MAINTENANCE MANAGEMENT APPROACHES AND MANUFACTURING PERFORMANCE

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DECLARATION

I declare that this is my original work and to the best of my knowledge, it has not been submitted to any other College, Institution or University for an academic award.

Signed:_____________________________ **Date:**_________________________

Mono, Martin

D61/75688/2012

This Research project has been submitted for examination with my approval as the university supervisor.

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DEDICATION

To my dear wife Elizabeth Mwero and daughter, Sasha Chebet for their support, understanding and patience throughout the entire period of the study.

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ABSTRACT

The purpose of this study was to establish the association between maintenance approach adopted and manufacturing performance. The study had four objectives to achieve: To determine the maintenance approaches adopted by manufacturing industries in Kenya; determine operations performance of manufacturing industries in Kenya; determine plant effectiveness of manufacturing industries in Kenya and to determine the relationship between maintenance approach adopted and manufacturing performance. The study used a cross-sectional research design targeting manufacturing firms based at Athi-River Export Processing Zone. A census involving 21 firms was carried out and simple random sampling was used to select 88 respondents who participated in the study. A questionnaire was used to collect primary data from the respondents. The data collected was analyzed using descriptive and inferential statistics. The findings were presented in tables. The study established that maintenance management approaches adopted by manufacturing firms in Kenya fall into three main categories. Approach that emphasizes high preventive and fast reactive maintenance by dedicated resources; Approach that emphasizes low preventive and fast reactive maintenance by dedicated resources and Autonomous maintenance. Approach emphasizing high preventive and fast reactive maintenance by dedicated resources is predominant among manufacturing firms. Maintenance approaches have varying levels of effectiveness with preventive maintenance outweighing reactive maintenance. Autonomous maintenance was found to be better than the other two in terms of manufacturing plant effectiveness and manufacturing performance. Acting via manufacturing plant effectiveness, maintenance management approach adopted has a positive influence on manufacturing performance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

AM:	Autonomous Maintenance
CBM:	Condition – Based Maintenance
EPZA:	Export Processing Zone Authority
GDP:	Gross Domestic Product
KNBS:	Kenya National Bureau of Statistics
KPMG:	Klynveld Peat Marwick Goerdeler
MANOVA:	Multivariate Analysis Of Variance
OEE:	Overall Equipment Effectiveness
PM:	Preventive Maintenance
RCM:	Reliability Centred Maintenance
RM:	Reactive Maintenance
TPM:	Total Productive Maintenance

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Today's business environment is highly dynamic and it does change rapidly and as a result, firms are under pressure to protect and grow their market share. Organizations experience multiple challenges including the ability to provide quality products at an affordable cost and promptly. To deal with these challenges, organizations must strive to examine their business functions to identify areas which need to be exploited for them to achieve competitiveness. Maintenance is one such area which can enhance a firm's profit and competitiveness by ensuring equipment availability, efficiency and ability to produce quality outputs and this depends on the effectiveness of maintenance strategies adopted by firms (Al-Najjar, 2007).

This chapter covers concepts in operations management including maintenance management, maintenance management approaches and the relationship between maintenance management approach and manufacturing/operational performance.

1.1.1 Operations Management

Operations management is concerned with the task of managing the process (or system) for the production of goods and services from the input resources which include labour, plant and machinery, materials and information (Johnston et al., 1993; Muhlemann et al., 1992). Operations management uses resources to appropriately create outputs that fulfil defined market requirements. Operations' core objectives are quality, cost, speed, flexibility and dependability (Slack et al., 2010)

Operations management is made up of six components grouped under three levels; strategic level includes operations strategy, system level entails quality and supply chain management. Finally, process level encompasses planning and control, project management and process design. For this study, process design component was of interest since it includes concepts which the study focused on.

Process level drives efficiency and effectiveness which in turn affects productivity of an operations system and the rate of return on assets. These assets include plant and machinery and they require to be kept in functional condition. This state is achieved through maintenance.

1.1.2 Managing Maintenance

Maintenance is the combination of all technical, administrative and managerial actions during the life cycle of an item, intended to retain it or restore it to, a state in which it can perform the required function (BS EN 13306:2010). Maintenance management refers to all the activities of the management that determine the maintenance objectives or priorities, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, and improving the methods including economical aspects in the organization (BS EN 13306:2010).

Maintenance management strives to ensure physical assets perform their required functions efficiently and effectively. When a machine/equipment malfunctions, it leads to loss of production, man-hours, speed, and precision among others. Consequently, the production processes are driven out of control resulting into increased production costs, defective products and delayed supplies. Additionally, a malfunctioning piece of physical asset jeopardizes the safety of employees or customers (Al-Najjar, 2007). Therefore, maintenance management plays an important role in influencing cost, quality, speed, flexibility and dependability objectives of an operations system. Effective maintenance management requires identification and implementation of appropriate maintenance approaches (Cooke, 2003).

1.1.3 Approaches to Maintenance Management

Approaches to maintenance management can be varied based on what triggers the maintenance activity, frequency of maintenance activity and who carries out the maintenance activity. Maintenance activity can be prompted by malfunctioning equipment or prearranged (Mobley, 2008).

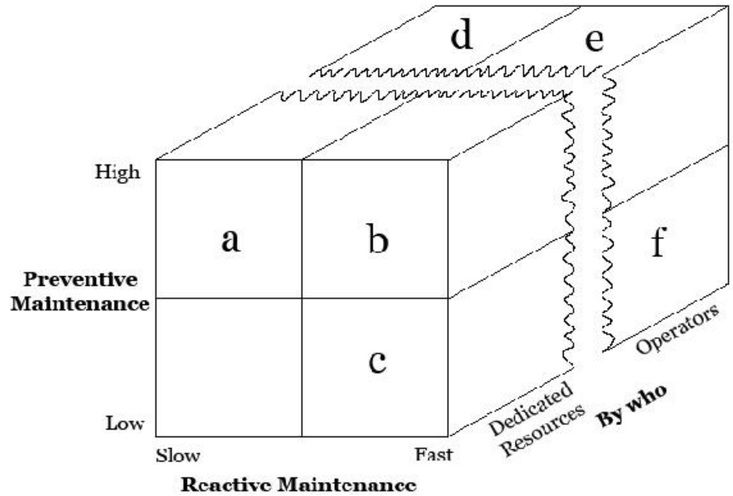
Reactive maintenance (RM) is maintenance carried out after fault recognition and intended to put an item back into a state in which it can perform a required function (BS EN 13306:2010). It is executed when a failure occurs or a functional problem is identified. Its key advantage is that facility need not be stopped. Its disadvantages are; the facility can breakdown at peak demand time leading to losses and a single failure can cause other multiple failures which could have been pre-empted by preventive maintenance (Mobley, 2008).

Preventive maintenance (PM) is maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item (BS EN 13306:2010). It should be noted that preventive maintenance strategies do not eliminate breakdowns totally. Its advantages include maintenance activity/down time is scheduled during low demand and it does act on facilities and equipment before they fail therefore reducing the cost of failure. Its disadvantages include labour intensiveness and performance of unneeded maintenance (Mobley, 2008).

Decision on who executes maintenance activity is an important factor to consider since it has influence on the efficiency and effectiveness of maintenance work. Both reactive and preventive maintenance can be done by dedicated resources or operators with dual skills to operate equipment and maintain them. Furthermore, a firm can involve entire workforce in maintenance by training them (Nakajima, 1988).

In the event an equipment fails, there are a number of activity options which can be implemented to restore it to a functional state. The first option is to replace/repair worn out parts as fast as possible. The pace of repair is determined by availability of standby equipment, spare parts and repair crew. The second option involves carrying out total inspection of the malfunctioning equipment and replacing/repairing worn out parts. The third option entails replacing old equipment with a new one (Mobley, 2008). Lastly, investigation of the cause of failure can be done with a view to improve the production processes and equipment design (Nakajima, 1988).

Based on the decisions described above, seven maintenance approaches can be identified as illustrated in figure 1 below:



Source: Researcher (2016)

Fig. 1: Variation of Maintenance Management Approaches

The identified practical approaches are; (a) High Preventive and Slow Reactive Maintenance by dedicated resources, (b) High Preventive and Fast Reactive Maintenance by dedicated resources, (c) Low Preventive and Fast Reactive Maintenance by dedicated resources, (d) High Preventive and Slow Reactive Maintenance by operators, (e) High Preventive and Fast Reactive Maintenance by operators and (f) Low Preventive and Fast Reactive Maintenance by operators.

Approach (e) which emphasizes PM and involvement of operators in maintenance activities has been described as autonomous maintenance (AM) (Nakajima, 1988). Improvements on AM to include investigation of failures and possible redesign of equipment and production processes gave rise to the seventh approach called- (g) Total Productive Maintenance (TPM). TPM is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce. The ultimate goals of TPM include zero defects, zero accidents and zero breakdowns (Nakajima, 1989).

The application of maintenance strategy options is determined by the type of facility in terms of the level of technology and the core business/function of a firm or an employee. In practice, firms opt for purely maintenance crew based maintenance or a mix of maintenance crew and operator based maintenance. The choice of a maintenance strategy option is influenced by the total maintenance cost, total cost of failure and the cost of maintenance activity (Mobley, 2008). Irrespective of who executes the maintenance activity, a high frequency of preventive maintenance will result in reduced breakdown and repair costs but with increased preventive maintenance costs. Fast repairs result in reduced cost of interruptions to production but with increased cost of repair crew and shops, spare parts, and standby machines (Mobley, 2008). The selected maintenance approach affects an organization's operational performance.

1.1.4 Maintenance Management Approach and Manufacturing Performance

Manufacturing/Operational performance refers to the measurable aspects of the outcomes of an organization's processes (Voss et al., 1997). There are five core dimensions of operational performance including quality, cost, speed/delivery, flexibility and dependability. Operational performance influences business performance measures such as customer satisfaction and market share.

Past studies have indicated the role of maintenance/maintenance approaches on operational performance of firms. Maintenance and productivity have a positive relationship (Khan and Darrab, 2010). Consequently, more productivity implies low cost of production and timely supply of products to customers. Furthermore, there exists a positive association between maintenance and quality of products (Ollila and Malmipuro, 1999). Therefore, to produce quality products, equipment must be maintained properly. TPM initiatives enhance productivity and cost effectiveness of an operations system. Additionally, it ensures quality outputs, safety and boosts morale of the workforce (Ahuja and Kumar, 2009). The various maintenance management approaches affect cost, quality, speed, flexibility and dependability in varying degrees owing to their efficacy. To meet the mentioned operational objectives and competitiveness, an organization must select an effective maintenance strategy.

1.1.5 Manufacturing Industry in Kenya

The industrial sector accounts for almost 20% of Kenya's economic activity and is dominated by manufacturing and energy production (KPMG, 2015). In 2014, Manufacturing sector accounted for 10% of the Kenya's Gross Domestic Product (GDP) and came second after combined Agriculture, Forestry and Fishing sectors which maintained dominance by contributing 27.3% of GDP (KNBS, 2015).

Food and consumer goods are now significant sub-sectors within the manufacturing sector. Kenya is expected to remain one of the top exporters of manufactured goods in the Sub-Saharan Africa (SSA) region for a foreseeable future. On competitiveness of its products on the international market, Kenya was ranked third (after Mauritius and Morocco) as per Africa's manufacturing environment index (MEI) (KPMG, 2015).

Despite the promising performance, Kenya's manufacturing industry still faces challenges including high cost of electricity, bureaucratic inefficiency, taxation, and inefficiency of production assets. Compared to developed countries, the technology and maintenance of manufacturing assets still remains low. This affects the efficiency and effectiveness of the physical assets and subsequently results into low productivity.

The key issues affecting the country's manufacturing sector include productivity, cost, quality, speed and availability/uptime of facilities. These factors influence competitiveness.

1.2 Research Problem

It has been reported that maintenance approach has a positive influence on operational performance of a firm which consequently enhances its competitiveness through higher product value perception and productivity. Productivity will influence cost and value perception will be derived from quality. The extent of influence depends on the approach adopted by a firm. Manufacturing industries struggle with productivity, cost, speed/delivery and quality issues. Optimization of maintenance strategy is hindered by limited capital, management method, socio-economic and cultural factors. A firm has to trade-off between repairs and degree of preventive maintenance. A high degree of preventive maintenance results in high preventive maintenance cost and low breakdown/ repair costs and this translates to minimum total maintenance cost.

Several studies have been carried out to establish the link between maintenance/ approach and operational performance (Khan and Darrab, 2010; Ollila and Malmipuro, 1999; Maletic et al., 2014; Ahuja and Kumar, 2009).

Khan and Darrab (2010) focused on the correlation between maintenance time, quality and productivity using data obtained from a sweet factory in Saudi Arabia. Ollila and Malmipuro (1999) study done in Finland concerned maintenance approaches and their relationship with quality. Maletic, Al-Najjar and Gomiscek (2014) did a study in a Slovenian textile company examining the impact of maintenance on a firm's competitiveness and profitability using unplanned machine time and product quality as dependent variables. A study by Ahuja and Kumar (2009) focused on one maintenance approach i.e. TPM and investigated its effect on manufacturing performance of a steel tube mill in India.

Few studies have been done on maintenance approaches in Kenya. Socio-economic and cultural differences can have influence on the choice of maintenance strategy. The study was carried out in Kenya and focused on a wider range of maintenance management approaches. It sought to answer the question: Does maintenance management approach adopted influence manufacturing performance?

1.3 Research Objectives

To answer the above research question, the following specific objectives were to be achieved:

i. Determine the maintenance approaches adopted by manufacturing industries in Kenya
ii. Determine operations performance of manufacturing industries in Kenya
iii. Determine plant effectiveness of manufacturing industries in Kenya
iv. Determine the relationship between maintenance approach adopted and manufacturing performance.

1.4 Value of the Study

The information generated from this study will be of interest to manufacturing organizations and researchers. With increasing global competition, firms are in search of ideas which can make them competitive. Therefore, good practices and strategies originating from this study will be implemented by manufacturing firms thereby improving their operational performance. Additionally, the findings can be valuable to service organizations. The outcome of this study will also be useful to scholars and students as it will broaden the existing knowledge on maintenance management and more specifically, the influence of maintenance approach adopted on operational performance of a manufacturing firm.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

In this chapter, literature was reviewed in three streams namely; maintenance approaches/strategies, manufacturing plant effectiveness and manufacturing performance measurement. Subsequently, the literature was summarized and a conceptual framework developed.

2.2 Maintenance Approaches/Strategies

Studies on maintenance approaches reveal that some approaches are applied more than others (Fraser et al., 2015). Literature indicates that choice of a maintenance strategy or its development may be an outcome of a number of factors including asset variety, automation, complexity, views on maintenance and production pressure (Cooke, 2003) and regional/country context (Gebauer et al., 2008).

Fraser et al., (2015) sought to identify and categorize the various maintenance management strategies in a conceptual study using literature review. They identified Reliability Centred Maintenance (RCM), Total Productive Maintenance (TPM) and Condition – Based Maintenance (CBM) as the most applied. They further found that approaches given different descriptive names, when analyzed based on decision points and dimensions, are actually the same. However, the study did not indicate the factors which influence the choice of maintenance strategies neither did it explain the role of socio-economic context and the impact of choice of approach on manufacturing performance.

The findings of Fraser et al., (2015) are consistent with studies of Cooke (2003) and Gebauer et al., (2008). Using a case study approach, the study by Cooke (2003) sought to establish the maintenance strategies adopted by British manufacturing firms and found out that preventive maintenance was the major strategy deployed by the case study firms although they had a tendency to slip back to reactive maintenance due to production pressure. On factors that may influence choice of a maintenance approach, Cooke (2003) suggests assets variety, automation, complexity, views on maintenance and production pressure and Gebauer et al., (2008) indicated context as a factor.

Cooke (2003) being a case study has limitation in terms of generalizability just like Fraser et al., (2015). The findings by Cooke (2003) about predisposition to fall back to reactive maintenance appear consistent with those of a statistical study by Gebauer et al., (2008) in China. This is an indicator that socio-economic issue may not be a major factor in the choice of a maintenance strategy.

2.3 Manufacturing Plant Effectiveness

Overall Equipment Effectiveness (OEE) measure is a monitoring and controlling tool and is appropriate to high volume processes where capacity utilization is crucial. Its credibility relies on accuracy of performance data. OEE is not only used to monitor production but also to manage improvement through comparison of initial OEE values with future OEE values (Dal et al., 2000).

Dal et al., (2000) carried out a case study to explore the use of OEE within a manufacturing firm based in the United Kingdom. They established that OEE measure is appropriate for determining the efficacy of an equipment or manufacturing line and it is a product of availability, performance efficiency and quality rates. The effect of geographical context on the use of OEE measure, its application to maintenance management approaches and influence on operations' core objectives were not clarified.

2.4 Manufacturing Performance Measurement

Cost, quality, speed, flexibility and dependability measures are the most appropriate to gauge manufacturing performance relative to a competitive strategy (White, 1996). Choice of performance measures is determined by a number of factors including purpose of measurement, level of detail required, time available for measurement, existence of predetermined data and cost of measurement (Tangen, 2003). White (1996) carried out a literature review to ascertain and categorize manufacturing performance measures within the framework of competitive strategy. The study examined diverse literature covering books, journals and trade publications in diverse fields including engineering and cost accounting. Findings are that manufacturing has a significant impact on the achievement of operations' competitive priorities; quality, cost, flexibility, speed and dependability. The study concludes that quality, cost, flexibility, speed and dependability constitute the core manufacturing performance measures.

The study suggests that these performance measures are practically composites of smaller measures categorized as; cost measure relates to the measures of unit cost, capital productivity, labour productivity and total factor productivity. Quality measure relates to customer complaints, pass rate, scrap level and defects per unit. Flexibility measure relates to production cycle time, set-up time, machine changeover time, adaptability to volume changes and equipment availability. Speed measure relates to order lead time, cycle time and material throughput time. Dependability measure relates to percentage on-time delivery, due date adherence and percentage of orders with incorrect amounts.

White (1996) is a conceptual study with the objective of identifying manufacturing performance measures. The study does not indicate the factors that may influence choice of performance measures neither does it apply the measures to maintenance approaches. Tangen (2003) in a conceptual study suggests purpose of measurement, level of detail required, time available for measurement, existence of predetermined data and cost of measurement as some of the factors that may affect selection of measures.

2.5 Summary and Research Gaps

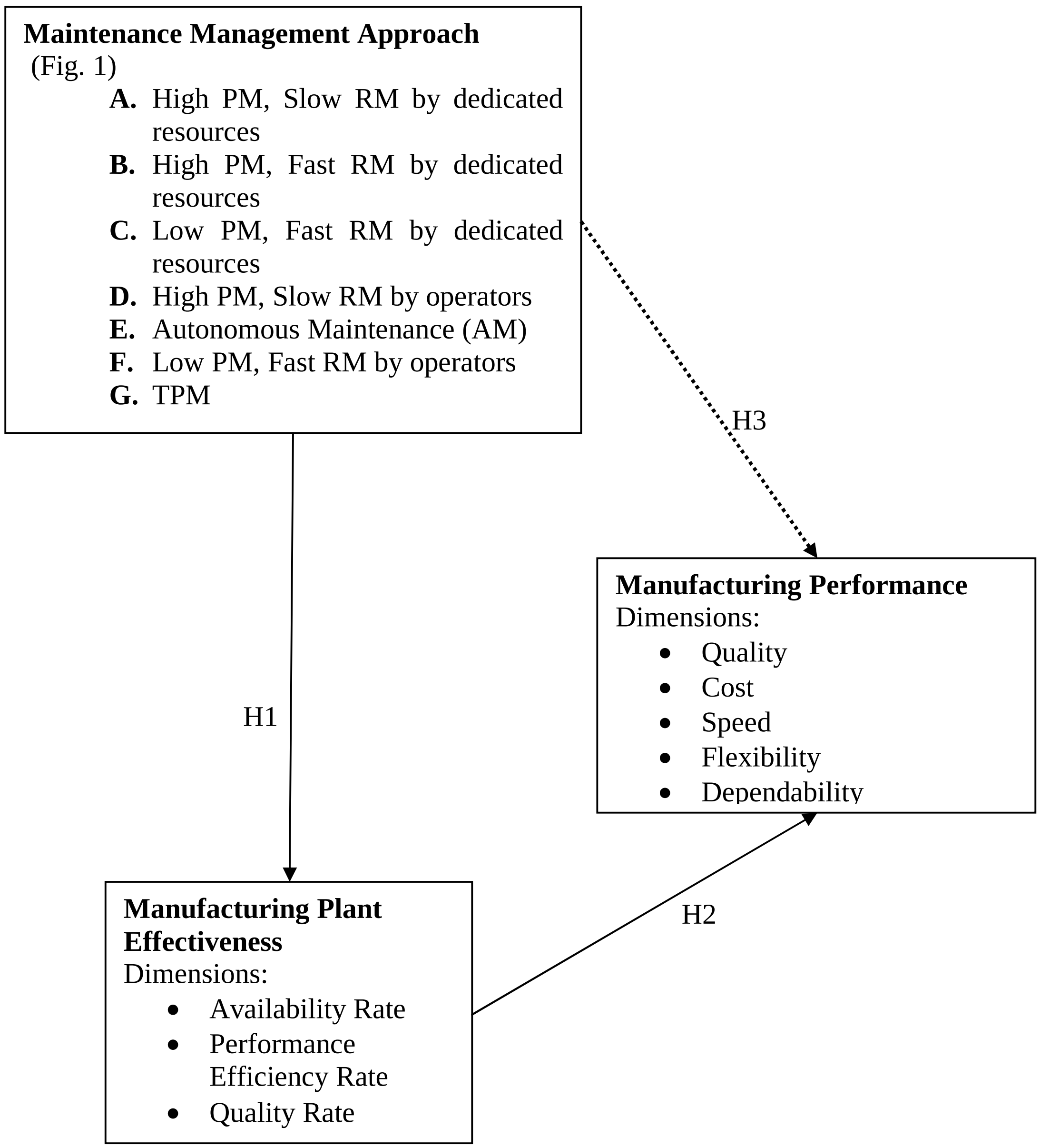
Findings and focus of the studies reviewed are summarized in the table 2.1 below:

Table 2: Summary of Literature Review

Study & Type	Focus & Findings	Gaps
Fraser et al., (2015), A Conceptual study	Popular maintenance approaches in practice. RCM, TPM and CBM identified.	Relationship to manufacturing performance not determined.
Cooke (2003) An empirical study	Maintenance approaches adopted by some of British manufacturing firms. RM and PM strategies identified. Asset variety, automation, complexity, views on maintenance and production pressure influence choice of maintenance approaches.	Relationship to manufacturing performance not determined. Socio-economic context
Gebauer et al., (2008), An empirical study	Maintenance approaches in Chinese manufacturing companies. Predictive, TPM and RM identified. RM is the predominant strategy.	Relationship to manufacturing performance not determined Socio-economic context
Dal et., (2000), An empirical study	Application of OEE within a British manufacturing firm. OEE measure is a monitoring and controlling tool and is appropriate to high volume processes. Its credibility relies on accuracy of performance data	OEE measure not applied to maintenance approaches. OEE influence on operations' core objectives not clarified Socio-economic context
White (1996), A Conceptual study	Manufacturing performance measures. Quality, cost, flexibility, speed and dependability measures identified.	Measures not applied to maintenance approaches
Tangen (2003), A Conceptual study	Manufacturing performance measures. Purpose of measurement, level of detail required, time available for measurement, existence of predetermined data and cost of measurement influence choice of measures.	Measures not applied to maintenance approaches

2.6 The Conceptual Framework

The issues for examination in the study were to determine the maintenance approaches adopted by manufacturing firms, their plant effectiveness and level of manufacturing performance and the relationship between maintenance management approach adopted and manufacturing performance. The identified variables and their relationships were conceptualized in the theoretical framework below:



Source: Researcher (2016)

Fig. 2: Conceptual Framework

2.7 Hypothesis

The relationships in the above figure can be examined by testing the following hypotheses:

H1: Maintenance management approach adopted has a positive influence on the manufacturing plant effectiveness.

H2: Manufacturing plant effectiveness has a positive influence on the manufacturing performance.

H3: Maintenance management approach adopted has a positive influence on the manufacturing performance.

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CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The study sought to establish maintenance management approaches adopted by manufacturing firms in Kenya, determine their manufacturing performance and the relationship between maintenance approach adopted and manufacturing performance. These objectives were achieved by examining maintenance management approaches adopted by industries and determining if there is any relationship with manufacturing performance.

In this chapter, the research methodology adopted was described. Details on research design, study population, sample design, data collection and data analysis techniques are presented.

3.2 Research Design

This study sought to determine status within population elements at a fixed point in time. Therefore, cross-sectional research design was adopted. In the cross-sectional study, a researcher does a comparison of different cases within the same parameters and this being an academic research project, it was time constrained hence the selected research design was appropriate.

Kumar et al., (2014) used this design in a similar study which focused on the impact of TPM implementation on Indian manufacturing industry.

3.3 Population Sampling

The target population was manufacturing firms situated at Athi-River export processing zone. The targeted firms were 21 in number (EPZA, n.d). These firms are not unique to the ones operating in other parts of the country since all of them generally employ staff exposed to the same socio-economic context and market accessibility is general. Further, the target population was convenient since the researcher works within the zone.

Given the relatively small size of the study population, a census was conducted and this implied data was collected from every possible case or group member.
A census does eliminate sampling errors thereby enhancing the level of precision of the study.

3.4 Data Collection

A structured – self administered- questionnaire was used to gather the survey data and was delivered by hand to each respondent and collected later. The selected method is appropriate for learning about opinions, attitudes, motivations, practices, beliefs, intentions and expectations of respondents (Cooper and Schindler, 2003).

The questionnaires were administered to 10 employees drawn randomly from manufacturing/production departments. Social desirability bias in the study was mitigated by using disguised questions, enlisting multiple informants and ensuring anonymity of the informants.

The questionnaire sought to find out how organizations plan and execute maintenance activities. Further, employees were asked for subjective opinions about their manufacturing plant effectiveness and manufacturing performance relative to other organizations in the same industry.

Maintenance management approach was measured by determining the relative level of investment on preventive and reactive maintenance infrastructures and the executor of maintenance activities (Cooke, 2003 & Gebauer et al., 2008). The level of investment was represented by the degree of PM and speed of RM. Manufacturing plant effectiveness was measured by determining respondents' relative perception of their level of equipment availability, performance efficiency and rate of producing quality products (Nakajima, 1988). Manufacturing plant effectiveness is based on the 'six big losses'. Availability loss relates to breakdown and set-up/adjustment losses. Performance loss relates to reduced speed and idling/minor stoppage losses and quality loss relates to defect/rework and start-up losses (Nakajima, 1988). Manufacturing performance was measured by elements of cost, quality, speed, flexibility and dependability (White, 1996).

To obtain data on maintenance management approach variable, the informants were given choices from which to select the option which most applied to their organizations. For manufacturing plant effectiveness and manufacturing performance variables, the respondents were asked to indicate their perceptions on their performance in given dimensions relative to other organizations.

Perceptual data was convenient for this study since most organizations classify their actual data as confidential. A study by Kumar et al., (2014) used this type of data. The items in the questionnaire are based on past studies.

3.5 Data Analysis

The unit of analysis was the organization. The data collected were summarized by organization and maintenance approach. Means and standard deviations were used to represent the variables. This is based on the central limit theorem which states that the mean of the sampling distribution of means is equal to the population mean. For the variable of maintenance approach, data were both categorical and perceptual.

Multivariate analysis of variance (MANOVA) and regression analysis were applied to achieve the objectives of the study and were performed at a 95% confidence level. The results of the study were interpreted as follows; for MANOVA, when F ratio is significant and $p<0.05$, then the null hypothesis was rejected. For regression analysis, when correlation coefficient $R<>0$, coefficient $B<>0$ and $p<0.05$, then the null hypothesis was rejected.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

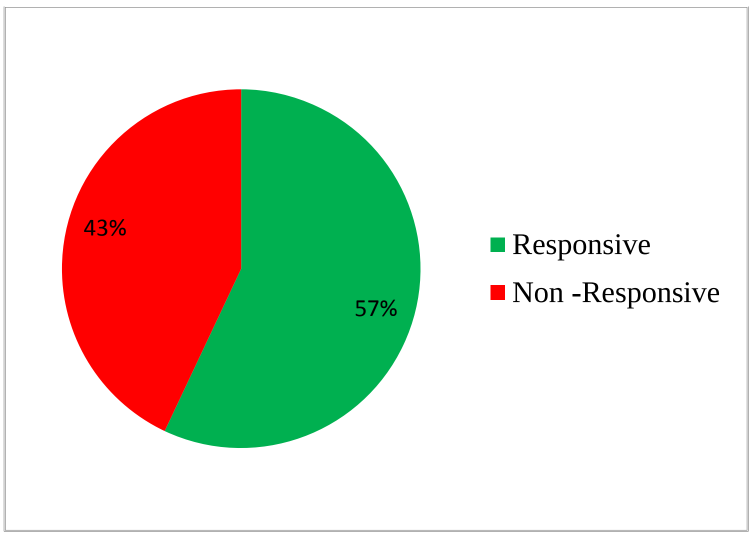
4.1 Introduction

This chapter covers analysis of data to establish the status of the variables and their statistical significance.

4.2 Results

4.2.1 Response Rate

Information was sought from 210 respondents across 21 firms. From the survey, 12 firms responded and this translated to 57% of the target population. Fig. 4.1 below graphically presents the response rate:



Source: Survey Data
Fig. 4.1: Firms' Response

Table 4.1 below shows response rates by firms. Firm 4 had a response rate of 20% which implies it had the lowest representation compared to the rest. However, the firm was not significantly different in terms of size, structure and culture. There were varying response rates with a mean of 73% across firms. The proportion of responsive firms and informants' average response rate were above 50% and as suggested by

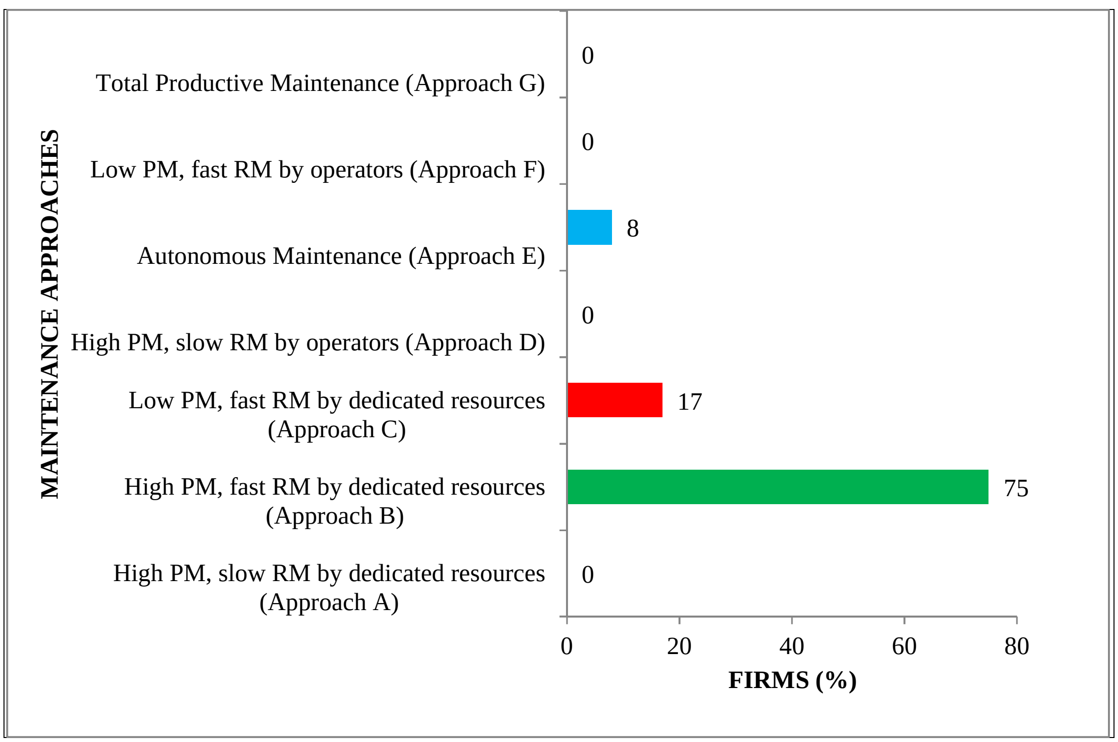
Mugenda and Mugenda (1999), they were considered sufficient for generalization of findings to manufacturing firms in Kenya.

Table 4.1: Response Status

Firm	Questionnaires Issued	Questionnaires Received	Response Rate (%)
1	10	10	100
2	10	7	70
3	10	4	40
4	10	2	20
5	10	10	100
6	10	10	100
7	10	3	30
8	10	9	90
9	10	8	80
10	10	8	80
11	10	7	70
12	10	10	100
Total	**120**	**88**	**73**

Source: Survey Data

Fig. 4.2 below presents maintenance approaches emphasized by manufacturing firms in Kenya:



Source: Survey Data

Fig. 4.2: Maintenance Approaches Emphasized

From figure 4.2 above, most of the firms investigated focus on high preventive and fast reactive maintenance by dedicated resources as this approach is applied by 75% of the firms studied. Approach E was the least used since only 8% of the firms adopted it. Additionally, none of the firms applied approaches A, D, F and G.

4.2.2 Summary of Variable values

Multi-item constructs used to represent variables of maintenance management approach, plant effectiveness and manufacturing performance were put through preliminary analysis to determine their values. The emphasized maintenance approach was the one most chosen by the informants. Constructs representing variables of manufacturing plant effectiveness and manufacturing performance were aggregated and means and standard deviations determined. Tables 4.2 and 4.3 below show the variable values.

Table 4.2: Variable values by Organization

			Organization											
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Maintenance Approach (Figs. 1& 4.2)			B	B	B	E	B	B	B	B	B	B	C	C
Manufacturing Plant Effectiveness (Scale: 1-5)		Mean	2.88	3.71	4.20	4.40	3.76	4.11	4.60	3.95	4.60	4.58	1.54	1.84
		Std Dev	0.17	0.75	0.43	0.85	0.79	0.48	0.00	0.73	0.32	0.31	0.22	0.31
	95% Confidence Interval	Upper Bound	3.20	4.09	4.70	5.11	4.08	4.44	5.18	4.30	4.95	4.93	1.92	2.16
		Lower Bound	2.56	3.34	3.70	3.69	3.44	3.78	4.02	3.60	4.25	4.22	1.17	1.52
Manufacturing Performance (Scale: 1-5)		Mean	2.94	3.58	4.74	4.59	3.94	4.15	4.94	3.69	4.26	4.43	1.66	1.78
		Std Dev	0.14	0.50	0.12	0.45	0.28	0.36	0.00	0.43	0.56	0.56	0.10	0.15
	95% Confidence Interval	Upper Bound	3.20	3.86	5.26	5.11	4.18	4.41	5.37	3.93	4.53	4.69	1.94	2.02
		Lower Bound	2.68	3.30	4.21	4.07	3.71	3.89	4.52	3.44	4.00	4.17	1.39	1.55

Source: Survey Data

Table 4.2 above indicates that the highest aggregate mean on manufacturing plant effectiveness was registered by Firms 7 and 9. They both posted a mean of 4.60 and Firm 11 scored the lowest mean of 1.54. On manufacturing performance, Firm 7 registered the highest mean of 4.94 whereas Firm 11 had the lowest mean of 1.66.

Table 4.3: Variable values by Maintenance Management Approach

			High PM, fast RM by dedicated resources (Approach B)	**Low PM, fast RM by dedicated resources** (Approach C)	**Autonomous Maintenance** (Approach E)
Manufacturing Plant Effectiveness (Scale: 1-5)		Mean	3.96	1.72	4.40
		Std Dev	0.75	0.31	0.85
	95% Confidence Interval	Upper Bound	4.12	2.05	5.37
		Lower Bound	3.79	1.39	3.43
Manufacturing Performance (Scale: 1-5)		Mean	3.94	1.73	4.59
		Std Dev	0.65	0.14	0.45
	95% Confidence Interval	Upper Bound	4.09	2.01	5.40
		Lower Bound	3.80	1.45	3.77

Source: Survey Data

Table 4.3 above indicates that based on the maintenance approaches adopted by the surveyed firms, approach E registered the highest means of 4.40 and 4.59 for manufacturing plant effectiveness and manufacturing performance respectively. Approach B had a cumulative mean of 3.96 for manufacturing plant effectiveness and 3.94 for manufacturing performance. Correspondingly, approach C had the lowest cumulative means of 1.72 and 1.73.

4.3 Hypothesis Testing

One of the objectives of the study was to establish the relationship between maintenance management approach adopted and manufacturing performance. This was achieved by performing the following statistical tests:

4.3.1 The relationship between Maintenance Management Approach and Manufacturing Plant Effectiveness

The hypothesis H1: Maintenance management approach adopted has a positive influence on the manufacturing plant effectiveness was investigated. The null hypothesis tested was H0: No significant difference between the means. To test the significance of data presented, multivariate analysis of variance (MANOVA) was done at a p-value of 0.05 and the results presented in Table 4.4 below:

Table 4.4: Multivariate Analysis of Variance for Maintenance Management Approach and Manufacturing Plant Effectiveness

Multivariate Tests[a]									
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Maintenance Management Approach	Pillai's Trace	.658	7.846	10	160	.000	.329	78.462	1.000
	Wilks' Lambda	**.348**	**10.999[b]**	**10**	**158**	**.000**	**.410**	**109.994**	**1.000**
	Hotelling's Trace	1.861	14.514	10	156	.000	.482	145.136	1.000
	Roy's Largest Root	1.852	29.631[c]	5	80	.000	.649	148.154	1.000
a. Design: Intercept + Maintenance Management Approach									
b. Exact statistic									
c. The statistic is an upper bound on F that yields a lower bound on the significance level.									
d. Computed using alpha = .05									

Dependent Variable: Manufacturing Plant Effectiveness

Explanatory Variable: Maintenance Management Approach

Source: Survey Data

From table 4.4 above, the results indicate; Wilks'Lambda (λ) = 0.348, $F (10, 158) = 10.999$, $p<0.001$, partial eta squared (η^2) =0.410, Power to detect the effect = 1.000. Since $p<0.05$ and F is significant, Wilks'λ indicates that (1 - 0.348) * 100 = 65.2% of the variance of the dependent variables is accounted for by the differences between maintenance approaches. Additionally, using the guidelines proposed by Cohen (1988), the value of partial eta squared obtained suggests a very strong correlation between maintenance approach and plant effectiveness ($\eta^2>0.14$). These results signify that maintenance approach did have a significant effect on manufacturing plant effectiveness variables. Therefore, the null hypothesis H0: No significant difference between the means was rejected and the alternative hypothesis accepted.

4.3.2 The relationship between Manufacturing Plant Effectiveness and Manufacturing Performance

The hypothesis H2: manufacturing plant effectiveness has a positive influence on the manufacturing performance. The null hypothesis tested was H0: coefficient B is equal to zero. The means for manufacturing plant effectiveness and manufacturing performance were tested for their significance, a regression analysis was done at a p-value of 0.05 and the results presented in Tables 4.5 and 4.6 below:

Table 4.5: Regression analysis for Manufacturing Plant Effectiveness and Manufacturing Performance

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.973[a]	.946	.941	.2632692	.946	176.374	1	10	.000
a. Predictors: (Constant), Manufacturing Plant Effectiveness									

Source: Survey data

From table 4.5 above, it is revealed that there is a statistically significant strong positive relationship between manufacturing plant effectiveness and manufacturing performance (R = 0. 973) and the effect size estimated by adjusted R^2 is 0.941 (about 94%). This implies that approximately 94% of the variation in manufacturing performance is explained by the variation in manufacturing plant effectiveness (Adjusted $R^2 = 0.941$, $p<0.001$).

Table 4.6: Relationship between Manufacturing Plant Effectiveness and Manufacturing Performance

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.032	.288		.110	.914
	Manufacturing Plant Effectiveness	1.003	.076	.973	13.281	.000
a. Dependent Variable: Manufacturing Performance						

Source: Survey data

Table 4.6 above indicates that the influence of manufacturing plant effectiveness on manufacturing performance was positive and significant (Standardized B = 0.973, t = 13.281, $p<0.001$). The results essentially confirmed that manufacturing plant effectiveness significantly influences manufacturing performance. The relationship can be explained by the equation: $Y = 0.032+ 0.973X$ where; Y is manufacturing performance and X is manufacturing plant effectiveness. Therefore, the null hypothesis H0: that the coefficient B is equal to zero was rejected and the alternative hypothesis accepted.

4.3.3 The relationship between Maintenance Management Approach and Manufacturing Performance

The hypothesis H3: Maintenance management approach adopted has a positive influence on the manufacturing performance was investigated. The null hypothesis tested was H0: No significant difference between the means. To test the significance of data presented, Multivariate analysis of variance (MANOVA) was done at a p-value of 0.05 and the results presented in Table 4.7 below:

Table 4.7: Multivariate Analysis for Maintenance Management Approach and Manufacturing Performance

Multivariate Tests[a]									
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Maintenance Management Approach	Pillai's Trace	.881	2.755	36	126	.000	.440	99.196	1.000
	Wilks' Lambda	**.176**	**4.764[b]**	**36**	**124**	**.000**	**.580**	**171.491**	**1.000**
	Hotelling's Trace	4.355	7.379	36	122	.000	.685	265.628	1.000
	Roy's Largest Root	4.279	14.976[c]	18	63	.000	.811	269.565	1.000
a. Design: Intercept + Maintenance Management Approach									
b. Exact statistic									
c. The statistic is an upper bound on F that yields a lower bound on the significance level.									
d. Computed using alpha = .05									

Dependent Variable: Manufacturing Performance

Explanatory Variable: Maintenance Management Approach

Source: Survey Data

From table 4.7 above, Wilks' $\lambda = 0.176$, $F (36, 124) = 4.764$, $p < 0.001$, partial eta squared (η^2) =0.580, Power to detect the effect was 1.000. Since $p<0.05$ and F is significant, Wilks' λ indicates that $(1 - 0.176) * 100 = 82.4\%$ of the variance of the dependent variables is accounted for by the differences between maintenance approaches. Furthermore, using the guidelines proposed by Cohen (1988), the value of partial eta squared obtained suggests a very strong correlation between maintenance approach and manufacturing performance ($\eta^2 > 0.14$). These results indicate that maintenance approach did have a significant effect on manufacturing performance. Therefore, the null hypothesis H0: No significant difference between the means was rejected and the alternative hypothesis accepted.

To confirm the direction of the relationship between maintenance management approach and manufacturing performance, the foregoing statistical tests were re-examined. Hypothesis test H1 confirmed that maintenance approach had a significant effect on manufacturing plant effectiveness and hypothesis H2 indicated a positive relationship between manufacturing plant effectiveness and manufacturing performance. Consequently, it can be deduced that maintenance management approach adopted do have a positive influence on manufacturing performance and it acts via plant effectiveness.

4.4 Discussion

From the analysis above, maintenance management approaches adopted by manufacturing industries in Kenya fall into three categories namely approaches B, C and E. In the order of popularity, approach B came first followed by approaches C and E respectively. This is corroborated by the study findings which indicated that 75%, 17% and 8% of the manufacturing firms implement approaches B, C and E respectively. These findings are consistent with those of Cooke (2003).

Maintenance approach E registered the highest cumulative means of 4.40 and 4.59 for manufacturing plant effectiveness and manufacturing performance respectively. Correspondingly, maintenance approach C registered the lowest cumulative means of 1.72 and 1.73. This implies that by involving operators in maintenance activities, the ability to pre-empt equipment failure is enhanced. Further, the approach encourages operators to own their equipment hence using them carefully. These findings are consistent with those of Nakajima (1988). Reactive maintenance as supported by scores registered by maintenance approach C, significantly lowers manufacturing plant effectiveness which ultimately reduces manufacturing performance.

Statistical tests performed revealed strong correlations between variables of the study. Maintenance management approach accounted for 65.2% and 82.4% of the variance in manufacturing plant effectiveness and manufacturing performance respectively. There existed a positive association between manufacturing plant effectiveness and manufacturing performance with an adjusted R^2 of 94.1% and standardized B coefficient of 0.973. Maintenance management approach adopted positively influence manufacturing performance via plant effectiveness and these findings are consistent with those of Ollila and Malmipuro (1999).

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The purpose of this study was to establish the association between maintenance approaches adopted and manufacturing performance. The study had four objectives to achieve: To determine the maintenance approaches adopted by manufacturing industries in Kenya; determine operations performance of manufacturing industries in Kenya; determine plant effectiveness of manufacturing industries in Kenya and to determine the relationship between maintenance approach adopted and manufacturing performance.

As regards maintenance approaches adopted, manufacturing firms implement diverse approaches which can be categorized into 3 namely; High PM, fast RM by dedicated resources (approach B), Low PM, fast RM by dedicated resources (approach C) and High PM, fast RM by operators (approach E). In terms of popularity, approach B came first followed by approaches C and E respectively. Firms which emphasized preventive maintenance registered high means for both manufacturing plant effectiveness and manufacturing performance. Approach E registered the highest cumulative scores for both plant effectiveness and manufacturing performance followed by approaches B and C respectively.

On the relationship between variables, maintenance management approach had a significant effect on manufacturing plant effectiveness which positively influenced manufacturing performance.

By and large, the objectives of the study were achieved through collection and analysis of data and carrying out statistical tests.

5.2 Conclusion

The study concludes that, preventive maintenance is the predominant maintenance approach adopted by manufacturing firms in Kenya. Most of the firms hardly involve operators in maintenance activities instead they prefer to use dedicated resources. Compared to reactive maintenance, the former approach enhances manufacturing plant effectiveness and manufacturing performance. The decision to involve operators in preventive maintenance ensures better results for the same.

On the relationship between maintenance management approach adopted and manufacturing performance in the manufacturing sector in Kenya, it was established that there exists a positive correlation between maintenance approaches applied by firms and their level of manufacturing performance.

5.3 Recommendations

The study revealed that maintenance management approaches have varying levels of effectiveness. It is therefore the responsibility of the decision maker to select and implement the most effective approach so as to remain competitive. The study identified autonomous maintenance (approach E) as the most appropriate for manufacturing firms.

5.4 Suggestions for further studies

Owing to the limited time and resources, this study did not sample all firms across diverse manufacturing sectors in Kenya. Therefore, there is need to expand the study to include the unrepresented segments as this will provide a broader picture about all manufacturing firms that are currently operating in Kenya.

A similar study targeting service organizations in Kenya can be done to compare maintenance approaches adopted and their impacts with those in manufacturing organizations. Finally, factors influencing choice of maintenance approaches and those promoting their effective implementation ought to be studied. This will provide crucial information to firms upon which they can improve their maintenance programs.

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Ref. No...................

APPENDIX 1: QUESTIONNAIRE

Dear Sir/Madam,

My name is Martin Mono. I am an MBA student at the University of Nairobi and I am undertaking a study focusing on an important management topic. You do have knowledge and vast experience worth sharing thus you will contribute immensely to understanding of decisions in manufacturing. Any information you provide will remain confidential. Data will be analyzed and results reported in summary form only. You are not required to give your name or any form of personal identification.

Demographic Factors (Please tick ✓ the appropriate box)

Staff Category:

☐ Managerial ☐ Supervisory ☐ Non-Supervisory

Which of the following statements are true on how you plan and perform your maintenance activities? (Please tick ✓ the appropriate box)

☐ We service equipment periodically	☐ We only attend to equipment when they break down
☐ We only attend to equipment when they break down	☐ We service equipment periodically
☐ We have a maintenance team which only maintains equipment	☐ Production staff partly carry out maintenance work
☐ Production staff partly carry out maintenance work	☐ We have a maintenance team which only maintains equipment
☐ We do failure analysis to improve our production processes and equipment	☐ We only restore equipment to a functional state
☐ We only restore equipment to a functional state	☐ We do failure analysis to improve our production processes and equipment

How do you perceive the speed with which broken equipment are restored to functional state? (Please tick ✓ the appropriate slash on the line)

Fast 2 1 0 1 2 Slow

How often are your equipment serviced? (Please tick ✓the appropriate slash on the line)

Frequently 2 1 0 1 2 Infrequently

Please indicate your perception of your Manufacturing Plant Effectiveness relative to other organizations in the same industry in the following dimensions:

(Tick ✓ the appropriate answer)

	Much higher	**Somewhat higher**	**Same as other**	**Somewhat lower**	**Much lower**
Time lost due to equipment failure/breakdown					
Time lost in setting up and adjusting equipment					
Time lost due to minor stoppages and reduced equipment speed					
The level of scrap/defect rate and rework					
Time lost whilst starting up equipment to get to steady state operating conditions after planned or unplanned shutdown					

Please indicate your perception of your Manufacturing Performance relative to other organizations in the same industry in the following dimensions:

(Tick ✓ the appropriate answer)

	Much worse	**Somewhat worse**	**Same as other**	**Somewhat better**	**Much better**
Due date adherence for orders					

Adaptability to volume changes in product demand					
Equipment availability					
	Much higher	**Somewhat higher**	**Same as other**	**Somewhat lower**	**Much lower**
Customer complaints					
Scrap level					
Defects per unit					
Unit cost					
Percentage of orders with incorrect amounts					
	Much lower	**Somewhat lower**	**Same as other**	**Somewhat higher**	**Much higher**
Product pass rate					
Capital productivity					
Labour productivity					
Total factor productivity					
Rate of on-time delivery for orders					
	Much longer	**Somewhat longer**	**Same as other**	**Somewhat shorter**	**Much shorter**
Production cycle time (Time taken to convert raw material into a finished product)					
Machine changeover time					
Order lead time					
Material throughput time (Time taken to convert raw material into a component or sub-assembly)					

End.

Thank you for your time. Your contribution will definitely expand the knowledge base in maintenance management.