS AVAILABILITY
<a href="#">Correlation (not corrected)</a>	-0.8	(0.80)	(0.40)	1.00	0.20
<a href="#">Correlation (corrected)</a>	-0.8	(0.80)	(0.40)	1.00	0.20
<a href="#">t-Test (n&gt;10)</a>	-1.88562	(1.89)	(0.62)	6.7 exp 7	0.29
Degrees of Freedom	2	2.00	2.00	2.00	2.00
Critical 2-sided T-value (5%)	4.303	4.30	4.30	4.30	4.30
Critical 1-sided T-value (5%)	2.92	2.92	2.92	2.92	2.92
D-square value (calculated)	18	18.00	14.00	-	8.00
D-square value (expected)	10	10.00	10.00	10.00	10.00
Standard Deviation	5.773503	5.77	5.77	5.77	5.77
<a href="#">z-Test</a>	1.385641	1.39	0.69	(1.73)	(0.35)
Probability	0.1646	0.16	0.48	0.08	0.73
Observations	4	4.00	4.00	4.00	4.00

The results for this region deviated from the others. It posted negative correlation against aution price/kgmt, MJ/KGMT, COST/KGMT and positive correlation against KGMT/CUMF and KWH/KGMT

## 4.2.6 Preferred Options to Handle Production Disruption

Research question no 6 aimed at establishing the preferred option the companies use to overcome the production disruption



*Figure 18- Preferred alternative to Handling Production Disruption*

The respondents preferred almost in equal measures buffer stock, large product inventory and investment in redundant machines.

## 4.3 Summary and interpretation of Findings

According to the presentation and analysis of data in 4.2, several observations were made. It was observed that there is a positive correlation between maintenance practices represented by % of equipment repaired under preventive maintenance and plant availability. The calculated t value of  $0.898 < 1.71$  critical t value for a one side test at  $\alpha = 0.05$  for 26 nos. Of respondents. Thus the null hypothesis is rejected and accept that maintenance practices does affect maintenance performance as reflected in plant availability.

The correlation between energy consumption in MJ/KGME and overall equipment for all region was shown to be negative. The calculated t were all lower than the critical for one side test  $\alpha = 0.05$  for the various number of factories in each region. The null

hypothesis is rejected and it is accepted that maintenance performance does affect manufacturing performance through the energy consumed.

The correlation between cost energy in Ksh/kgmt against overall equipment is also shown to be negatively correlated for six regions with  $t$  calculated lower than critical  $t$  for one test  $\alpha = 0.05$ . The null hypothesis is again rejected. And it is accepted that maintenance performance does affect manufacturing performance through energy cost.

In the correlation for the kilograms of made tea made per cubic meter of firewood and the overall equipment effectiveness, the results showed positive correlation for all regions with calculate  $t$  value lower than the critical  $t$  value for one test  $\alpha = 0.05$ . again it is accepted that maintenance affects manufacturing performance through the amount of made tea made per cubic metre of firewood .

The correlation between Kilowatt hour per kg of made and overall equipment effectiveness showed mixed results with region 7 showing positive correlation while five factories showed negative correlation. The factories that showed negative correlation all had calculated  $t$  less than critical  $t$  value for one test  $\alpha = 0.05$ . The null hypothesis is rejected and it is accepted that maintenance does affect manufacturing performance through the kilowatt hours consumed per kilogram of made tea.

The correlation between auction price payment and overall equipment effectiveness showed a positive correlation for six regions and a negative correlation for region seven. The factories with positive correlation had calculated  $t$  value lower than critical  $t$  value for one test  $\alpha = 0.05$ . The null is thus rejected and it is accepted it is accepted that maintenance performance does affect manufacturing performance by affecting the amount of bonus paid to the farmers.

## **5 CHAPTER FIVE - SUMMARY, CONCLUSION AND RECOMMENDATIONS**

### **5.1 Introduction**

This chapter summarises the findings of the study in relation to its objective. It gives conclusion drawn from the study and highlights the policy recommendation, limitations of the study and recommendation for further research

### **5.2 Summary of the findings**

The study established that 76% of maintenance carried out in KTDA factories is preventive while 20% is breakdown maintenance. The study found that factories have varying levels of plant availability ranging from a low of 46% to a high of 88%. The study established that there is positive correlation between the % of preventive maintenance and plant availability. The study also showed that there is negative correlation between the % of breakdown maintenance carried out and plant availability.

The study showed positive correlation between the plant availability and Auction price and Firewood consumption in KGMT/CUMF. There was negative correlation between Plant availability and Thermal energy measured in MJ/KGMT, Energy cost per Kg of made tea and KWH/KGMT.

The study established that the factors that affect maintenance performance are, individual capabilities, resource allocation, work design and technical capability. Respondent build buffer stocks and invest in redundant machines to cope with production disruption.

### **5.3 Conclusion**

In conclusion it can be deduced from that study that for KTDA factories to reduce thermal energy consumed in MJ/KGMT, reduce cost of energy in Ksh/KGMT, reduce electrical power consumed in KWH/KGMT and to increase the KGMT per cubic Metre of firewood and to increase the increase the auction prices, the factories have to improve the plant availability by improving maintenance practices.

To do this the factories have to monitor and improve and control preventive maintenance programs. The factories have to address the factors that affect maintenance performance like individual capabilities, work design, resource allocation and technical competence.

#### **5.4 Policy Recommendation**

The role of maintenance in creating plant availability has been proved through this research to play a crucial role in manufacturing plant performance. It is recommended that this performance measurement be improved further to incorporate efficiency in production and quality in one figure, the overall equipment effectiveness OEE which is given by  $OEE = \text{Availability} \times \text{productivity} \times \text{Quality rate}$

It is further suggested that the following parameters as recommended by Hansen, (2002), be used for benchmarking.

<65% - unacceptable

65% - 75% - Satisfactory

75% - 85% - Good

85% -90% - Vey Good

Above 90% - Exceptional performance – World class standard.

#### **5.5 Limitations of Study**

It was not possible to get 100% of the questionnaires returned. This was mitigated by data mining from current performance reports. The study was carried out in a cross sectional study and since tea production is affected by seasonal dynamics like weather, exchange rate among others, the study could not establish the effect of seasonal dynamics on maintenance and manufacturing performance. The study was also limited to KTDA Managed factories.

#### **5.6 Recommendation for Further Research**

It is recommended that using the current levels of plant availability as a base line a longitudinal study is carried out in order to capture the sesonal dynamics effect on manufacturing performance and maintenance performance. Plant Availability improvement program can then be carried and monitored against the current baseline.

It is also recommended that similar studies be carried out in other Non KTDA managed tea processing factories in order to Benchmark their performance against KTDA'S.

It is further recommended that further studies be carried out in regions which deviated from the norm in correlation analysis. This was seen in region seven. Data for a whole year for each factory can be analyzed to establish if what was generalized for the region is applicable to each factory.

## REFERENCES.

- Ahlmann, Hans (1998). *The Economic Significance of Maintenance in Industrial enterprises*. Lund University, Lund Institute of Technology, Sweden.
- Ahuja, I.P.S. and Khamba, J.S. (2007), “An evaluation of TPM implementation initiatives in an Indian manufacturing enterprise”, *Journal of Quality in maintenance Engineering*, Vol. 13 No. 4, 338-52
- Al-Najjar, B. (2000). *Impact of Integrated Vibration-based Maintenance on Plant-LCC:A Case Study*. Third International (Refereed) Conference Quality, Reliability and maintenance-2000, Oxford, England,
- Bellgran, M., & Säfsten, E. K. (2010). *Production System Development*. Springer, UK.
- British Standards Institution, , 1984. BS3811 Glossary of maintenance terms in Terotechnology, BSI, London
- Coetzee, J.L. (1999), “A holistic approach to the maintenance problem”, *Journal of Quality in Maintenance Engineering*,
- Crespo Márquez, A. 2007. *The Maintenance Management Framework. Models and Methods for Complex Systems Maintenance*, United Kingdom: Springer.
- Dekker, R. (1996), “Applications of maintenance optimization models: a review and analysis”, *Reliability Engineering and System Safety*, Vol. 51, 229-40.
- Dwight, R. (1995). *Concepts For Measuring Maintenance Performance*, In Martin , .. (Ed), *New Development In Maintenance: An International View*, IFRIM, Eindhoven, 109-125.
- Hansen, R.C. (2002), *Overall Equipment Effectiveness: A Powerful Production/Maintenance Tool for Increased Profits*, Industrial Press Inc., New York,
- Jonsson, P.,& Lesshammar, M. (1999). *Evaluation and improvement of manufacturing performance measurement systems – the role of OEE*. *International Journal of Operations and Production Management*, 19(1), 55-78.
- Kelly, A. 2006. *Maintenance and the industrial organization in Strategic maintenance Planning*, United Kingdom: Butterworth-Heinemann.
- KNBS, 2012, *Economic Survey 2012*. Government Printer, Nairobi.
- Liyanage, J. P. & Kumar, U. (2002) *Process of Maintenance Performance Management and Its Imperatives Within the Offshore Petroleum Industry (Part II): Value Based Maintenance Performance Management (VBMPM). SMRP solutions*,
- Madu, C. (2000). *Competing Through Maintenance Strategies*. *International Journal of Quality and Reliability Management* 17:9, 937-948.

- Mobley, R. (2004). *Engineering Maintenance fundamentals*. Amsterdam: Butterworth- Heinemann/Elsevier Science.
- Mugenda A and Mugenda M (2003), *Research Methods: Quantitative and Qualitative approaches*, ACTS Publishers, Nairobi
- Parida A (2006) *Development of a multi-criteria hierarchical framework for maintenance performance measurement: Concepts, issues and challenges*, Doctoral thesis, Luleå University of Technology, 2006:37,
- Parida A, Chattopadhyay G and Kumar U (2005) Multi criteria maintenance Performance measurement: a conceptual model. Proceedings of the 18th International Congress COMADEM, 31st Aug-2nd Sep 2005, Cranfield, UK, 349–356.
- Pintelon, I. , Van Puyvelde, F. and Gelders, L., *An Extended Age Based Policy for a Continuous Production Environment* , International Journal for Production Resources, Vol. 33, 1995,pp.2111-2123 .
- Saunders MNK, Lewis P, Thornhill A. (2007) *Research Methods for Business students*. 5 Edition. Philipines : Pearson Education –
- SLACK, N., CHAMBERS, S. & JOHNSON, R. 2007. *Operations management*, Prentice Hall. United Kingdom
- Swanson, L. (2001), “Linking maintenance strategies to performance”, International Journal of Production Economics, Vol. 70 No. 3, 237-44.
- Wessa, P. (2013), *Free Statistics Software*, Office for Research Development and Education, version 1.1.23-r7, URL <http://www.wessa.net/>.
- White, P.G., 1996. A survey and taxonomy of strategy related performance measures for manufacturing. *International Journal of Operations & Production Management* 16 (3), 42–61.
- Wireman T (2007) *How to calculate return on investment for maintenance improvement projects*, , Industrial Press Inc., New York, NY.
- World Bank (2007). *Kenya: Investment Climate Assessment*, draft. Washington D.C:
- Yin, R. K. (2003). *Case study Research: Design and Methods*. Third Edition, Sage publication, Thousands Oak, California, USA

## APPENDIX- 1

### SURVEY INSTRUMENTS

AMONG THE FOLLOWING MAINTENACE PRACTICES INDICATE THE APPLICABLE % OF THE TYPE OF MAINTENANCE CARRIED IN YOUR ORGANIZATION		
ITEM	FACTOR	%
1	Repairs are carried out after a breakdown occurs	
2	Replace parts before they break based on a schedule	
3	replace parts based on established interval	
4	Replace parts based on their condition after parameter	
5	Other type	
	TOTAL	100%

For the following issues indicate the score based on How they affect maintenance performance using the following weights, score (0)no effect, score (1) minor effect, score (4) medium effect, score (9 ) major effect and add then add scores for each management issue				
FACTOR	Maintenance Management issue	Underlying causes Score	Individual score	Total Score
F1	Policy	Maintenance policy unclear		
		Policy not communicated to staff		
		Policy not supported by actions of senior managers		
F2	Resource allocation	Resource allocation Inadequate system for work planning and prioritization		
		Inadequate provision of resources to achieve scheduled maintenance, eg people, parts, equipment and time		
		Failure to schedule necessary maintenance due to resource constraints		
		Inadequate system of recording and prioritizing equipment defects		
F3	Communication	Formal communications Inadequate system of informing staff about maintenance and safety requirements and priorities		
		Inadequate system of team briefing to promote safety and reliability		
		Inadequate system for staff to report maintenance problems		
		Adequacy of communication channels not monitored or reinforced		
F4	Change Management	Lack of consideration given to changes in plant or organisation		
		Poor planning of changes		
		Procedures and training not updated to reflect changes		
		Changes inadequately monitored		
F5	Work design	Procedures not readily available at place of work		
		Job beyond physical capability of person		
		Job routine and repetitive causing lack of attention		
		Poor use of skills causing loss of competence		
		Excessive tiredness because of excessive overtime		

F6	Individual Capabilities	Individual capabilities Lack of care or self-checking during task		
		Failure to obtain assistance when required		
		Failure to use required procedures, equipment or personal protective equipment (PPE)		
		Failure to report maintenance problems or inspection/calibration results		
F7	Competence (Technical and inter personal )	Inadequate technical training for task (technical and interpersonal skills)		
		Inadequate training in personnel skills, eg teamwork		
		Inadequate training of supervisors in line-management skills		
		Inadequate training of maintenance managers in leadership skills		
F8	Team Work	Poor teamwork with temporary work teams		
		Poor communication within and between teams		
		Poor support from other team members (eg of same craft discipline)		
		Team members not promoting good practices and not criticizing poor ones		

AMONG THE FOLLOWING FACTORS WHICH ONE REFLECT THE PREFERRED  
ALTERNATIVE TO HANDLE PRODUCTION DISRUPTION WITH 1 BEING THE LEAST  
PREFERRED AND 5 BEING THE MOST PREFERRED

ITEM	FACTOR	1	2	3	4	5
1	Redundant machines					
2	Buffers					
3	Larger Products inventory					
8	OTHERS					

<b>FOR THE FOLLOWING KPI INDICATE THE AVERAGE PLANT PERFORMANCE</b>						
<b>REGION</b>	<b>ENERGY usage MJ/KgMt</b>	<b>F.wood Usage -KgMt/CUM</b>	<b>ELECTRICITY usage - Kwh/KgMt</b>	<b>COST INTENSITY- ksh/KgMt</b>	<b>Availability</b>	<b>average auction price</b>
TARGET						
FACTORY 1						
FACTORY 2						
FACTORY 3						
FACTORY 4						
FACTORY 5						
FACTORY 6						
FACTORY 7						
FACTORY 8						
FACTORY 9						
FACTORY 10						
FACTORY 11						
FACTORY 12						

	APPENDIX 2 - TYPE OF MAINTENANCE CARRIED OUT %																										
FACTORY	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	AVE
Bdm	15	10	15	60	20	18	20	10	60	8	10	20	10	15	16	20	50	32	5	10	16	1	20	20	5	30	19.85
sch pm	46	50	40	15	10	44	42	25	10	70	60	45	20	55	50	42	0	30	30	52	26	97	5	0	50	10	35.54
interval pm	10	10	10	15	40	10	10	20	15	10	15	10	50	15	6	11	0	10	20	6	8	1	5	0	30	20	13.73
cbm	24	20	30	5	20	23	23	40	10	12	12	25	15	10	25	18	50	23	40	27	50	1	70	80	13	40	27.15
Others	5	10	5	5	10	5	5	5	5	0	3	0	5	5	3	9	0	5	5	5	0	0	0	0	2	0	3.73
total pm	80	80	80	35	70	77	75	85	35	92	87	80	85	80	81	71	50	63	90	85	84	99	80	80	93	70	76.42
total bd	20	20	20	65	30	23	25	15	65	8	13	20	15	20	19	29	50	37	10	15	16	1	20	20	7	30	

APPENDIX 2- FACTORS AFFECTING MAINTENANCE PERFORMANCE - THE HIGHER THE EFFECT																												
Policy	9	17	17	14	14	14	14	14	22	1	14	14	11	3	14	11	2	14	14	14	27	9	14	14	14	14	9	12.85
resource allocation	6	31	13	21	10	2	2	31	16	20	36	4	7	10	2	13	5	21	36	2	13	12	14	31	15	12	14.81	
Communication	7	21	21	10	7	6	6	31	21	7	21	6	6	7	6	16	2	23	13	6	14	3	21	10	18	2	11.96	
management and change	5	4	13	10	10	1	1	21	31	4	15	1	9	1	2	16	1	26	21	1	16	7	26	9	15	10	10.62	
work design	5	35	3	16	11	2	2	35	27	4	44	4	7	3	3	20	1	15	24	2	6	2	62	31	8	19	15.04	
individual capabilities	11	31	18	21	23	7	7	26	13	7	14	7	7	6	8	16	4	13	31	7	36	5	31	31	23	15	16.08	
Competence-Technical	6	21	7	16	13	5	5	36	21	16	26	4	5	10	4	16	1	21	36	5	26	0	21	31	7	13	14.31	
APPENDIX 2- PREFERRED OPTION OF DEALING WITH BREAKDOWNS ON SCALE OF 1-5																												
Redudant machines	2	2	3	0	2	2	2	1	4	1	2	2	2	2	3	2	2	2	1	3	4	1	1	5	1	1	53.00	
Buffers	1	1	2	0	3	1	1	2	4	5	1	1	1	1	1	1	1	3	5	1	2	5	3	3	0	2	51.00	
Large product inventory	2	2	1	0	4	1	1	4	1	2	1	1	1	1	1	1	2	2	4	1	2	5	5	4	3	1	53.00	
Others	0	3	1	0	0	1	1		1	0	1	1	1	0	3	1	0	0	0	1	0	0	0	3	0	0	18.00	

TABLE 12- KTDA FACTORIES Maintenance and manufacturing Performance Measurements for August 2013						
FACTORY	ENERGY usage MJ/KgMt	F.wood Usage - KgMt/CUM	ELECTRICITY usage - Kwh/KgMt	COST INTENSITY- ksh/KgMt	Availability Month	average auction price
<b>REGION-1</b>	<b>To-Date</b>	<b>To-Date</b>	<b>To-Date</b>	<b>To-Date</b>		2013.00
F1	35.76	234.42	0.70	19.75	75%	3.23
F2	27.63	310.77	0.68	19.56	78%	3.24
F3	45.84	184.07	0.85	28.98	61%	3.24
F4	33.33	255.25	0.72	26.50	79%	3.23
F5	41.80	202.71	0.87	29.42	75%	3.24
F6	46.25	190.95	0.96	22.05	56%	3.23
F7	46.52	177.25	0.82	18.88	81%	3.32
F8	37.16	228.71	0.81	24.96	58%	3.27
F9	36.60	227.86	0.67	20.88	68%	3.29
F10	33.87	248.01	0.65	20.76	72%	3.29
F11	45.20	185.16	1.16	26.91	58%	3.25
F12	38.11	223.34	0.73	22.55	74%	3.27
<b>AVERAGE</b>	<b>39.01</b>	<b>222.38</b>	<b>0.80</b>	<b>23.43</b>	<b>0.70</b>	<b>3.26</b>
<b>REGION 2</b>						
F13	39.23	214.38	0.80	22.46	65%	3.30
F14	47.49	177.18	0.98	27.76	65%	3.24
F15	52.27	158.18	0.84	24.76	52%	3.24
F16	46.01	180.26	0.78	21.89	88%	3.47
F17	45.55	182.48	0.80	20.96	65%	3.23
F18	41.26	206.45	0.98	23.59	56%	3.20
F19	43.98	193.96	1.06	29.29	65%	3.26
F20	46.09	182.73	0.96	23.56	62%	3.24
F21	36.02	237.18	0.88	21.07	65%	3.27
<b>AVERAGE</b>	<b>44.21</b>	<b>192.53</b>	<b>0.90</b>	<b>23.93</b>	<b>0.65</b>	<b>3.27</b>
<b>REGION 3</b>						
F22	38.80	218.66	0.81	21.82	70%	3.36
F23	35.45	238.08	0.75	20.44	90%	3.36
F24	33.53	241.31	0.33	12.35	79%	3.37
F25	32.53	262.56	0.79	20.01	68%	3.35
F26	43.98	189.88	0.77	21.82	52%	3.45
F27	54.54	150.20	0.69	22.20	51%	3.29
F28	26.84	314.55	0.58	16.27	63%	3.37
F29	48.79	169.85	0.79	20.97	58%	3.19
<b>AVERAGE</b>	<b>39.31</b>	<b>223.14</b>	<b>0.69</b>	<b>19.49</b>	<b>0.66</b>	<b>3.34</b>
<b>REGION 4</b>						
F30	32.00	277.76	1.10	22.43	69%	3.22
F31	32.22	271.13	0.97	20.75	89%	3.29
F32	32.64	261.02	0.78	18.40	70%	3.12
F33	32.16	274.63	1.05	21.75	88%	3.28

F34	30.15	283.08	0.73	17.00	87%	3.41
F35	29.23	293.31	0.74	17.39	79%	3.28
F36	28.84	306.66	0.96	20.06	81%	3.28
F37	29.77	293.73	0.90	20.22	92%	3.29
AVERAGE REGION 5	30.88	282.66	0.90	19.75	0.82	3.27
F38	30.85	272.23	0.58	14.14	82%	3.13
F39	33.61	249.25	0.65	15.33	77%	3.08
F40	34.79	238.76	0.52	14.73	81%	3.08
F41	36.11	233.31	0.68	17.04	55%	3.08
F42	36.36	227.32	0.56	14.85	79%	2.96
F43	38.39	216.67	0.55	16.15	55%	3.03
F44	38.66	216.01	0.62	16.87	60%	3.11
F45	38.82	214.18	0.64	16.82	69%	3.04
F46	40.86	203.24	0.67	17.25	26%	3.05
F47	41.37	200.90	0.66	20.65	60%	3.05
F48	43.37	191.27	0.66	18.25	50%	3.06
F49	45.22	180.67	0.53	17.29	55%	3.05
AVERAGE REGION 6	38.20	220.32	0.61	16.61	0.62	3.06
F50	43.31	190.91	0.77	13.97	80.0%	3.22
F51	35.75	235.35	0.78	13.03	86.7%	3.12
F52	33.52	252.06	0.72	12.65	59.6%	3.23
F53	42.50	188.86	0.11	11.65	61.6%	3.13
F54	38.51	213.86	0.35	13.10	82.0%	3.15
F55	40.72	202.94	0.73	13.75	62.2%	3.12
F56	46.07	179.86	0.82	15.57	56.8%	3.14
F57	48.52	170.80	0.87	16.20	58.1%	3.09
F58	44.25	188.59	0.79	15.11	58.8%	3.17
F59	37.82	222.37	0.80	14.04	60.3%	3.12
F60	46.09	178.52	0.75	14.96	56.9%	3.12
F61	30.28	285.31	0.86	13.49	72.2%	3.10
AVERAGE REGION 7	40.61	209.12	0.70	13.96	0.66	3.14
F62	39.16	215.00	0.82	22.36	54.5%	3.04
F63	39.97	213.00	0.95	24.25	46.6%	3.11
F64	34.08	246.00	0.67	18.87	65.4%	3.09
F65	34.13	254.00	0.96	22.91	72.0%	3.01
AVERAGE	36.84	232.00	0.85	22.10	0.60	3.06

**TABLE 13- CORRELATION BETWEEN MAINTENANCE PRACTICES AND AVAILABILITY**

**PREVENTIVE MAINTENANCE VS OEE**

Spearman Rank Order Correlation - Ungrouped Data	
Statistic	Value
<a href="#">Correlation (not corrected)</a>	0.189744
<a href="#">Correlation (corrected)</a>	0.180365
<a href="#">t-Test (n&gt;10)</a>	0.898337
Degrees of Freedom	24
Critical 2-sided T-value (5%)	2.064
Critical 1-sided T-value (5%)	1.711
D-square value (calculated)	2370
D-square value (expected)	2925
Standard Deviation	585
<a href="#">z-Test</a>	-0.948718
Probability	0.3422
Observations	26

**BREAKDOWN VS OEE**

Spearman Rank Order Correlation - Ungrouped Data	
Statistic	Value
<a href="#">Correlation (not corrected)</a>	-0.166838
<a href="#">Correlation (corrected)</a>	-0.180365
<a href="#">t-Test (n&gt;10)</a>	-0.898337
Degrees of Freedom	24
Critical 2-sided T-value (5%)	2.064
Critical 1-sided T-value (5%)	1.711
D-square value (calculated)	3413
D-square value (expected)	2925
Standard Deviation	585
<a href="#">z-Test</a>	0.834188
Probability	0.4008
Observations	26