STATUS OF PRODUCTION EQUIPMENT MAINTENANCE ENGINEERING IN THE GHANAIAN MANUFACTURING INDUSTRY

By

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DECLARATION

I hereby declare that this submission is my work towards the MSc and that to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been in the text

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DEDICATION

I dedicate this thesis to my wife, Priscilla and my parents, Mr. and Mrs. Francisco Ribeiro.

ABSTRACT

Ghana's manufacturing industry consists of four main sectors, namely woodworking, food processing, metal working and textiles and garments. Earlier research works report a large stock of manufacturing equipment used in the industry but indicate low maintenance culture among firms. This calls for an investigation to help gain insight into the status of maintenance engineering as well as maintenance-related challenges facing manufacturing companies in Ghana.

This work explores the status of production equipment maintenance in selected companies from Kumasi, Accra and Tema registered with the Association of Ghana Industries. A questionnaire was designed and administered in a survey that involved visits to these companies. Data collected was analysed using the MS Excel and Stata 10 software packages.

The findings reveal that most of the respondent firms are private consisting mainly of large and medium scale firms with the greater majority being large. In addition, majority of firms in Ghana are semi-automated. Contrary to the perception of low maintenance culture, companies undertake regular maintenance.The most preferred maintenance strategy is preventive shut down maintenance. Further, it also emerges that training for maintenance staff is poorly organized and this sometimes necessitates the need for contract maintenance. In addition, during maintenance operations manufacturers employ little or no high end technological techniques and tools. Again, despite the existence of internal safety policies there are no stringent measures to ensure compliance. The general challenges facing firms in the implementation of their maintenance strategies include cost of shut down, cost of spare parts, legal issues with contractors, among others. On the whole, larger enterprises take maintenance activities more seriously than smaller scale ones.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

There are four major sectors in the manufacturing industry in Ghana, namely woodworking, metal-working, food processing, and textiles and garments and together they comprise 70 percent of manufacturing employment in Ghana (Frazer, 2004). Most of these industries are import substitution industries because they produce for local market domestic goods which are usually imported. Currently, there is a large stock of manufacturing equipment found within the various companies across the country. They range from those manually operated to those fully automated. Research conducted within the Kumasi Metropolis on some recognized manufacturing firms, some of which manufacture for export, showed that majority (70%) use manual equipment for production, 20% semi-automated, and 10% fully automated equipment (Adejuyigbe, 2006).

Today's market conditions place great emphasis on variety, performance and quality of products. In order to meet these requirements manufacturers have been compelled to utilize complex and sophisticated machines. Over time, the driving need to meet and improve on the requirements has shifted the trend of manufacturing to high levels of automation (Raouf and Ben-Daya, 1995). The objective behind automation is to achieve higher productivity and profit in order to effectively stay competitive in business. High levels of automation require that the machines employed operate without trouble and this requirement has changed the technology and operating philosophy of manufacturing

industry around the world (Mishra and Pathak, 2004). Despite the successes chalked in this arena, one important factor that necessarily has to be always considered is cost of maintenance. The high and rising capital costs of modern production machines as well as high maintenance costs, which have an estimated range of 15% - 40% of production cost, are developments which have forced companies to pay attention to maintenance (Löfsten, 1999; Coetzee, 1999).

Further, technology is becoming increasingly complex, with electronics, robotics and computer control now influencing every aspect of manufacturing and maintenance. This has led to many changes in maintenance activities. Special and continuous training programmes are required to provide relevant knowledge, understanding and skills to service the increasingly specialized equipment and keep up with development in industry (Mishra and Pathak, 2004).

British Standard 3811:1974 states that maintenance is a combination of any actions carried out to retain an item in, or to restore it to, an acceptable condition. Manufacturing industry today has employed many maintenance strategies and philosophies in order to reduce cost, improve the availability of machines and equipment and increase profitability. In addition, various computerized maintenance management systems, which employ customized software, are available to manufacturing companies to facilitate efficient maintenance management of the increasing number of complex devices equipment and systems utilized on a daily basis (DiPaolo, 2010). Bamber et al., (1999) reports that an effective maintenance activity can make a significant contribution to company profitability through increased production efficiency, plant, availability and reliability.

1.2 STATEMENT OF THE PROBLEM

Some research has been conducted on the manufacturing sector in Ghana. There exists general information which is easily accessible about the location, products and activities of manufacturing companies. However there is still an information gap on maintenance activities being undertaken within the industry. Amoako-Gyampah et al., (2001) and Adejuyigbe, (2006) report that there is some level of maintenance activities taking place within the industry but offer no specific details; for example the type of maintenance strategy adopted, equipment and technology employed, the role of the maintenance manager, training and documentation among others.

There is a general perception that Ghanaians lack a culture of maintenance (Afranie, 2004) and as a result do not employ any maintenance policies or strategies in their manufacturing firms. It is believed that this attitude has led to the plethora of renovations and replacements of structures and equipment which has cost the nation dearly in monetary terms and has stunted national growth (Obeng-Odoom and Amedzro, 2011). There is some research to support the notion that in developing countries manufacturing companies find it easier to replace than to maintain because of lack of skill (Söderbom, 2000).

This research seeks to provide insight into maintenance engineering in manufacturing firms in Ghana. It is the researcher's belief that this work would help bring to the fore the challenges and prospects of maintenance engineering in the country.

1.3 JUSTIFICATION

Completion of this research work would yield the following benefits:

1. Contribution to knowledge in academia

The research would give information about the status of production equipment maintenance engineering in Ghanaian manufacturing industry. It would yield information on issues ranging from the type of maintenance policies in place to strategies and philosophies behind the activities of maintenance adopted, cost and savings made, human resource involved, among others, thereby bridging the information gap. This knowledge contributed to academia can easily be accessed for further research.

2. Information for the manufacturing industry in Ghana

In capital intensive industries today, maintenance costs can represent as much as of 30% -50% of total operating costs (Al-Najjar, 1996). The importance, scope and cost of the maintenance function to nations have grown in all proportions to the advances in engineering technology. For example the cost of maintenance and operational safety was about $23billion in 1991 in Sweden while in the United Kingdom it was estimated at $1.95 billion (Al-Najjar, 1996). The research hopes to reveal the cost of maintenance in each of the selected manufacturing companies and the nation as a whole. This, coupled with information from literature, could shed light on how maintenance costs can be effectively managed.

The results of the research would also serve as a source of information to stakeholders in manufacturing industry in Ghana about the status of production equipment maintenance engineering, the challenges faced and its prospects. Further it would provide information on current trends in maintenance engineering and management for manufacturing companies in Ghana.

3. Entrepreneurial and employment prospects

One of the growing areas in maintenance engineering is outsourcing. Contract maintenance is making deep inroads into maintenance management (Gopalakrishnan et al., 2004). The results of this research could serve as stimulus for people to start providing contract maintenance services as well as equipment. Other services that can be rendered include maintenance training for staff and information technology thereby creating employment.

4. Management of challenges

The outcome of the research can be accessed and utilized by manufacturers in Ghana to improve their maintenance activities.

1.4 OBJECTIVE

The overall objective of this research is to determine:

i. the status of production equipment maintenance engineering in Ghanaian manufacturing industry

ii. the prospects and challenges in the practice.

1.5 METHODOLOGY

To achieve the set objective, literature was gathered and reviewed to enable the researcher identify the necessary data to collect and analyze.

A questionnaire was designed and administered in a survey involving visits to manufacturing industries in Kumasi, Accra and Tema. Interviews were also done, where necessary, to clarify relevant pieces of information provided by the respondents. Data collected was analyzed using MS Excel and Stata10 to facilitate drawing of appropriate conclusions. The results from the analysis were used to draw appropriate conclusions and give recommendations.

1.6 SCOPE OF THE WORK AND THESIS ORGANIZATION

This research work explores the status of production equipment maintenance engineering in selected companies registered with the Association of Ghana Industries drawn from Kumasi, Accra and Tema. These cities were chosen because they have the highest concentration of manufacturing companies in Ghana.

The details of the various chapters are explained below. Chapter 2 reviews the literature on maintenance, the types available, common and modern practices. Chapter 3 examines the questionnaire design adopted in undertaking the research work while chapter 4 reports on the analysis of the results. Chapter 5 discusses the results obtained. The work presents its recommendations and final conclusions in chapter 6.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Good maintenance engineering is essential to the success of any manufacturing or processing operation. One of the major components to a company's success is to possess a quality maintenance department that can be depended upon to discover systematic flaws and recommend solid, practical solutions (Damewood, 2010).

There are many definitions of maintenance but a more comprehensive one given by Telang and Telang (2010) defined it as "the combination of all technical and related administrative actions including supervision, with an aim to retain an item in, or restore it to a state in which it can perform a required function". This definition clearly identifies two distinct activities in maintenance; the technical and the administrative. The technical activities are grouped under maintenance engineering and deal with the actual tasks carried out on equipment while the administrative activities are grouped under maintenance management and basically deal with the management aspects of maintenance. It is worth noting that an optimum and efficient interaction between the two fields is necessary to achieve best results. Maintenance management has become more predominant and has become a major factor in achieving overall productivity in industrial organizations (Telang and Telang, 2010).

Maintenance has evolved from non-recognized function which comprised of simple tasks such as cleaning, lubrication and simple repairs to being an important element in industrial

management and productivity. The need for maintenance engineering and management is increasingly becoming important to manufacturing industries due to rising prices of equipment, systems, machinery and infrastructure (Telang and Telang, 2010). Again, this need is also growing because of intricate computerized manufacturing and production systems with their requisite modern equipment which is becoming complex and requiring a host of personnel, skill and related systems to manage them (Damewood, 2010). To put the situation in perspective, before 2006, the United States of America spent approximately US$300 billion annually on plant maintenance and operations alone (Dhilion, 2006). Further, many other factors including ruthless competitive market forces, strict supply schedules and quality controls, legislationbacked safety and environmental regulations have added to the already grave situation (Telang and Telang, 2010).

Manufacturing companies, the global economy and the world as a whole, have undergone significant changes and there is competition everywhere. The world has turned global and competition is everywhere. These new challenges have led to deep transformations in companies thereby affecting maintenance as well. As a result of this transformation, maintenance has come to a position of enhanced and well-deserved importance, due to its incidence on overall company competitiveness (Santiago, 2010).

When maintenance in an organization is neglected it leads to ever frequent breakdowns which result in costly repairs and faster deterioration of valuable and usually expensive equipment and inevitably has far reaching detrimental consequences on production as a whole. This makes a high state of maintenance efficiency not only desirable but also very obligatory for industrial well-being at all levels and even at the national level (Gopalakrishnan and Banerji, 2004).

2.2 OBJECTIVES OF MAINTENANCE

The objectives of maintenance are to:

i. ensure maximum availability of plant, equipment and machinery for productive utilization through planned maintenance;

ii. maintain plant equipment, and facilities at an economic level of repairs at all times, to conserve these and increase their lifespan;

iii. provide the desired services to operating departments at optimum levels, through improved maintenance efficiency;

iv. provide management with information on the cost and effectiveness of maintenance; and

v. achieve all the above-mentioned objectives as economically as possible

The objectives of maintenance can therefore be summarized as the systematic and scientific upkeep of equipment for prolonging its life, assuring instant operational readiness and optimal availability for production at all times whilst making sure that the safety of man and machine is never jeopardized at reasonable cost (Gopalakrishnan and Banerji, 2004; Santiago, 2010, Telang and Telang, 2010).

2.3 IMPORTANCE OF MAINTENANCE

Benefits that can be derived from a well-organized maintenance system include minimization of downtime, improvement in total availability of the system and extended useful life of the equipment, safety of personnel and reduction in costs.

- Minimization of downtime

A properly organized maintenance schedule helps to prevent failures and hence minimizes downtime (Mishra and Pathak, 2006).

- Improvement in total availability of the system

Increased availability usually leads to an increase in output and also improvement in the quality of products. Increased availability and high reliability of well-maintained machines also improves the morale of workforce in the long run (Cooke, 2003; Mishra and Pathak, 2006).

- Extended useful life of the equipment

The useful life of equipment is also dependent on nature of maintenance applied. Cost effective and optimum maintenance prolongs life of equipment (Mishra and Pathak, 2006; Franklin, 2008).

- Safety of the personnel

Random failure of machinery can cause unnecessary injury to personnel. Proper maintenance of equipment can and will prevent injuries. This saves the company in terms of financial resources such as hospital bills and compensations among others (Franklin, 2008).

- Reduction in costs

Good maintenance practices result in improved reliability of machines within the plant. Improvement in reliability also leads to reduction in maintenance costs. As breakdowns become fewer, maintenance spending in the area of materials, labour, contractors and

spare parts among others also decrease leading to overall reduced cost of maintenance (Franklin, 2008).

2.4 THE MAINTENANCE DEPARTMENT

The maintenance department was one of the lowly regarded departments in most organizations. In recent years however, there has been a gradual attitudinal change towards the way corporate managers view the maintenance function. One of the most important reasons for the change is that maintenance departments have become major cost centers whose activities can no longer be ignored (Hiatt, 2009). The maintenance department has also evolved to have extended roles and this makes it imperative to involve it as an equal partner in the entire decision making process of the organization (Gopalakrishnan and Banerji, 2004). Even though the management of many manufacturing organizations recognize the need for a maintenance department, the rightful place which it has to occupy within the organizational structure is yet to be recognized (Gopalakrishnan and Banerji, 2004).

2.5 MAINTENANCE ORGANIZATION

2.5.1 Types of Maintenance Organization

There are three types of maintenance organizations; centralized, decentralized and partially decentralized (Gopalakrishnan and Banerji, 2004; Santiago, 2010).

- **Centralized**

The centralized maintenance organization is usually found in small and compact factories where inter-unit and inter-departmental communication is fast. This type of organization is placed under the chief maintenance manager who is of the same rank as the production manager, both of whom report to the general manager (Gopalakrishnan and Banerji, 2004).

- **Decentralized**

The decentralized maintenance organization is recommended for companies which are large and whose units are located in far areas making inter-unit communication difficult. In this type of organization, there is a separate maintenance set up for each unit and functions. The head of the unit is the production chief who can be selected either from the production or the maintenance streams depending on the seniority and sustainability among the available personnel in either streams of specialization (Gopalakrishnan and Banerji, 2004).

- **Partially Decentralized**

The partially decentralized organization is a modified form of the decentralized organization and also suitable for large plants with far flung units. With this type of organization, the day-to-day maintenance of equipment is carried out by a group of maintenance workers who are attached to, and are responsible to, the production manager of that unit. However, important maintenance functions like planning and scheduling of maintenance work, drawing up of schedules, master-process sheets, work specification, documentation, maintenance costing, major overhauls, procurement of spare parts, are all

kept directly under the chief maintenance manager. Organizations like this serves the needs of the production manager (Gopalakrishnan and Banerji, 2004).

Today's trend is to have mixed organizations, with some sectors decentralized and partly centralized, acting in a supporting role to all the decentralized sectors, to better face changing realities (Santiago, 2010).

2.5.2 Effectiveness of Maintenance Organization

For a maintenance department to fulfill its role efficiently, it is important to have an organization which is balanced, rationalized and healthy to manage and control in plethora of activities (Gopalakrishnan and Banerji, 2004). In order to achieve this objective, certain factors would have to be given due consideration. Chief among the parameters include (Gopalakrishnan and Banerji, 2004):

a. Team spirit

   The organization consists of people and it is wise to bring them together to work as a team. This can be done with generation and sustenance of team spirit. Where team spirit exists work is done easily with little confusion.

b. The plant engineer

   It is good leadership that can bring people together and instill as well as sustain the necessary team spirit that will encourage the team to work. The onus of keeping the team spirit going rests on the shoulders of the plant / maintenance engineer. Basically, he or she should be technically competent, knowledgeable and cost

conscious to be an effective and efficient leader of the team; and should also be able to plug all loop-holes which lead to waste of time, talent and effort.

c. Philosophy

All maintenance departments must have a philosophy and policies to regulate its activities. These must be reflected honestly and sincerely by the deeds and actions of each person within the department.

d. Policy

Once a philosophy has been adopted for use, the policies of the organization should be documented for use. These policies should be clearly understood by its users as guidelines for user who falls within its framework. Policies may be formal or informal and have to be regularly assessed, reviewed and updated to reflect the changing activities of the department. Policies may cover issues such as maintenance of plant, machinery salary and hours of work among others.

e. Span of control

In order to avoid wasted employee effort and lack of effective monitoring there should be a reasonable numerical proportion between the supervisor and the supervised. This is because there is a limit to the number of people an individual can supervise effectively. Given the nature of work and levels of the people being supervised it is important that the ratio is correctly ascertained to optimize the supervision time, employee talent.

f. Development of subordinates

Man is the most important cog in the wheel of the machinery of production and has to be handled with utmost sensitivity and care. Staff must be trained and regularly updated on current maintenance practices to manage and maintain the complex machines employed in modern manufacturing (Gopalakrishnan and Banerji, 2004). Today, a good maintenance technician must now be trained in: automation, instrumentation, electronics, electricity, hydraulics, pneumatics, mechanics, industrial safety, quality, computer science, and language skills, besides the specific knowledge of the process, which is fundamental in order to understand the operation of whatever he must maintain (Santiago, 2010). Generally, the less educated and skilled the worker is the more supervision he would need. When more enlightened subordinates are left on their own they tend to improve in their growth and development (Gopalakrishnan and Banerji, 2004).

g. Clear enunciation of functions

One of the major hindrances to team work is distorted or loose definitions of functions, responsibilities and authority. To avoid confusion and duplication of effort and functions it is important that subordinates are made to know the scope and limit of their positions in very clear terms. This will promote better and healthier functioning of the organization (Gopalakrishnan and Banerji, 2004, Telang and Telang, 2010).

2.6 MAINTENANCE MANAGEMENT STRATEGIES

It is essential for any organization involved in the utilization of machinery, plant, equipment and facilities to possess and follow a clear cut maintenance policy to ensure its well-being. The choice or adoption of a maintenance policy must be such that it is suited to its needs and can effectively and efficiently be implemented (Gopalakrishnan and Banerji, 2004). Maintenance systems are directly linked with resources available to the industry in order to achieve stated maintenance objectives. Again, the choice of a maintenance system is influenced by company priorities and requirement, plant condition, age, internal resource levels, safety and other statutory regulations (Telang and Telang, 2010). Maintenance system can broadly be classified under the following categories; planned maintenance and unplanned (reactive) / run to failure maintenance system.

2.6.1 Unplanned Maintenance

Unplanned maintenance refers to the repair, replacement or restoration activities performed on a machine or facility after the occurrence of a failure in order to bring it to, at least, its minimum acceptable condition. The tasks which are undertaken under this system are mainly event driven (Mobley, 2004).

The major maintenance systems under unplanned maintenance tasks are emergency and breakdown (run-to-failure).

Emergency

This is maintenance carried out as fast as possible in order to bring a failed machine or facility to a safe and operationally efficient condition. Usually failures which have occurred and require attention are unexpected (Gopalakrishnan and Banerji, 2004).

Breakdown (run-to-failure)

Also referred to as repair maintenance (Gopalakrishnan and Banerji, 2004), this system of maintenance is only undertaken when the machinery or equipment has failed (Mobley, 2004). In this system of maintenance less concern is given to operating conditions of critical plant machinery; the major focus is how quickly the machine can be returned to service. This method, however, is both ineffective and the most expensive. The cost involved in utilizing this maintenance system is at least three times that of the planned maintenance systems (Mobley, 2008a).

Other maintenance types under the unplanned maintenance system are rebuilds, repairs and remedial (Mobley, 2008a).

2.6.2 Planned Maintenance

Also known as preventive maintenance, this system improves on the routine maintenance system and requires the maintenance work to be planned in advance. It is carried out with forethought, control and records to a predetermined plan. Emphasis is placed on the equipment's needs and the expected requirements from the machine. The system is centered on recommendations made by the equipment manufacturers.

Instructions for maintenance in this system are more detailed and thorough (Gopalakrishnan and Banerji, 2004). Generally all planned maintenance systems includes activities that plan, record and control all work done to keep a plant at acceptable maintenance levels. This includes long range planning and day-to-day maintenance work planning. Its use results in making effective time and cost estimates and brings about saving in time and cost by improving the control mechanism (Gopalakrishnan and Banerji, 2004).

Planned maintenance can be broken down into three major maintenance systems: predictive, improvement and corrective maintenance systems.

Corrective maintenance

Corrective maintenance can be defined as maintenance carried out to restore machinery which have ceased to meet acceptable condition (Gopalakrishnan and Banerji, 2004). Corrective maintenance, as a subset of comprehensive preventive maintenance focuses on regular planned tasks that will maintain all critical plant machinery and systems in optimum operating conditions. Unlike, breakdown maintenance, its effectiveness is based on the life-cycle costs of critical plant machinery, equipment and systems. The major concept of corrective maintenance is that proper and complete repairs of all developing problems are made on as-needed basis. Also the repairs are made by welltrained craftsmen and verified before the machine is returned to operation (Mobley, 2008c).

Predictive maintenance

Predictive maintenance is a maintenance technique that applies regular evaluation of actual operating conditions of equipment, production systems and plant management functions to optimize total plant operation (Mobley, 2008d). The objective of this system is to gain the ability to predict an impending failure well in time thus avoiding failures which could cause penalty costs and even create health and safety hazards (Gopalakrishnan and Banerji, 2004). To achieve this objective condition monitoring / condition-based monitoring or reliability centered maintenance is a prerequisite (Tse, 2002). This is because its implementation is based on the application of two methods of monitoring; statistical based monitoring and condition-based monitoring. Statisticalbased monitoring is a tool in reliability-centered maintenance which uses statistical approaches to determine the maintenance plan (Adjaye, 1994) while condition monitoring is a method of extracting information from equipment which enables the maintenance engineer to indicate its condition in quantitative terms. When it is effectively applied, this maintenance system can identify most of the factors that limit the effectiveness and efficiency of the whole plant. The output of a predictive maintenance programme is data which should be effectively acted on to derive its benefits (Zhou et *al*., 2006; Mobley, 2008d).

Improvement maintenance

This is a maintenance system which aims at reducing or eliminating entirely the need for maintenance. One important classification of this type of maintenance is design out. With this type of maintenance system, equipment are so designed as to need the least possible

maintenance because long term repair or replacement can be very expensive (Gopalakrishnan and Banerji, 2004; Mobley, 2008a).

Contract maintenance

Currently, there is a trend towards outsourcing for maintenance service. This is due to the need for greater specialization in technical aspects, or due to company strategy of focusing on key business areas (Santiago, 2010; Telang and Telang, 2010). Regarding this type of strategy, organizations take the following into consideration when contracts are being drafted to ensure that acceptable quality of services is rendered (Santiago, 2010):

- the specifications of the service
- the qualifications of the suppliers and their quality levels
- types of contracts and of course the criteria for supervision
- approval and acceptance of the service rendered

Some of situations that generate the need for contractors include the following:

- where it is not financially viable to establish a maintenance department with its attendant infrastructure and staff
- where special permits / licenses are needed before maintenance can be done. For example in cases of fire, use of explosives and high tension electric fittings
- where the company does not have access to spare parts, even on the open market

The benefits of outsourcing maintenance activities include better and faster work done, exposure to outside specialists and greater flexibility to adopt new technologies (Tsang, 2002). Other benefits include reduction in staff leading to reduction in labour costs,

employment of specialized and experienced expertise which results in effective maintenance done and savings in expenditure on related tools, facilities and staff are some of the benefits of implementing contracted out maintenance (Telang and Telang, 2010). There can also be some downsides to implementing this maintenance system. First, there can be cost escalation which would result in budgetary problems. Again, occasionally, the contractor can be discovered to be incompetent and even sluggish after the contract has been awarded. Further, quality of the maintenance activity can sometimes be ignored since the contractor has nothing to lose after having signed the contract. Finally, contract workers may steal company technology and indulge in pilferage.

2.6.3 Maintenance Philosophies

The maintenance systems described above are the common ones utilized in most manufacturing industries (Telang and Telang, 2010). Other common ones include routine maintenance, deferred maintenance, window and opportunity maintenance, etc. Coetzee (1999) iterates that despite the availability of planned maintenance practices described above there are other strategies which have been adopted by various manufacturing companies to enable them increase their maintenance efficiencies. These include Total Productive Maintenance (TPM), Reliability-Centered Maintenance (RCM) and Computerized Maintenance Management Systems (CMMS) among others. These strategies are not tasks in themselves but are principles or philosophies applied to already available maintenance strategy to derive maximum effectiveness (Coeztee, 1999; Bamber et al., 1999; Telang and Telang, 2010).

TOTAL PRODUCTIVE MAINTENANCE (TPM)

There are many definitions of total production maintenance but the common view held by many authors is that it is a company-wide approach to plant or equipment care that involves the active participation of more than just the maintenance department working on maintaining and improving overall equipment effectiveness (Bamber et *al*, 1999: Mobley, 2008j). The major objective for the implementation of total productive maintenance is to continuously improve the availability and prevent the degradation of equipment and hence achieve maximum effectiveness (Mobley, 2008j).It is a maintenance strategy that couples the principles of maintenance engineering and total quality management (TQM). The benefits gained by implementing this hybrid maintenance strategy have made it a prime strategy to be adopted for the enhancement of maintenance quality of products and processes (Pramod et *al*., 2006). It is considered by many authors as a strategy that is indispensable to manufacturing companies in their efforts at attaining a world-class manufacturing status; a status which will help them gain competitive advantage in the ever increasing global competitive environment (McKone et al., 2001; Ahuja and Khamber, 2007). Again, it facilitates cost reduction and improves quality and delivery of maintenance (McKone et al., 2001).

Computerized Maintenance Management Systems (CMMS)

CMMS is a computerized management software whose primary purpose is to capture the maintenance history of an organization. Basically, most CMMSs perform the basic

function of raising work order to cover repairs and maintenance of buildings, plants and equipment as well as provide a scheduling facility for planned preventive works for maintainable assets. They can also be customized to collect costing details for labour and materials related to the work performed. (Burton, 2001)

According to Nyman and Levitt (2009) it also supports and fosters the following:

- efficiency of maintenance resources (both hourly and salaried), thereby lowering unit cost
- improvement of responsiveness and service to internal customers
- improvement of asset reliability, capacity assurance, and equipment up time
- better delivery performance and product quality to external customers • lower unit costs and increased profitability

These systems are now a necessary part of managing and controlling assets, plant and equipment maintenance in modern manufacturing, facilities and service industries (Burton, 2001). CMMS has the advantage of being a system which can serve as a platform for the successful implementation of Total Productive Maintenance, Reliability-Centered Maintenance and the other major maintenance systems for effective maintenance and achievement of organizational goals (Olszewski, 2008; Crain, 2003).

Reliability-Centered Preventive Maintenance

This maintenance system is a process which is systematically used to identify all the functions and functional failures of assets. The process also identifies all likely causes for these failures and then proceeds identify the effects of these likely failure modes and to identify in what way those effects impact the plant. The data collected is then analyzed to determine the most appropriate maintenance task to apply (Wikoff, 2008; Mobley, 2008e).

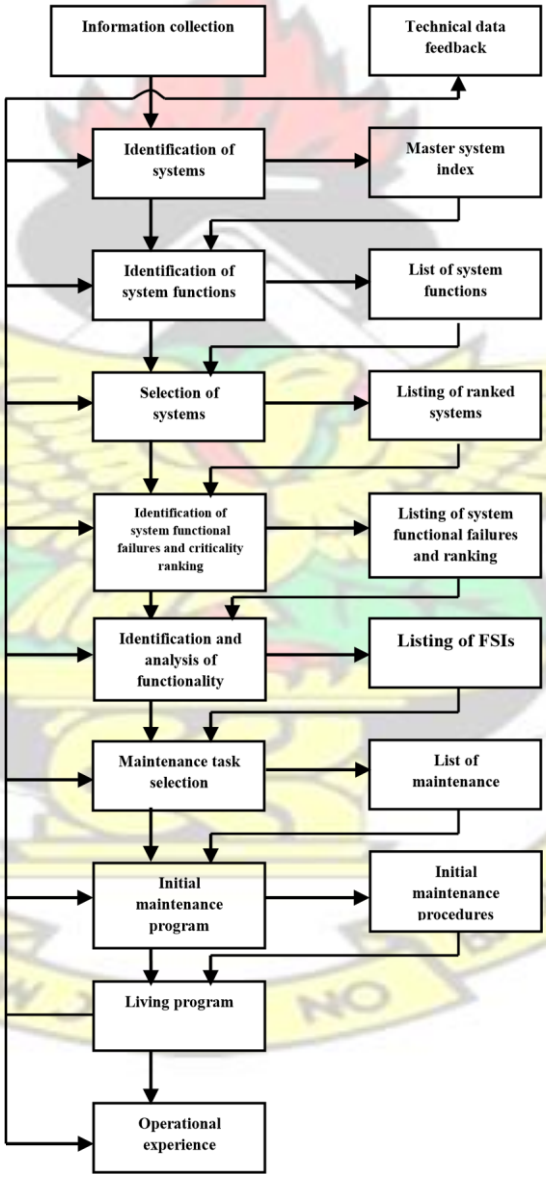

Figure 2.1 Developmentof Tasks of a Reliability-Based Maintenance Programme

2.6.4 Tools for Solving Maintenance Problems

Unlike other industrial activities, maintenance is a problem solving activity which includes resolving what has already occurred, predicting what can occur and taking appropriate steps to counter it as well as reduce its effects. Usually, faults leading to failure are statistical in nature and modern tools such as Fault Tree Analysis and Failure Modes and Effects Analysis are used to solve them. These tools analyze collected data and use the process information to solve or prevent the problem (Telang and Telang, 2010).

Fault Tree Analysis (FTA)

Fault Tree Analysis is a method that identifies all possible causes of a particular system failure mode. It considers the failure of system components acting alone or in combination and provides a basis to calculate the possibility of occurrence. This tool has the advantages of identify the most probable causes of failures or faults without applying trial and error, providing a means for qualitative and quantitative reliability analysis and facilitating the improvement of subsequent designs of equipments.

Failure Modes and Effects Analysis (FMEA)

This tool, like the Fault Tree Analysis studies and identifies the failure modes and proceeds to study and understand the effects the failure is like to bring. It facilitates the implementation of reliability-centered maintenance system very well.

While FTA is carried out over whole systems, FMEA is done in relatively greater detail on parts or subassemblies. Both tools are complementary to each other. Usually the combine analysis of FMEA first followed by FTA is most effective.

2.7 MAINTENANCE TESTING AND DIAGNOSTIC EQUIPMENT AND TECHNIQUES

In order to undertake effective and efficient maintenance non-destructive testing facilities have been designed for the accurate measurement of characteristics of components of equipment and equipment themselves. The tests do not affect the components or equipment functionally or physically. There is a plethora of testing devices and techniques which are developing at a very fast rate worldwide and are progressively being made available indigenously. Organizations are progressively embracing their use and applying them in predictive maintenance practices and systems. A brief description of some of the techniques is done below (Gopalakrishnan and Banerji, 2004).

2.7.1 Maintenance Techniques

Maintenance operations require the application of appropriate techniques to enhance its efficiency. Some of the techniques employed currently in industry include magnetic particle detection, eddy current testing and radiography among others. The following discussion briefly describes the application of a few of them.

Magnetic particle detection

This technique is used to locate sub-surface and surface discontinuities in ferromagnetic materials. To apply this technique, a test piece is magnetized and finely divided ferromagnetic particles are sprinkled over it. The particles facilitate the identification of surface cracks and porosity.

Eddy current testing

This method is employed to measure electrical conductivity, magnetic permeability, grain size, heat treatment condition and hardness. The eddy current detects seams laps, cracks, voids and sorts out dissimilar metal compositions.

Radiography

This technique utilizes the fact that when a body is exposed to radiation it shows variation in amounts of radiation absorbed and unabsorbed due to variation in its density and thickness. The unabsorbed radiation, which passes through the body, can then be recorded on film or photo sensitive paper and viewed through a radiographic viewer to locate defects.

Acoustic emission testing

This is defined as a high frequency stress wave generated by the rapid release of strain energy that occurs within a material during crack development or plastic deformation. This method is capable of detecting the minutest of increasing flaws. It is reported that no other method can match is capability (Gopalakrishnan and Banerji, 2004).

Spectrometric oil analysis procedure (SOAP)

This is a technique used to monitor the condition of machines by analyzing the concentration of metal elements present within the used oil samples taken and analyzed at regular intervals with the help of a spectrometer. With this method its analysts can detect wear and diagnose problems from any part of the machine from the usual concentration of metal in the oil sample taken without having to dismantle it. This method helps to

increase equipment availability by averting unnecessary maintenance work and also facilitates the reduction of oil costs.

Other techniques in use worth mentioning are in situ metallography; strain monitoring, vibration monitoring, holography, thermal and leak testing, hardness, creep and spark testing.

2.7.2 Maintenance Testing and Diagnostic Equipment

These techniques call for the use of specialized equipment to enable effective detection of defects and faults within the component or the equipment as a whole. There are a host of them but a brief description and particular functional details of a few are given below (Gopalakrishnan and Banerji, 2004; Mobley, 2008f,g,h,i).

Ultrasonic hardness tester

This instrument is used to read surface hardness in Rockwell C, of bearings and shafts among others. It is a light-weight probe which has to be held against a surface to take a reading. A reading can effectively be taken in 2 to 3 seconds.

Eddy current tester

This is an instrument with a pointed probe which spots tiny discontinuities on or below the metal surface without contact while the machine or component is being scanned.

Thermopile heat flow sensor

This is a gadget which can be connected to any vacuum-tube voltmeter and calibrated to read the extent of heat loss due to insulation or to check the efficiency of the different areas on a heat transfer surface.

Pocket-sized thermistor thermometer

This gadget is shaped like a pocket watch with battery and probes and gives a temperature reading within a few minutes.

2.9 MAINTENANCE STAFF

In addition to maintenance equipment, personnel still remain an important resource for maintenance activities and management as maintenance, despite evolution in technology, still remains a very personnel intensive business function. (Pintelon and Van Puyvelde, 2006)

The maintenance staff usually consists of the operators, maintenance specialists or technicians, supervisors, foremen, a maintenance controller, and a records clerk. All these staff report to the maintenance manager, who maybe a recognized member of management or where that position is not recognized, report to management.

Maintenance workers are usually specialized in one of the following technical disciplines: mechanics, electronics, instrumentation or automation (Pintelon and Van Puyvelde, 2006). Due to the rapid evolution of equipment employed for production, it is essential that whenever new equipment is purchased the maintenance and operating personnel be trained to fully equip them with the appropriate maintenance skill.

2.8.1 The Maintenance Manager

In the maintenance function, the central figure is usually the maintenance manager. The maintenance manager is known by many titles even though the function is the same. Some of the titles include engineering manager, maintenance manager, chief engineer, plant manager, maintenance superintendent, works engineer, plant engineer, and others. Maintenance activities and management have evolved and so has the job of the maintenance managers. Maintenance managers now have more business and accounting responsibilities than they have ever had. They are also responsible for the operational, tactical and strategic aspects of the company's maintenance management. Further, they are also consulted on strategic decisions which include purchases of new installations, design policies, etc (Pintelon and Van Puyvelde, 2006).

2.8.2 Operators

Operators have moved on from roles which require them to just man the equipment. Today, they are made fully responsible for the equipment they handle and assist in the development of maintenance tasks such as cleansing, inspection and lubrication among others. They also participate in the definition of the modification and redesign of machinery. In addition they facilitate the formulation of maintenance plans. (Santiago, 2010)

2.8.3 Technicians

They are accountable for the following maintenance tasks: maintenance of equipment and installations in their sector, attend to emergencies that may occur and diagnose problems as well as providing support to operators. They are technically poly-functional and have a sense of belonging to the operations team; they have closer access to the feeling of the process (Santiago, 2010).

2.9 WORKSHOPS

It is essential that every organization that carries out maintenance sets aside an area, commonly known as a workshop. This may be an area where machines and equipment are repaired or tested. The workshop's principal customers include the maintenance manager, the chief engineer, who is concerned with the manufacture for capital and project work and finally customers from outside the company. Internal requests for the use of the workshop are usually channeled through the maintenance manager or the chief engineer, depending on who is in charge. A workshop is important to the maintenance department for the following reasons (Corder, 1976, Mishra and Pathak, 2006):

1. It is a place where machining and fabrication of parts for emergency maintenance repairs can take place where the parts required are not available from the store stocks. This facilitates the reduction of down time during emergency repairs.
2. It is also the place for the machining and fabrication of parts for planned maintenance where equipment have to stripped down for identification, correction , modification and possible replacement of faulty components.

3. It is also the place where, for some large companies, capital construction works which include the manufacture of specialist production machines are designed by the company. This construction has to be done in-house in order to effectively observe industrial secrecy.
4. Where there is less work to be done, it can accept outside work to generate some income.

2.11 MAINTENANCE COSTS

After the machines are procured and installed, the activity, which ensures best utilization of machines, is maintenance. It is difficult for production managers to appreciate the role(s) maintenance plays during production. Three reasons can be attributed to this (Mishra and Pathak, 2006; Kister, 2008):

1. The machine or equipment not serving when being maintained

   Production loss is probably the biggest loss to an industry as the entire business depends on the output. Hence production managers find it difficult to release the machine for maintenance unless break down is encountered. Even when break down is encountered pressure is mounted in maintenance staff to hurriedly repair and get the machine back onto the production line.

2. Maintenance cost is "sunk" cost

   Cost of maintenance is usually high in terms of costly spares, skilled manpower and many other related expenditure heads. Unfortunately, however, the benefits of maintenance are always indirect and not immediately felt. Production managers therefore tend to feel that no additional value has been added to the product by

maintenance expenditure(s) or expenditures incurred during maintenance go to waste.

3. Maintainability of the machine is doubtful

   It has often been a common observation that just after overhauling the machine shows occurrences of faults and breakdowns. This phenomenon is known as maintenance induced problem. Though statistically such situations are less in number, few of such occasions are enough to put the maintainability of the machine as well as competence of the maintenance staff in doubt.

Maintenance cost and its elements

Maintenance costs can be put into two categories; direct and indirect costs.

2.10.1 Direct Costs

Direct costs include all expenditures directly incurred for maintenance and which are visible. Elements which make up direct costs include:

a. Material cost

This captures the cost of spares and consumables used for maintenance. Spares are the wearable components of equipment that have to be replaced to bring back the equipment to new condition after its failure. Consumables are not components of the equipment but essential materials such as lubricants, hydraulic fluids for maintenance. Others include oil seal felts, bolts and nuts, and bearings.

b. Labour cost

This includes the salaries and wages of the workmen, supervisors and managers.

c. Direct expenses

This includes various heads depending on the type of industries and machinery. Examples of such expenses are cost of utilities (steam, electricity, compressed air, water etc), payment of outsourced maintenance activities, and direct overheads (centralized services and inventory holding costs)

2.10.2 Indirect Costs

These are costs that can be attributable to maintenance. They may not have been incurred by maintenance staff but the general rule is that if the direct or indirect responsibility can be attributed to maintenance staff then it is an indirect maintenance cost. Some of these cost incurrence situations are as discussed below:

i. Cost of down time

Down time causes huge volume loss which is directly the loss of contribution, for example steam required to be continuously supplied. Again, deferment of production due to down time also causes delayed delivery (hence delayed income), loss of market share, and loss of good will. These costs can be attributed to maintenance.

ii. Cost of bad workmanship

Lack of quality in maintenance is directly reflected in product quality, cost and safety. For example incorrect adjustments, wrong calibrations and alignments may cause degradation

in product quality. These may further lead to a fall in the production rate and a rise in consumption of energy or some consumables hence increases in cost of maintenance.

iii. Cost of over maintenance

"Over maintenance" occurs when more maintenance actions are undertaken than it is required. These actions bring down the equipment availability due to higher shut down durations and higher direct costs. Secondly, it may increase the risk of maintenance induced failure and hence further increase the cost.

iv. Spares stock out cost

Cost of holding inventory is visible hence it is treated as a direct cost. However, if adequate and correct spares are not available at the right time the equipment may remain down for a longer period adding to the cost of down time. This makes the cost of holding no spares at all greater than that of inventory holding cost. Thus, costs due to opportunity losses caused by maintenance or a maintenance action causing more future cost incurrence are indirect costs in maintenance.

Other costs to the employer include equipment down time, repair and or replacement costs, sometimes, recruitment and training costs and worker de-motivation leading to loss of production (Gopalakrishnan and Banerji, 2004).

2.11 Health and Safety Management

Safety management is the identification and implementation of actions intended to control the threats of harm. Safety management promotes two major concepts; the safe place and safe person concepts. The safe place concept seeks to enjoin the manager to ensure that

the material elements of work (equipment, machinery, working environment, etc) are safe and without risk of injury having regard to acceptable safety standards. The safe person concept encourages the implementor to adopt strategies to protect persons from excessive exposure to risks by providing personal protective equipment (Melomey and Tetteh, 2011).

Accidents can occur everywhere and a non-existent or even inferior system of ensuring safety leads to unavoidable, undesirable and unwarranted accidents. There is a perception that high levels of automation has led to a corresponding increase in accidents. Those who hold the perception explain that automation has increased the reliability of machines which has led to some amount of operator and maintenance staff carelessness. This in turn has generated complacency which resulting in accidents. Before an accident takes place some forewarnings are available. These forewarnings, when heeded and taken care of, can help to prevent avoidable accidents. Failure to report incidents for thorough investigation to prevent these accidents can be extremely expensive (Gopalakrishnan and Banerji, 2004).

Accidents involve people or the machines and often result in injury, loss and or damage. In the case of persons involved, apart from the loss, disability or pain, the psychological suffering he or she feels cannot be quantified in monetary terms. For the employer, the damage, medical, legal and compensation cost can be huge. Other costs the employer can incur include repair and or replacement costs and sometimes recruitment and training costs especially in cases where the injured worker has to be replaced (Gopalakrishnan and Banerji, 2004).

Several studies show that there is a close correlation between asset reliability and safety of workers in a company. Safety management therefore has become one of the important

factors in industrial management today. Though current paradigm makes safety a shared responsibility of all employees the maintenance department has a direct responsibility for the implementation of the programme (Dabbs, 2008).

Breakdown of equipment place employees in awkward positions and especially when the maintenance strategy adopted by the company is reactive in nature, maintenance personnel often like to take short cuts in an effort to get the equipment running. This action exposes them to and increases the likelihood of injury (Franklin, 2008). While undertaking maintenance workers are also exposed to wide variety of hazards which can be physical, biological and even psychosocial. They may be at the risk of:

- Developing musculoskeletal disorders through working in awkward postures and sometimes in unfavourable conditions such as extreme heat or cold
- Exposure to asbestos while maintaining old buildings or industrial installations ▪ Asphyxiation in confined spaces
- Exposure to the detrimental effects of chemical agents such as greases, solvents and acids
- Accidents such as falling or being hit by machinery or the machinery being switched on accidentally (osha.europa.eu)

Safety management is therefore an important factor in industrial management to both the employer and employees. It is the responsibility of management to ensure that a safety policy exists and is adhered to. To ensure that the company benefits fully from safety activities, it is august for the top management to initiate a safety culture and also set up an internal safety department to sustain the activities of the culture. It is reported that the

culture of safety is most effective when it emanates from the top hierarchy and percolates down to one and all within the organization (Gopalakrishnan and Banerji, 2004).

It has become imperative for industries to develop safety management systems and train safety professionals to prevent and control accidents, injuries, illnesses and other similarly caused harmful events in industries (Melomey and Tetteh, 2011). Currently, some of the tools used to develop safety management systems in industries include the six sigma, ILO: 2000, ISO9000:2000, ISO 14001:2004, the most current being BS OHSAS 18001:2007 (Williamsen, 2008; Aniagyei, 2011). Another way of ensuring safety is in regular training of employees in safety practices. To facilitate training some institutions utilize simulators. This equipment is increasingly being used for basic training and retraining. Simulators possess the advantage of being able to simulate different types of crises a worker may face while handling a familiar or complex piece of machinery, takes away the edge of complacency, and sharpens the senses of the worker, making him aware of the dangers he would face in the field (Gopalakrishnan and Banerji, 2004).

Ensuring good safety management practices have benefits to both the employer and the employee. Some of the benefits the employer receives include reduction in insurance costs and compensation liabilities, prevention of replacement of expensive machines and or components of the machine and improvement in the working climate within the firm among others. On the other hand, adherence to good safety practices boosts employee confidence and allows him to enjoy his work and also protects him from injury which could destroy his earning power and further protects him from losing his earning capacity for the future (Gopalakrishnan and Banerji, 2004).

2.11.1 Safety Related Laws

International safety related laws

Due to the importance of safety there are international laws instituted by international bodies to govern, regulate and periodically review and upgrade health and safety laws across the globe. The International Labour Organization, ILO is one the international bodies which promote the implementation of health and safety at workplaces. ILO convention 155, part ii, article 4 states that "each member shall, in the light of national conditions and practice and in consultation with the most representative organizations of employers and workers formulate, implement and periodically review a coherent national policy on occupational safety, occupational health and the working environment" (Adonteng, 2011).

Industrial Health and Safety in Ghana

There are at least nine governmental agencies backed by various acts, established and mandated within the country to ensure that workplaces are safe. Notable among them for purposes of this discussion are the following (Annan, 2011):

- **Inspectorate Division of Minerals Commission**

Backed by the Mining Regulations LI 665, this organization is tasked to monitor and control organizational health and safety activities in the mining industry.

- **Environmental Protection Agency (EPA)**

This agency is empowered by the EPA Act 1994, Act 490 to monitor the implementation of the Environmental Management System.

- **Ghana Labour Commission**

This body derives its powers from the Labour Act 2003, Act 651 to regulate industrial relations and employee well-being at workplaces.

- **Department of Factory Inspectorate**

This is a governmental agency empowered by Act 328, 1970 and charged with ensuring that shops, offices and factories in Ghana conform to health and safety standards in Ghana.

- **Ghana Standards Board**

Empowered by the standards Decree, 1973, the Ghana Standards Board is charged to set standard and inspect goods for conformance to the set standards in the country. ▪ **Ghana National Fire Service**

Powered by the Ghana National Fire Service Act of 1997, Act 537, this agency is charged with the prevention and management of undesired fires.

Safety management practice has not fully developed in Ghana and has been limited to processing and payment of compensation to workers who are injured through accidents (Melomey and Tetteh, 2011). Annan (2011) reports that though Ghana is a member of the

183 member countries of the ILO it has not been able to ratify the ILO convention 155, 1981 and so the nation has no established authority dedicated to occupational health and safety at national level as indicated in the R164 Occupational Health and Safety Recommendation, 1981. More importantly, despite increasing industrialization, it does not have a comprehensive national health and safety policy. Again, it has not got any regulatory body tasked to develop, monitor and regulate health and safety standards and guidelines across industries. Rather, the occupational health and safety legal requirements are fragmented under different jurisdictions.

Another challenge he reports is lack of knowledge of these regulatory agencies and the associated legal framework by employees. Hence, their inability to request for suitable working conditions at their various workplaces or seek legal action if the requests are denied. These challenges, coupled with lack of funding for monitoring activities, qualified employees, appropriate equipment and standard modes of reporting accidents have weakened the ability of the nation and its instituted agencies, as a whole, to effectively and efficiently standardize, monitor and regulate health and safety activities in industries as well as to conform to international safety standards (Melomey and Tetteh, 2011).

2.12 MAINTENANCE PERFORMANCE MEASUREMENT

The success of an organization depends on the effective utilization of its manpower and resources. One of the major objectives of an organization is to be able to use the potential of each employee for the benefit of an individual as well as that of the organization. The most essential consideration in this regard is to identify the parameters that would measure

maintenance performance. These parameters are used in generating a maintenance evaluation index (MEI). Information gained from the interpretation of the index is valuable and helps to develop a relationship between maintenance performance and production cost. This information is important for management decision making (Mishra and Pathak, 2006).

The main benefits of the evaluation are improved maintenance performance and decrease in labour costs. In addition, proper evaluation of maintenance activities facilitates the identification of causes of unnecessary delays in performance which are duly reduced.

CHAPTER THREE

3.0 METHODOLOGY

3.1 SAMPLE SELECTION

Information about prospective respondents was gathered from the Association of Ghana Industries (AGI). Using the AGI compilation of registered members for 2011, 60 manufacturing companies were randomly selected and given questionnaires. Of these thirty responded positively. These firms which are located mainly in Kumasi, Accra and Tema, can be deemed representative of the manufacturing sector of Ghana.

3.2 QUESTIONNAIRE DEVELOPMENT AND ADMINISTRATION

A questionnaire was developed and used to gather information from the selected manufacturing companies. Both closed and open-ended questions were used in the

questionnaire. The open-ended questions were mainly to enable the researcher identify major challenges experienced by the respondents whilst implementing some aspects of maintenance. They were free to use their own words to express their opinion and further elaborate on the subject matter. The closed-ended questions provided possible answers from which they were asked to choose. The questionnaire consisted of ten (10) sections. These are as shown in Table 3.1.

Table 3.1 Major Sections of the Questionnaire

Section	**Subject Matter**
A	Company information
B	Effectiveness of maintenance organization
C	Planned maintenance procedure and documentation
D	Maintenance cost
E	Maintenance incentives
F	Maintenance systems and strategy
G	Staff training
H	Infrastructure and spare parts
I	Safety management
J	Maintenance performance management

3.3 PILOT SURVEY

To test the effectiveness of the survey instrument a pilot survey was conducted on 3 manufacturing companies in the Ashanti region. The questionnaire was administered personally. This survey enabled the researcher to identify any lapses in the questionnaire to be corrected.

3.4 FIELD WORK AND MODE OF ANALYSES OF DATA

The field work took approximately three months to complete. Questionnaires used for data gathering work were distributed to selected manufacturing companies in Kumasi, Accra and Tema. Due to the nature of operating procedures in all the selected companies the questionnaire was structured in such a way that the respondents could complete it without help. Where the respondents needed clarification of an issue the researcher aided them in person or by telephone. At the time of the questionnaire collection the researcher used the opportunity to interact with the firm's contact person. This enabled him to gain greater insight into the issues being researched. The questionnaire used for the survey is shown in the appendix.

Data collected from the field was analyzed using Stata 10 analysis software and MS Excel to generate results and the necessary graphs.

CHAPTER FOUR

4.0 RESULTS

4.1 CHARACTERISTICS AND PROFILE OF THE RESPONDENT MANUFACTURING COMPANIES

4.1.1 Geographical Location of Respondents

Out of the 30 respondents 23.3 % were located in the Ashanti Region and 76.7% were located in the Greater Accra region. By city, 23.3% were located in Kumasi, 26.7% in Accra and 50% in Tema.

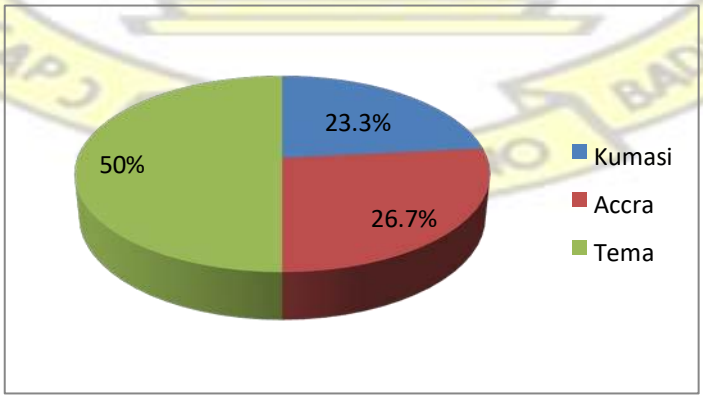

Figure 4.1 Location of Respondents by City

Further, based on the National Board for Small Scale Industries (NBSSI) categorization, as shown in Figure 4.2 it was observed that 53.4% of respondents are large scale enterprises, 33.3% are medium scale enterprises and 13.3% gave no indication of their size. The results (Figure 4.3) also show that within Kumasi 57.1% of the respondents are large scale enterprises while 28.6% are medium scale enterprises. In Accra, 25% of the respondents are medium scale enterprises while 62.5% are large scale enterprises. In Tema, 46.7% are large scale enterprises while 40% are medium scale enterprises.

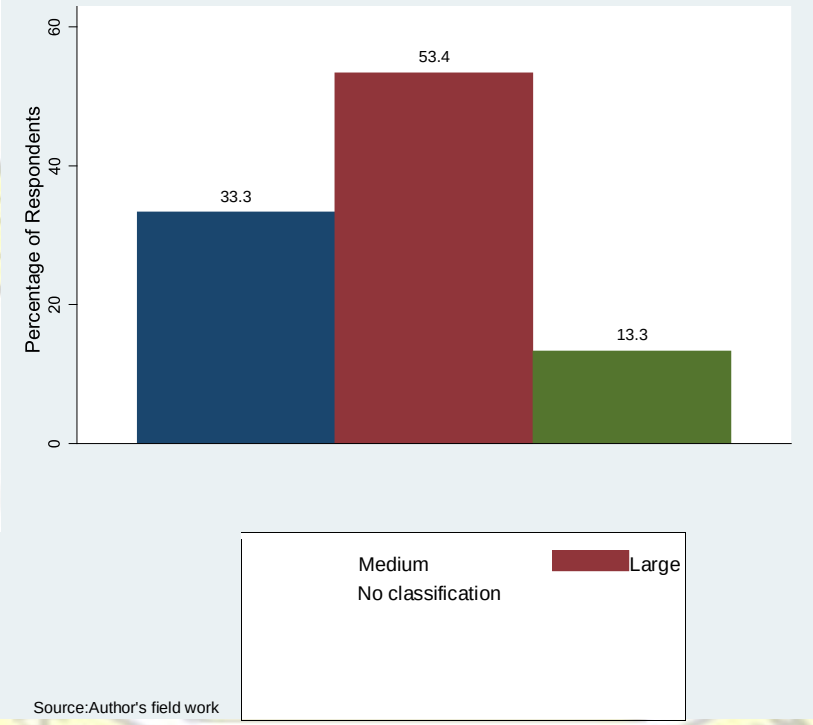

Figure 4.2 Distribution of Respondents According to NBSSI Categorization for Companies in Ghana

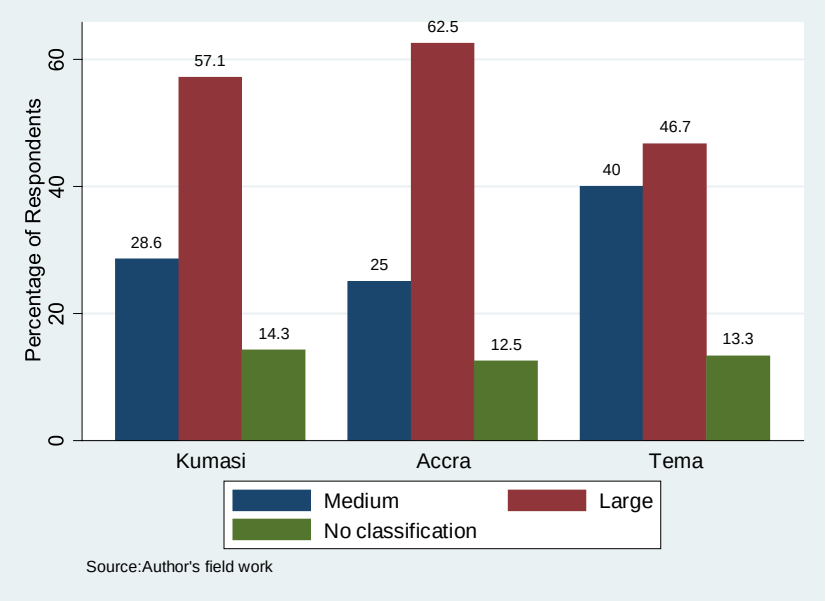

Figure 4.3 Distribution of Respondents According to NBSSI Categorization for Companies in Ghana by City

4.1.2 Industrial Sector of Respondents

The major sub-divisions of manufacturing captured in the survey include metal working, food processing, and production of consumer, pharmaceutical and chemical goods. Others are plastic packaging, oil and gas products, aluminium products, wood processing and cement. These results are displayed in table 4.1. Within the various sectors majority of the companies, with the exception of metal working, are large scale enterprises as shown in Figure 4.4.

Table 4.1 Industrial Sector of Respondents

Industrial sector	**Percentage of respondents**
Metal working	16.7
Food processing	23.3
Consumer goods	10

Pharmaceutical goods	20
Food and Chemical	3.3
Others	26.7

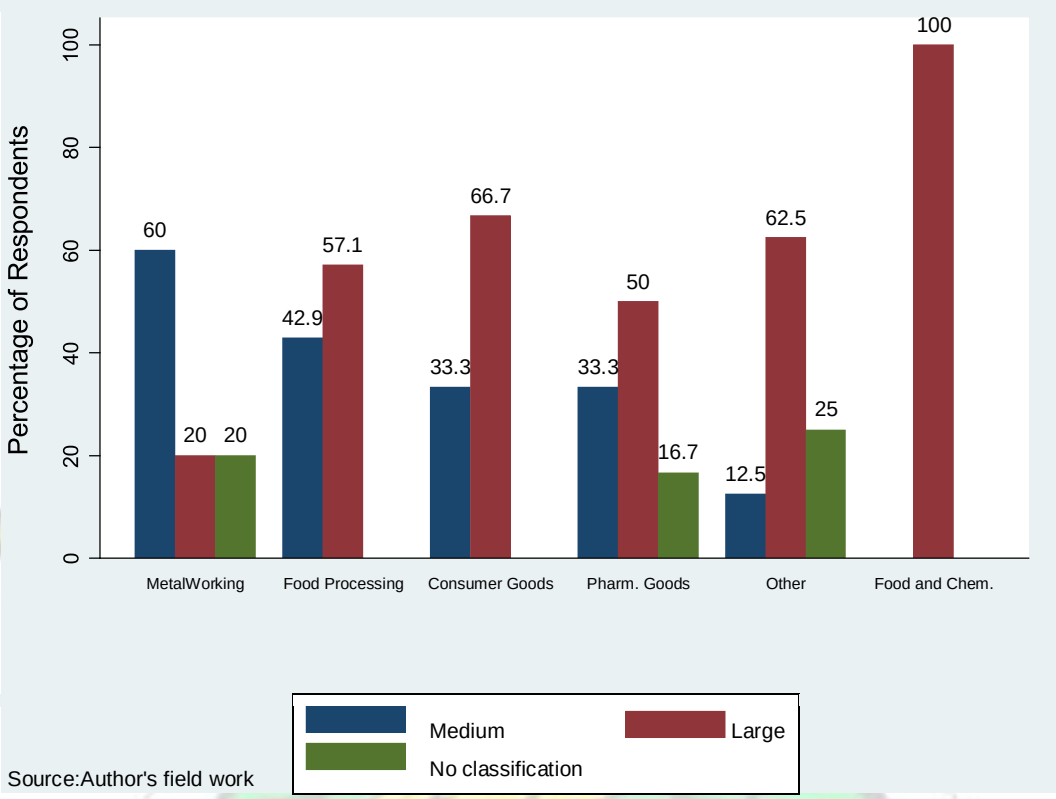

Figure 4.4 Industrial Sectors of Respondents Based on the NBSSI Classification of Companies in Ghana

4.1.3 Form of Ownership of Respondents

Ofthe companies which responded3.3% are state-owned, 60% are of private-ownership, 10% are Ghanaian – foreign joint ventures, 3.3% are Ghanaian joint ventures, and 16.7% are public limited liability companies. Six point seven percent were found to be a private limited liability companies (Figure 4.5).

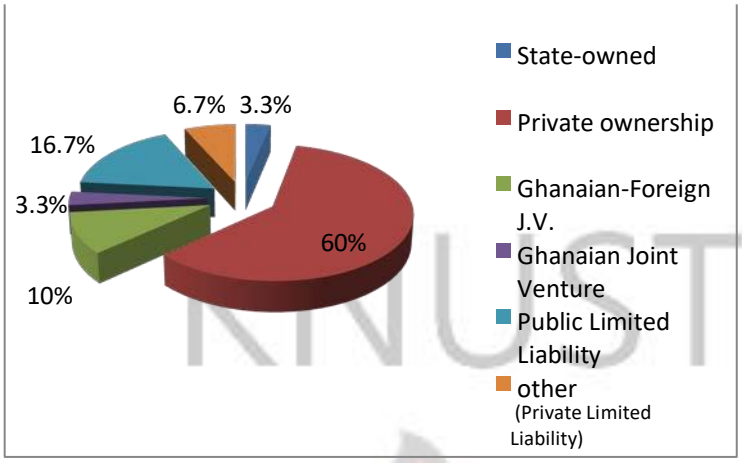

Figure 4.5 Ownership Patterns of Respondents

Company categorization based on the NBSSI scheme (Figure 4.6) shows that the stateowned enterprises, Ghanaian joint ventures (J-V (Gh)) and the public liability companies fall in the large-scale category. With private ownership, however, majority of the enterprises are medium while for Ghanaian-foreign joint ventures (J-V(Gh-Foreign)) there are equal percentages of medium and small scale enterprises. The "other" represents those who have private limited liability.

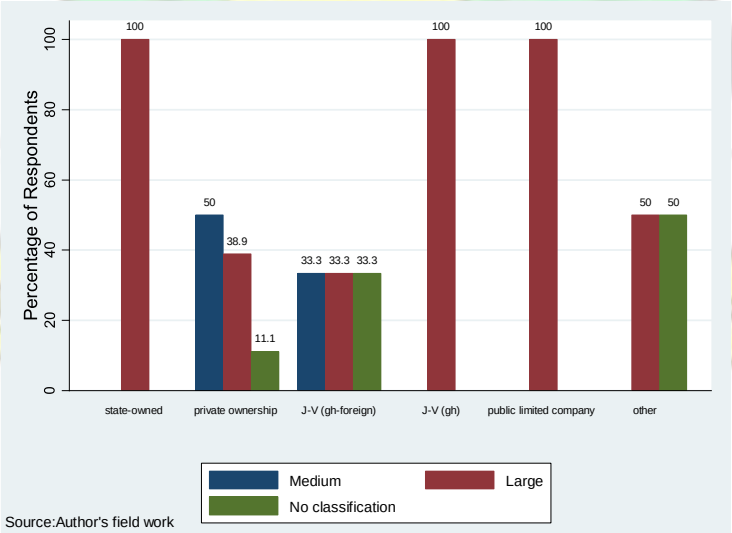

Figure 4.6 Distribution of Respondents According to Form of Ownership

4.2 EFFECTIVENESS OF MAINTENANCE ORGANIZATION

4.2.1 Maintenance Department

The results show that 83.3% of respondents retain maintenance departments. It was also observed (Figure 4.7) that 52% of those who answered "yes" to the question "do you have a maintenance department" are large scale enterprises while 32% are medium scale. Sixteen percent of respondents who retain maintenance departments gave no indication about their status.

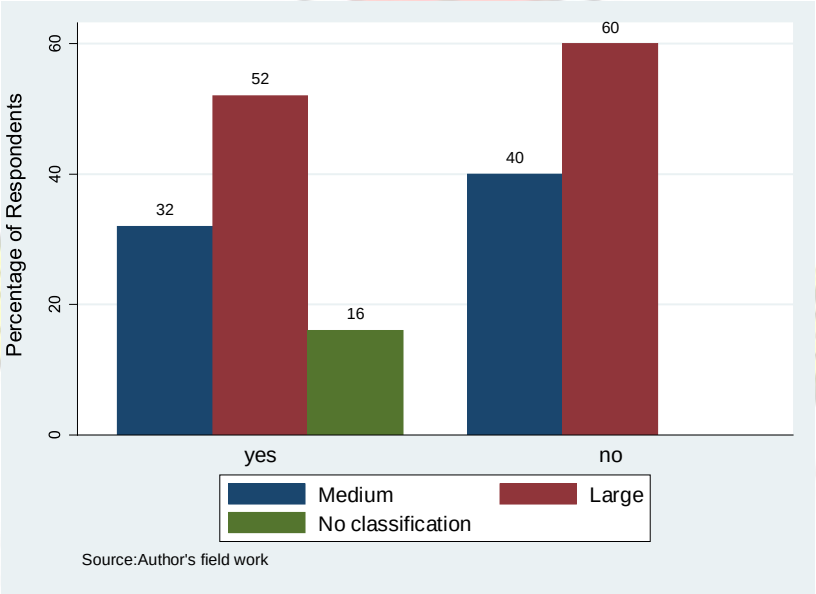

Figure 4.7 Firms that Retain Maintenance Departments Based on Firm Size

4.2.2 Type of Maintenance Organization

It is observed that 66.7% of the respondents use a centralized maintenance organization, 3.3% use a decentralized and 20% utilize a partially decentralized maintenance organization. Ten percent were observed to apply neither. None of the respondents use a

combination of two or three maintenance organizations respectively.Further analyses as displayed in Figure 4.9 shows that the respondents who use the centralized maintenance organization consist of 55% large scale enterprises, 25% medium scale enterprises.Twenty percent gave no response about their status. The respondents who use decentralized maintenance system are large scale enterprises. Of those who employ the partially decentralized maintenance organization 50% are large scale while 50% are medium scale enterprises.

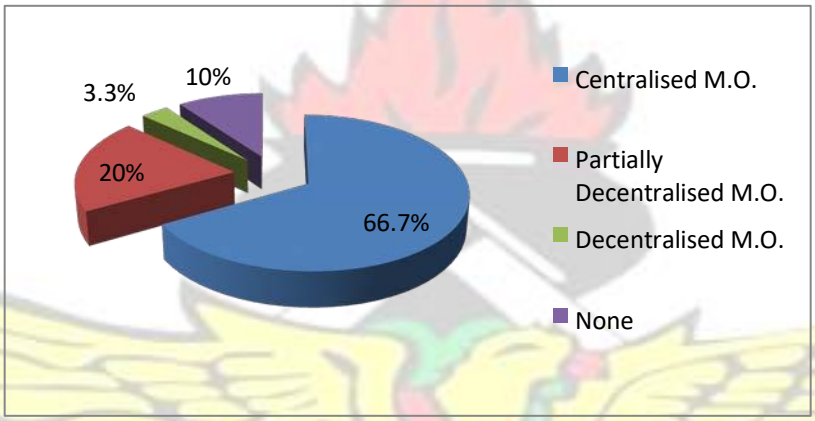

Figure 4.8 Type of Maintenance Organizations (M.O) Employed by Respondents

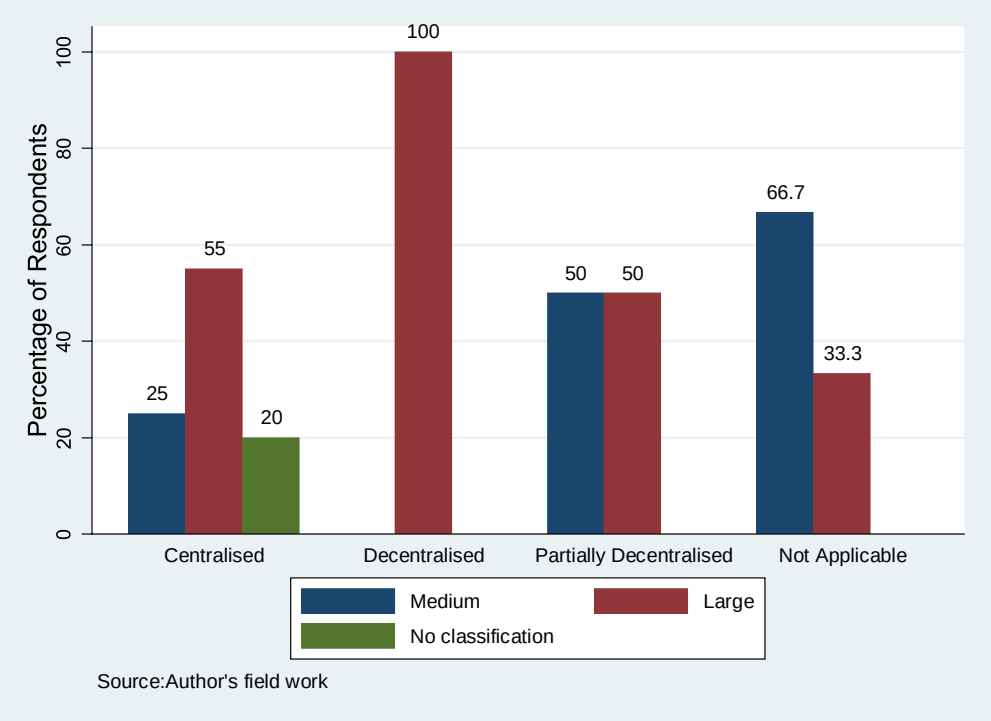

Figure 4.9 Maintenance Organizations Utilized by Respondents by Firm Size

4.2.3 Participation in Choice and Purchase of Equipment

From the analysis 90% responded yes whilst 10% responded no to whether the maintenance department is consulted in the selection of new or replacement equipment. A breakdown of the results (Figure 4.10) showed that 55.6% are large scale enterprises, 29.6% are medium scale enterprises and 14.8% did not specify their status.

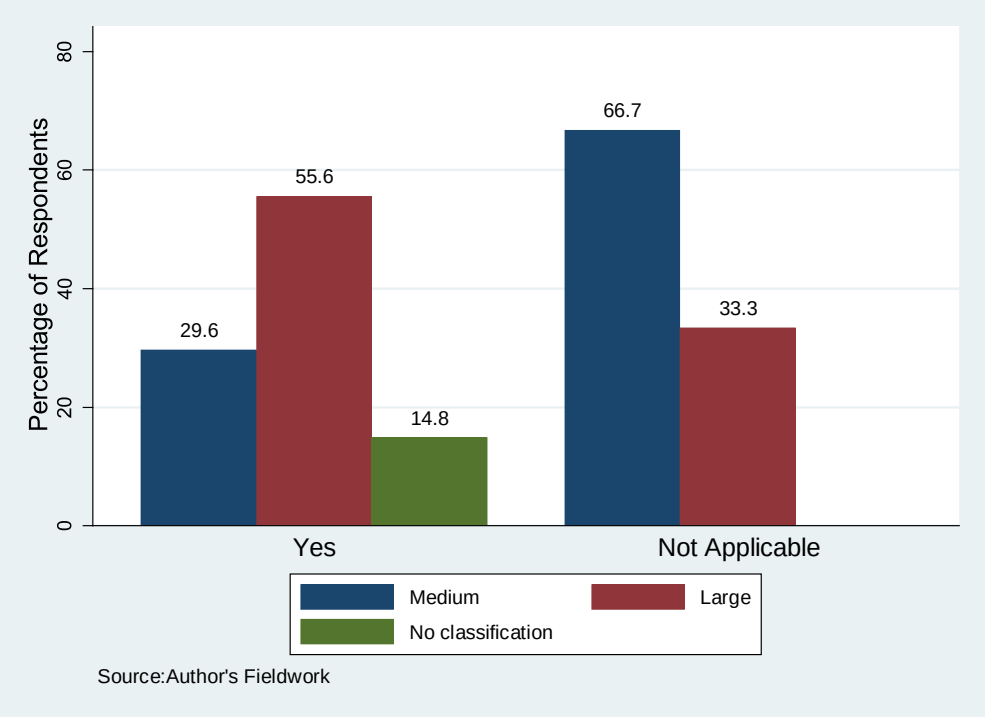

Figure 4.10 Involvement of Maintenance Department in Equipment Purchase Decisions

4.3 MAINTENANCE PROCEDURES AND DOCUMENTATION

4.3.1 Work Order System in Use

The major types of work order in manufacturing are standing order and work order. Of the total number of respondents 26.7% use work order whilst 50% apply standing order. Sixteen point seven percent apply no work order system and 6.6% utilize both (Figure 4.11). Analyses based on NBSSI categorization show that for the total number of respondents who employ standing order for maintenance activities 62.5% are large scale enterprises while 12.5% are medium scale enterprises. Of the respondents who use direct work 66.66% are large scale enterprises while 26.7% are medium scale enterprises. A summary of the results is shown in Figure 4.12.

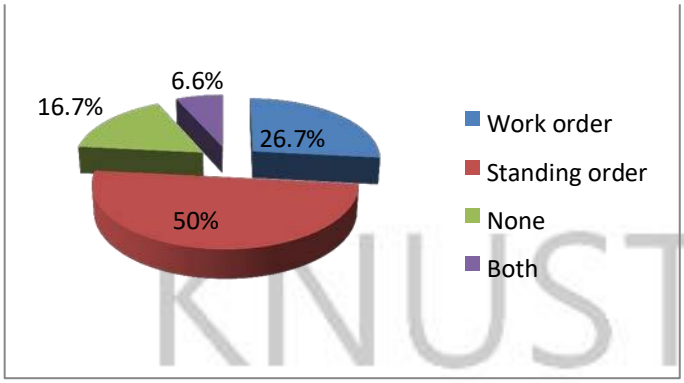

Figure 4.11 Work Order Systems Implemented by Respondents Organized by Type

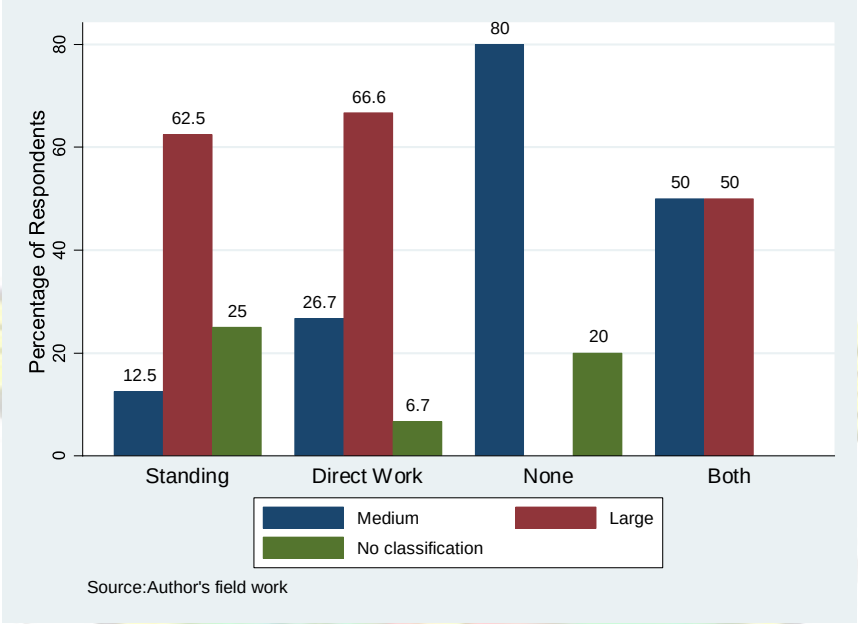

Figure 4.12 Work Order System Used by Respondents Organized by Firm Size

4.3.2 Integration of CMMS into Maintenance Management System

Only 26.7% of respondents have integrated CMMS into their maintenance management systems while 73.3% have not. Of the number of respondents who use CMMS 50% are large scale enterprises, while 37.5% are medium scale enterprises.

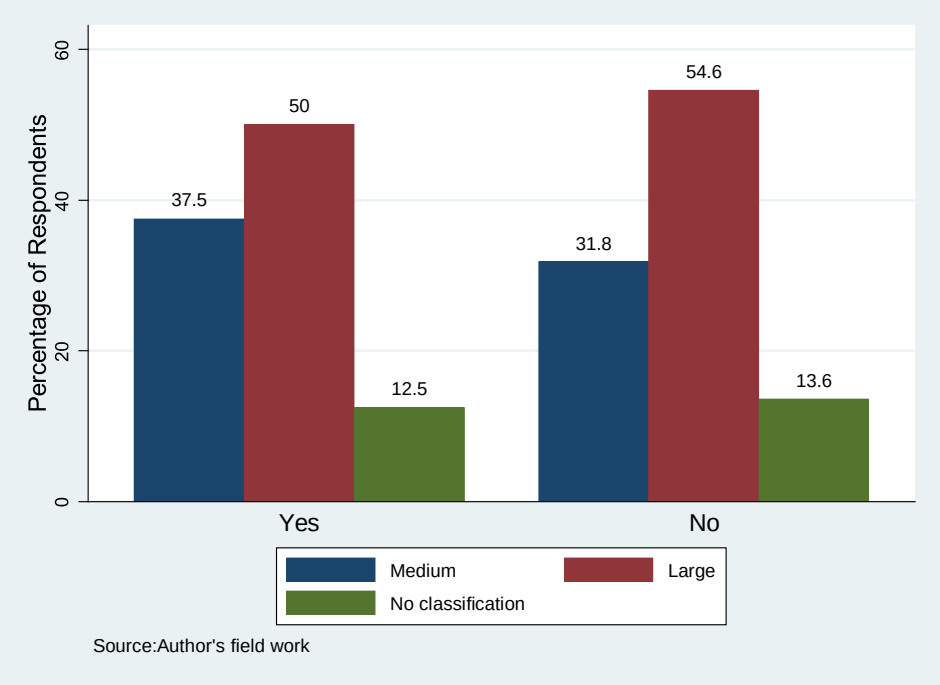

Figure 4.13 Distribution of Respondents Who Have Integrated CMMS into their Maintenance Management System by Firm Size

4.3.3 Impact of CMMS on Documentation and Maintenance Procedure

All of the respondents (26.7%) who use CMMS claim that CMMS has improved their documentation and procedure for maintenance activities.

4.4 MAINTENANCE COST

Due to the heavy protocol associated with delivery of information, most companies declined to offer information on their annual turnover and the amount spent on maintenance. However, they offered information on the proportions of some important elements which made up their maintenance cost. Analyses of the data show that 83% of respondents spend up to 45% of maintenance expenditure on labour, 72.2% of respondents

spend up to 45% of maintenance expenditure on outsourcing maintenance and repair work, 61.1% of respondents spend up to 45% of maintenance expenditure on electricity, spares and other things which include water.

4.5 INCENTIVE SCHEMES FORMAINTENANCE STAFF

From the analyses of the data 40% of respondents operate an incentive policy for staff. Of these 33.4% offer financial incentives, 3.3% offer non-financial and 3.3% offer both with 60% offering none at all. Those who offer incentives to maintenance staff reported improved maintenance output. Further analyses (Figures 4.14 and 4.15) show that of the respondents who have an incentive policy 41.7% are large scale enterprises while 33.3% are medium scale ones.

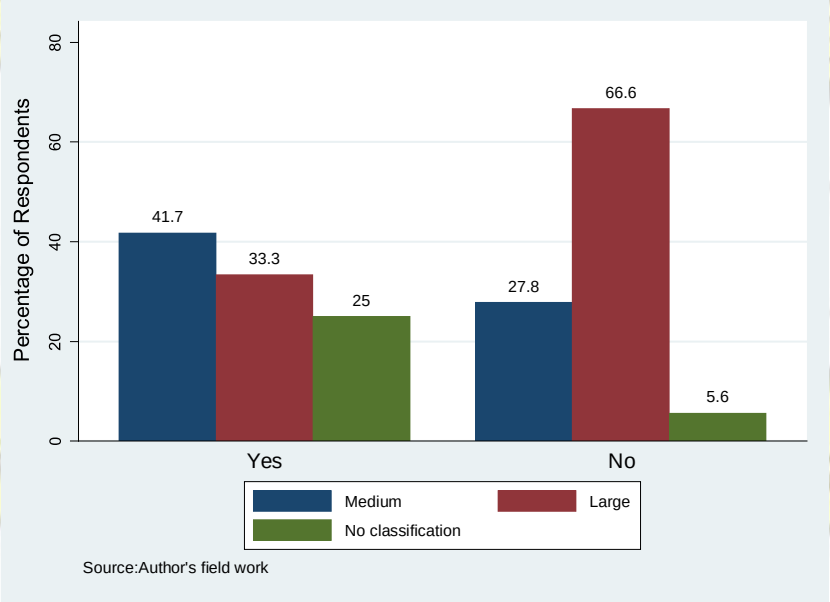

Figure 4.14 Distribution of Respondents Who Offer Incentives to Maintenance Staff

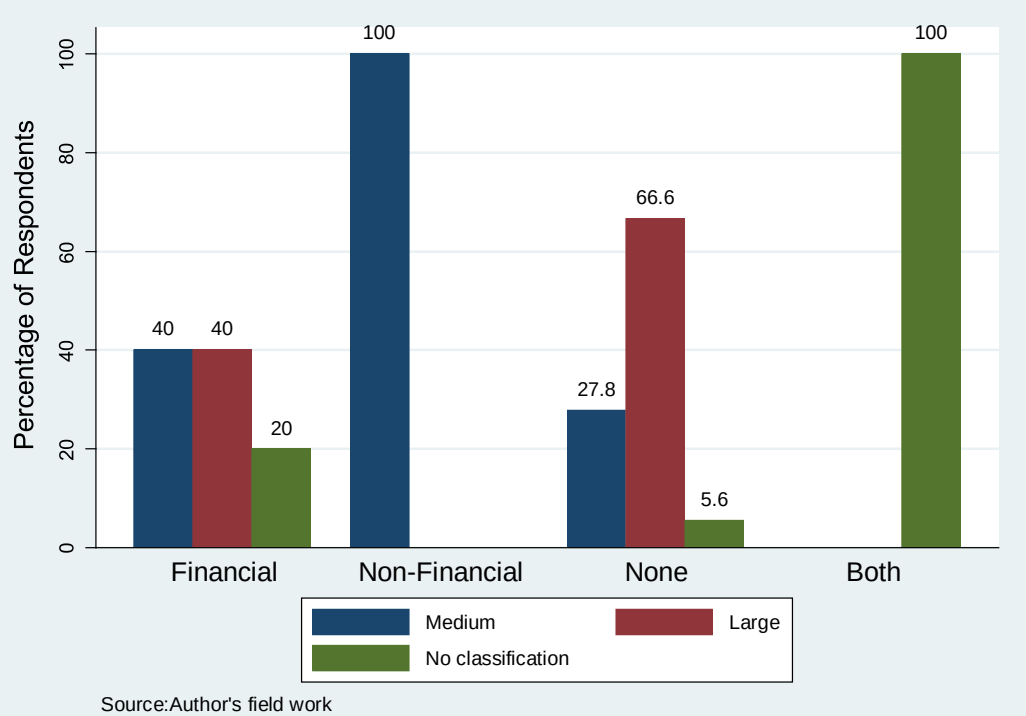

Figure 4.15 Distribution of Respondents According to Types of Maintenance Incentives

4.6 MAINTENANCE SYSTEMS AND STRATEGY

4.6.1 Organization of Maintenance and Repair in-House

Companies were also asked to indicate the percentage of maintenance and repair work done in-house. A summary of the distribution is shown in Figure 4.16. It is found that respondents who conduct 50% of maintenance activities in-house are all medium scale enterprises. Seventy percent of respondentsconduct maintenance activities in-house. Of this percentage 50% are large scale enterprises while 33.3% are medium scale enterprises. Those respondents who undertake all maintenance and repair work in-house are all large enterprises.

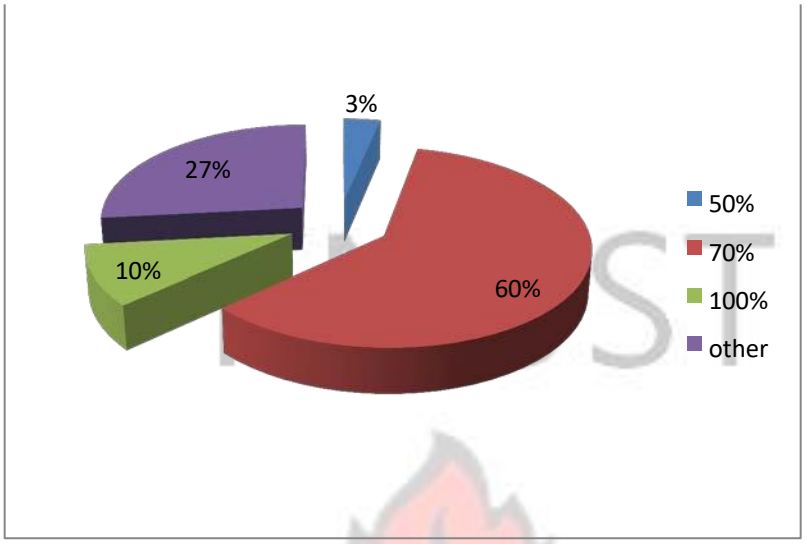

Figure 4.16 Distribution of Levels of Maintenance and Repair Work Conducted by Respondents In-House

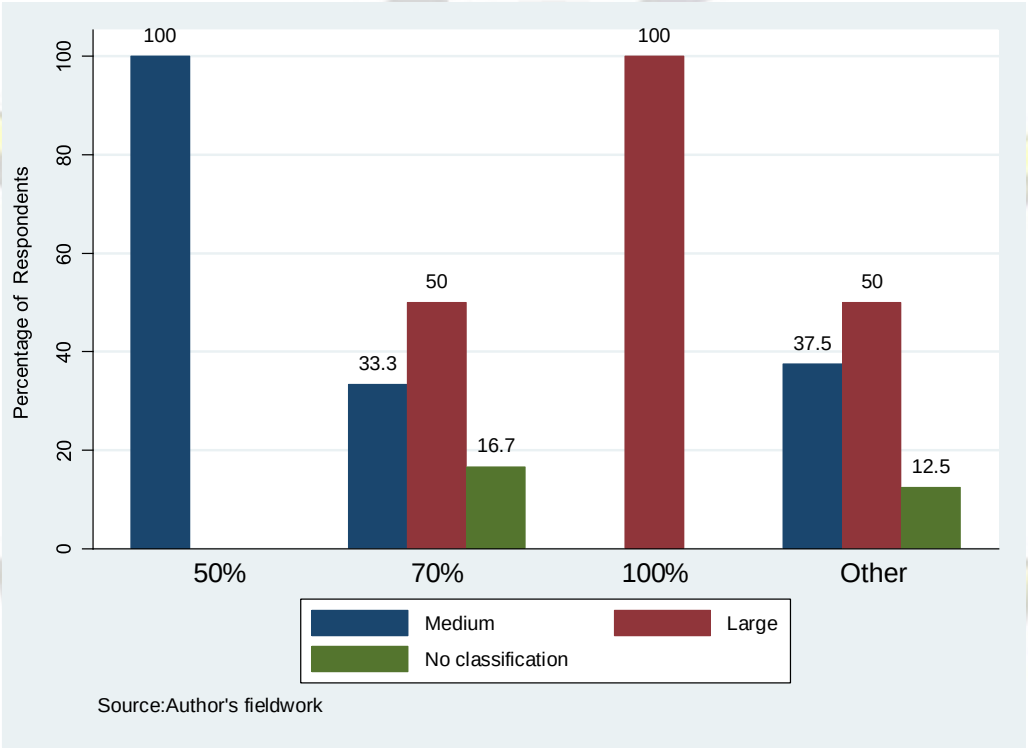

Figure 4.17 Distribution of Levels of Maintenance Operations Conducted In-House by Firm Size

4.6.2 Level of Automation of Production Processes

Analyses of the results of the production processes of respondents, illustrated in Figure 4.18, shows that 16.7% use manual production processing, 70% are semi-automated, 10% fully automated and 3.3% use manual and semi-automated production processes respectively.Those who use manual and semi-automated production processes have two factories within one premises and produce two different products using the production processes separately and independently. It can also be seen that 75% of those whose production processes are manually operated are large scale enterprises while 25% are medium scale enterprises. Forty-five point four percent of the number of respondents who use a semi-automated production process are large scale enterprises while 36.4% are medium scale enterprises. Of the number of respondents who operate fully automatic production processes 66.7% are large scale enterprises and 33.3% are medium scale enterprises. A summary of the results is shown in Figure 4.19.

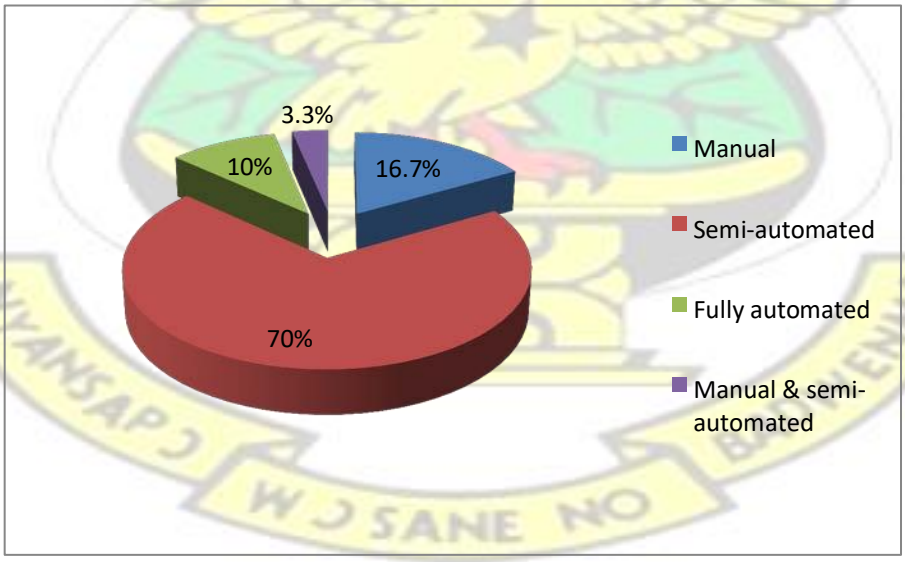

Figure 4.18 Level of Automation of Production Processes of Respondents

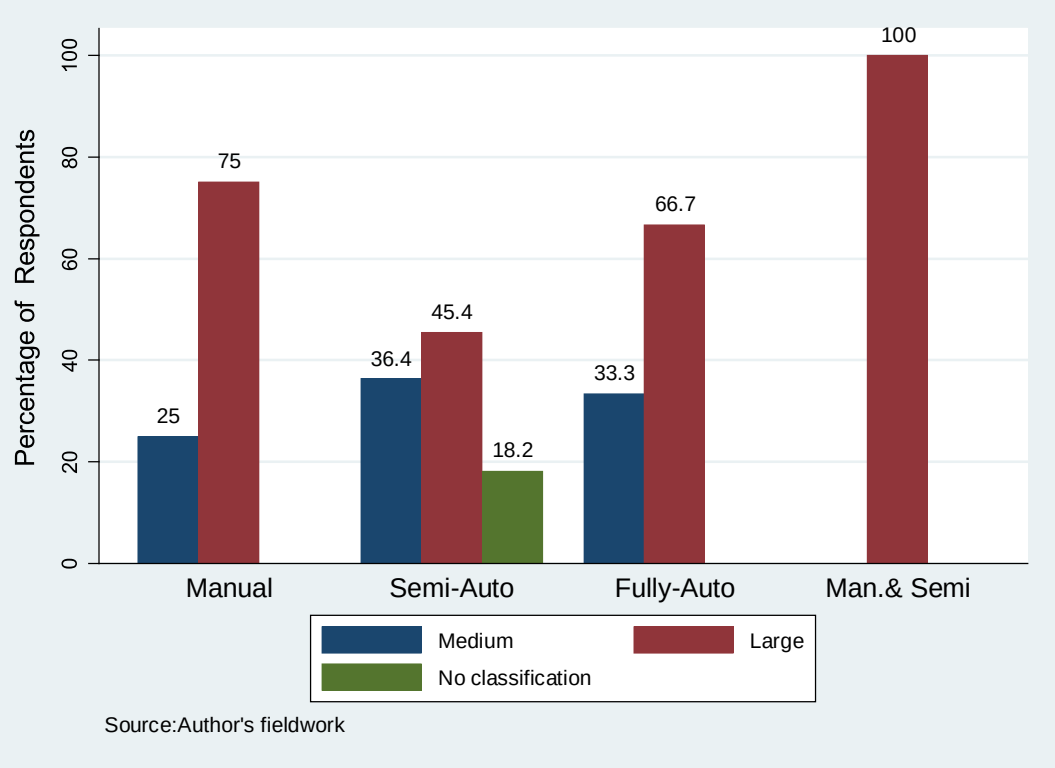

Figure 4.19 Levels of Automation of Production Based on Enterprise Size

4.6.3 Maintenance Systems and Strategies Employed

It was observed that respondent firms do not employ one maintenance strategy for all equipment. All of them make use of a combination of different strategies to suit their production schedules. A summary of the data collected is displayed in Table 4.2.

Table 4.2 Maintenance Systems and Strategies Employed by Firms

Maintenance category	**Maintenance system or strategy**	**Sub system**	**Percentage of respondents**
Unplanned (Run to failure)	Emergency		26.6
	Breakdown		26.6
Planned maintenance	Predictive	Statistical-based	20
		Condition-based	53.3
	Preventive	Running	36.7
		Routine	56.7
		Opportunity	46.7
		Shut down	60
	Improvement	Design out	20
		Shut down	43.3
	Corrective	Deferred	33.3
		Remedial	20
		Shut down	43.3
	Total productive		6.7
	Contract		50

Sixty two point five percent of firms that use emergency maintenance are large scale enterprises while 25% are of medium size. Further, of the number of respondents who use emergency maintenance strategy 50% are large scale while 50% are medium scale enterprises (Figure 4.20).

From the percentages of respondents obtained for each of the planned maintenance strategies in Table 4.2 further analyses was conducted to the preferences of the large scale and medium scale enterprises. The results are shown in Figures 4.21-4.28.

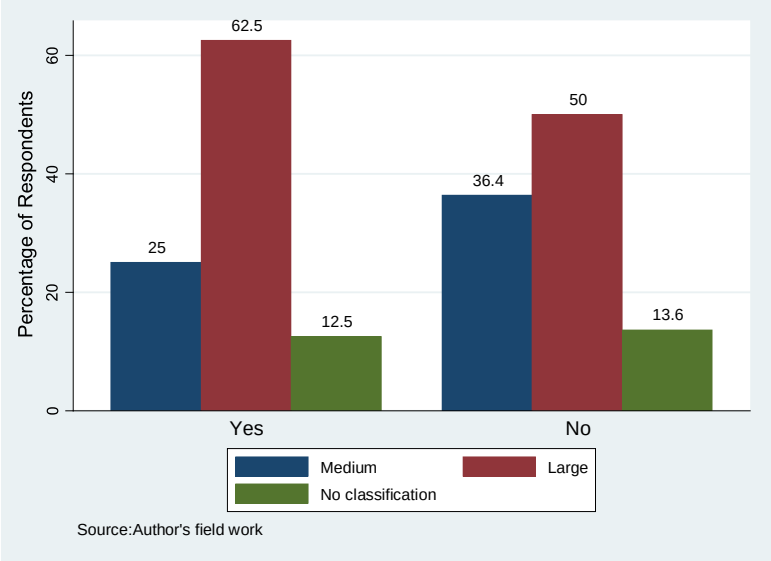

Figure 4.20.1 Distribution of Respondents Who Employ (Unplanned) Emergency Maintenance

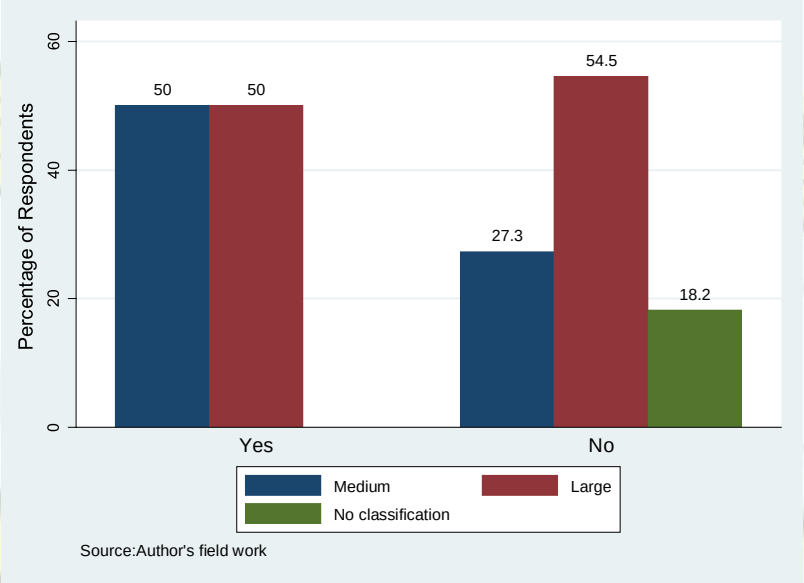

Figure 4.20.2 Distribution of Respondents Who Employ (Unplanned) Breakdown Maintenance

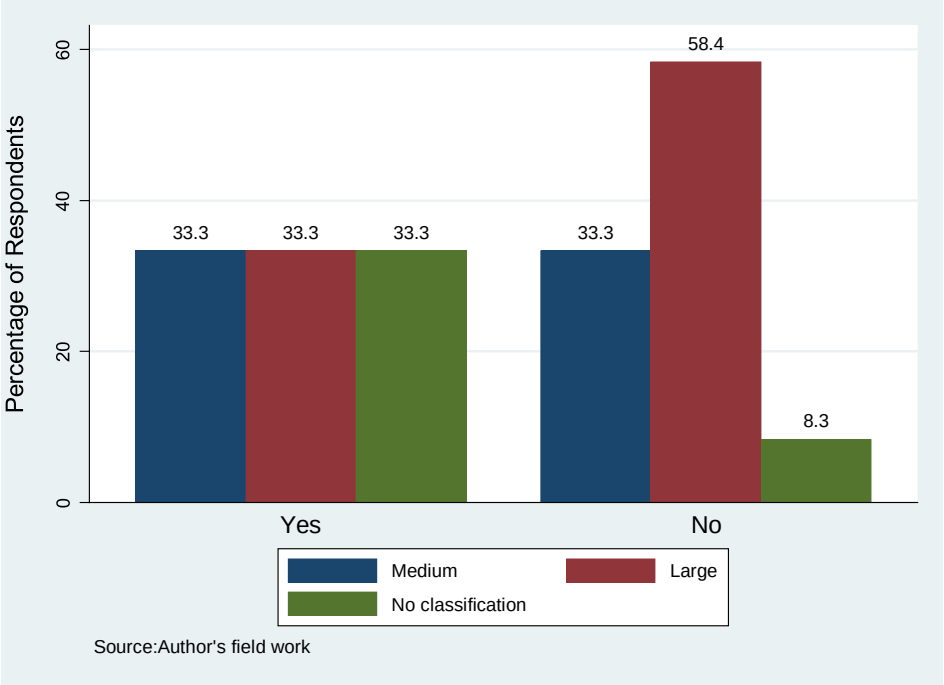

Figure 4.21.1 Distribution of Respondents Who Employ Statistical-Based Predictive Maintenance

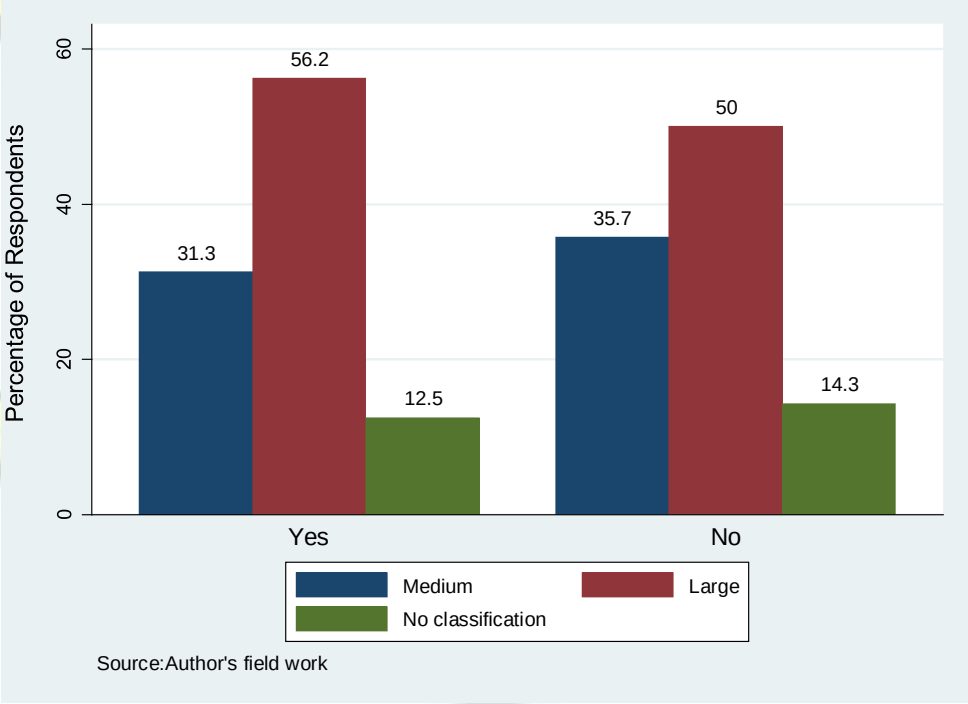

Figure 4.21.2 Distribution of Respondents Who Employ Condition-Based Predictive Maintenance

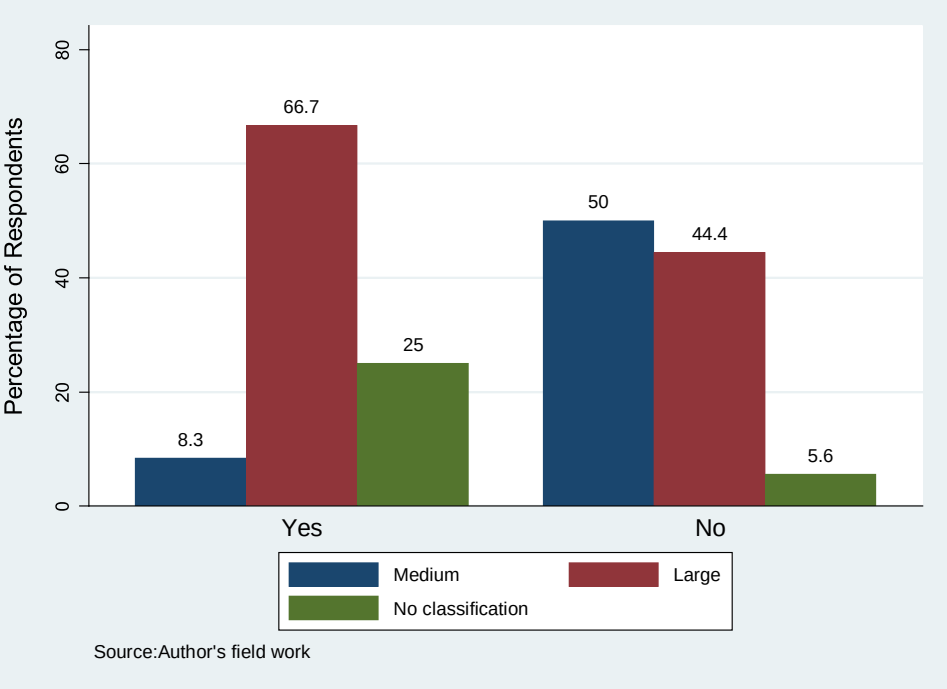

Figure 4.22.1 Distribution of Respondents Who Employ Running Preventive Maintenance

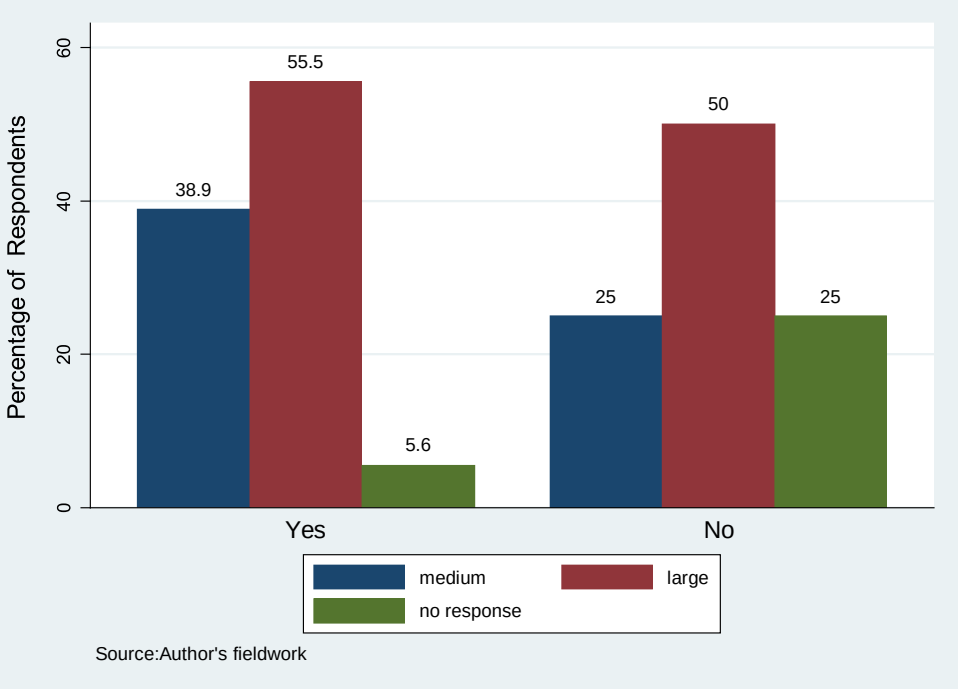

Figure 4.22.2 Distribution of Respondents Who Employ Routine Preventive Maintenance

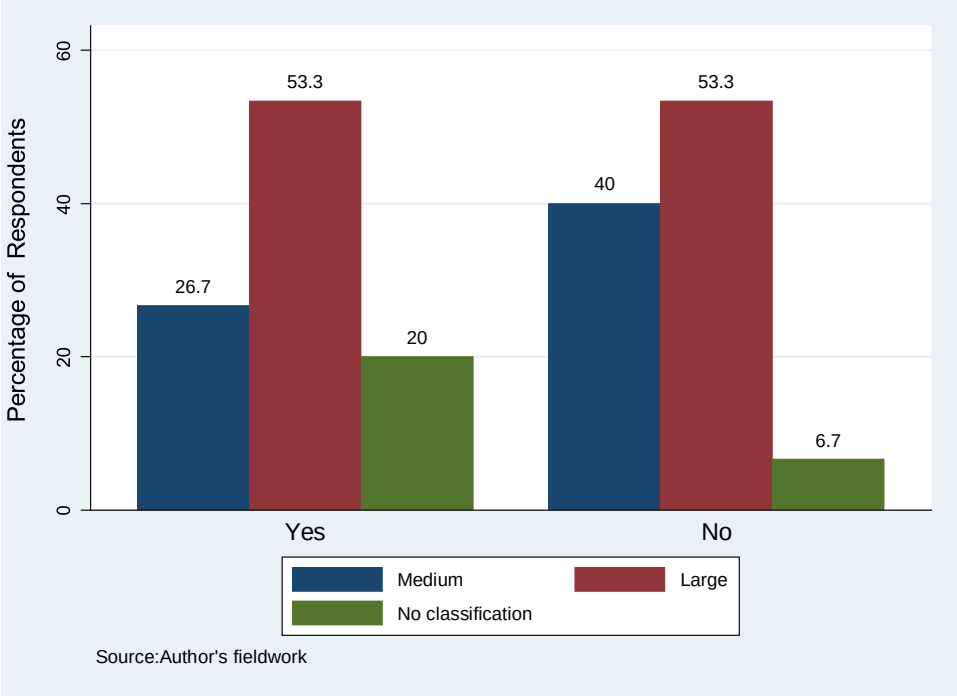

Figure 4.23.1 Distribution of Respondents Who Employ Opportunity Preventive Maintenance

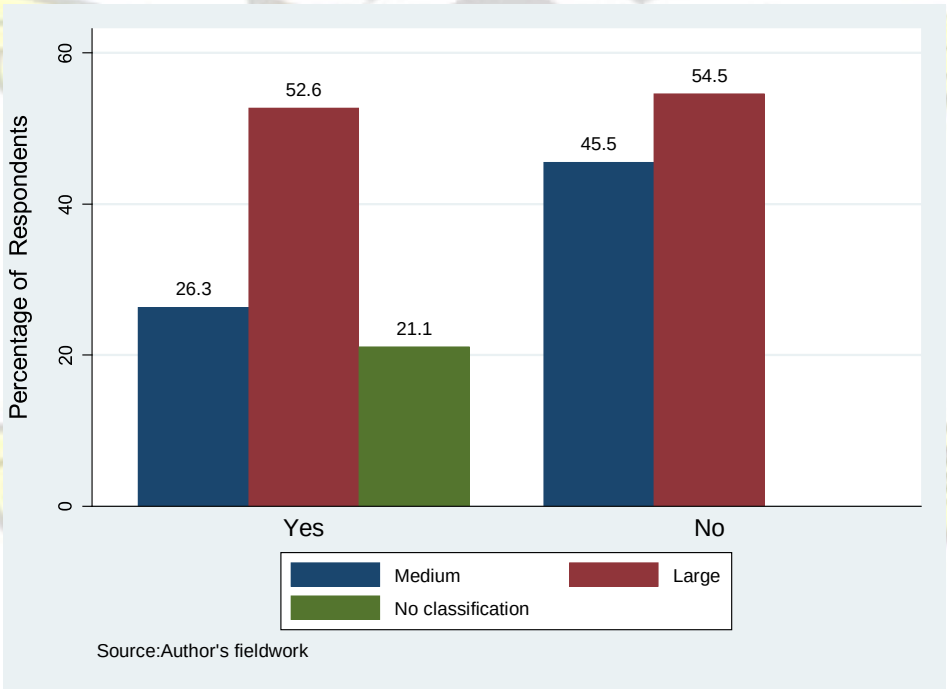

Figure 4.23.2 Distribution of Respondents Who Employ Shut Down Preventive Maintenance

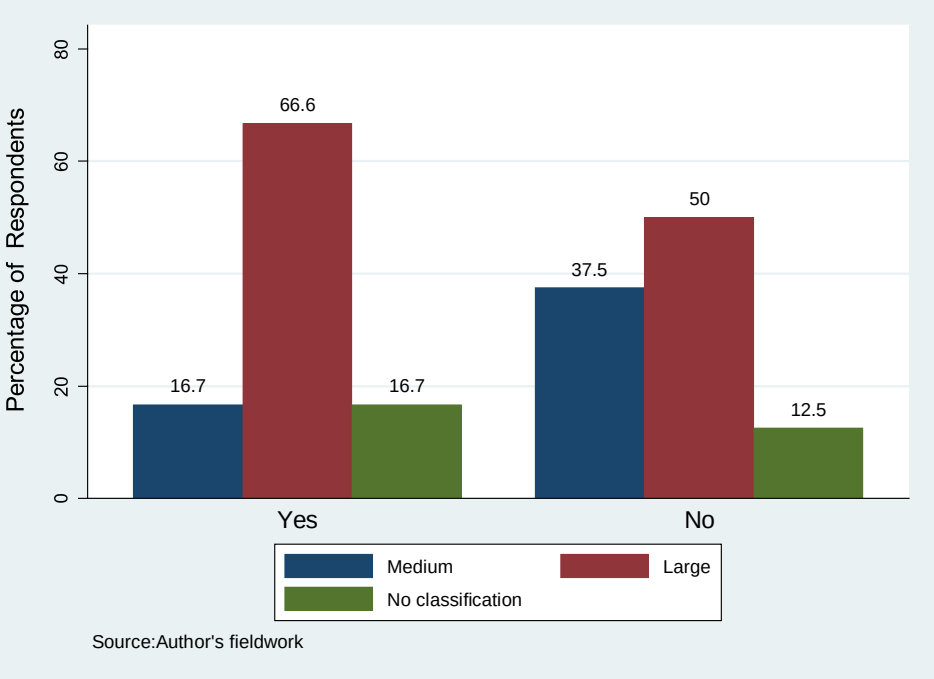

Figure 4.24.1 Distribution of Respondents Who Employ Design Out Improvement Maintenance

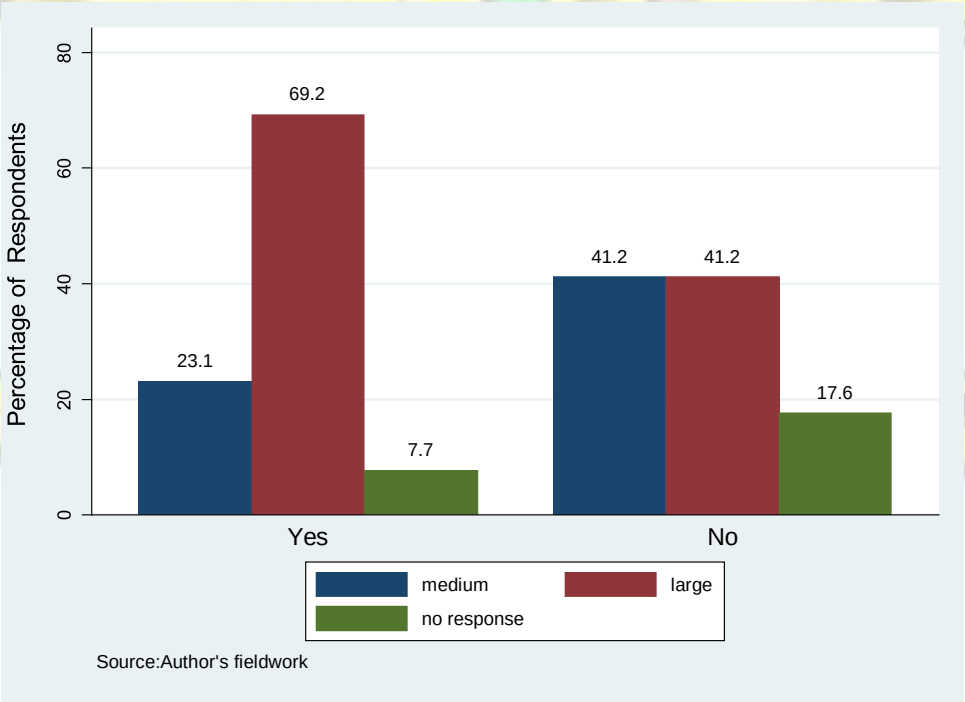

Figure 4.24.2 Distribution of Respondents Who Employ Shut Down Improvement Maintenance

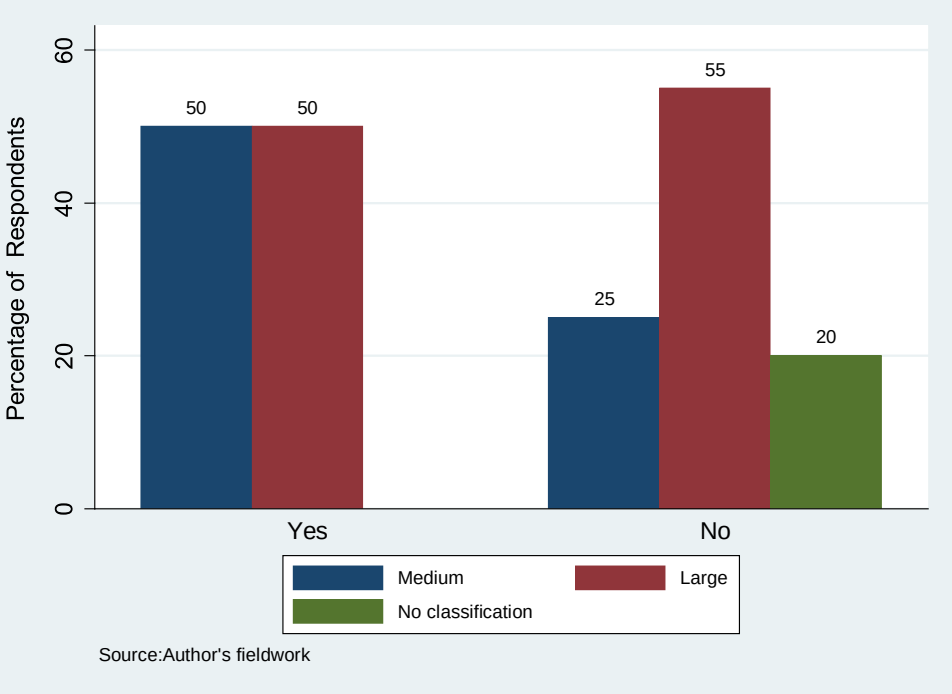

Figure 4.25.1 Distribution of Respondents Who Employ Deferred Corrective Maintenance

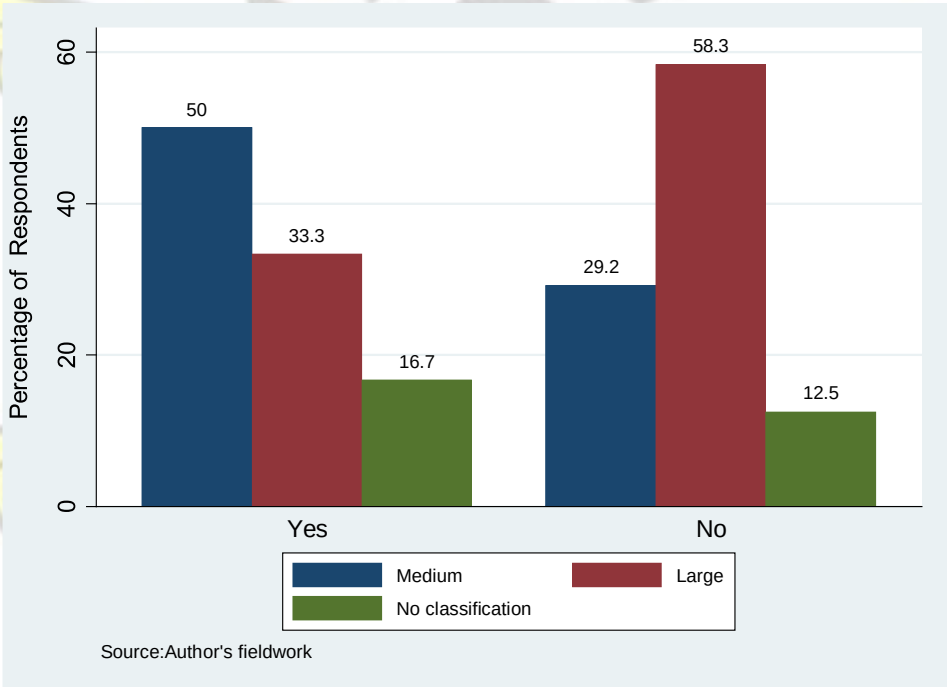

Figure 4.25.2 Distribution of Respondents Who Employ Remedial Corrective Maintenance

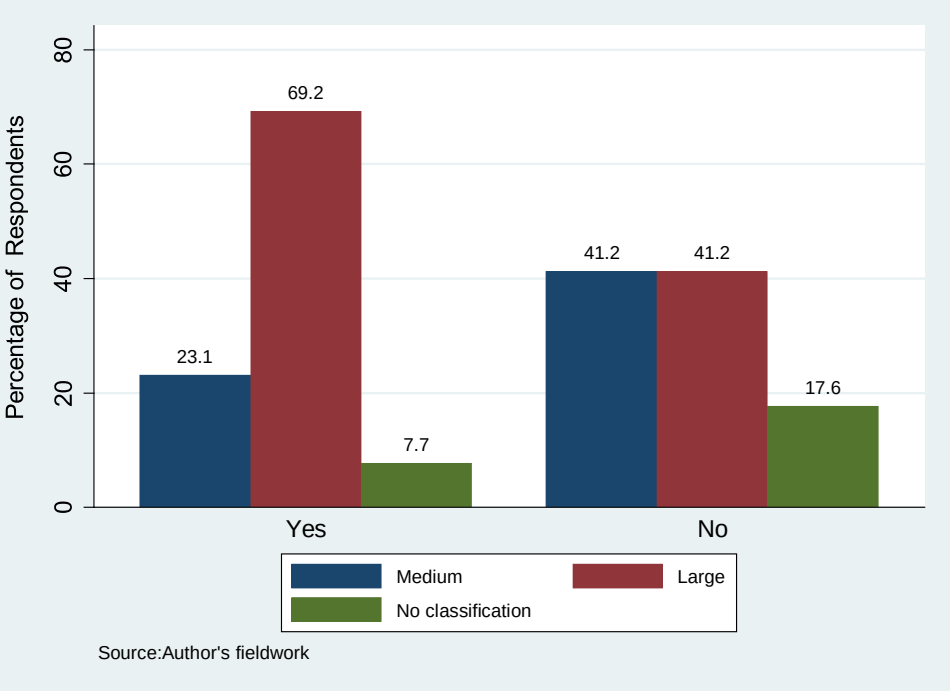

Figure 4.26 Distribution of Respondents Who Utilize Shut Down Corrective Maintenance

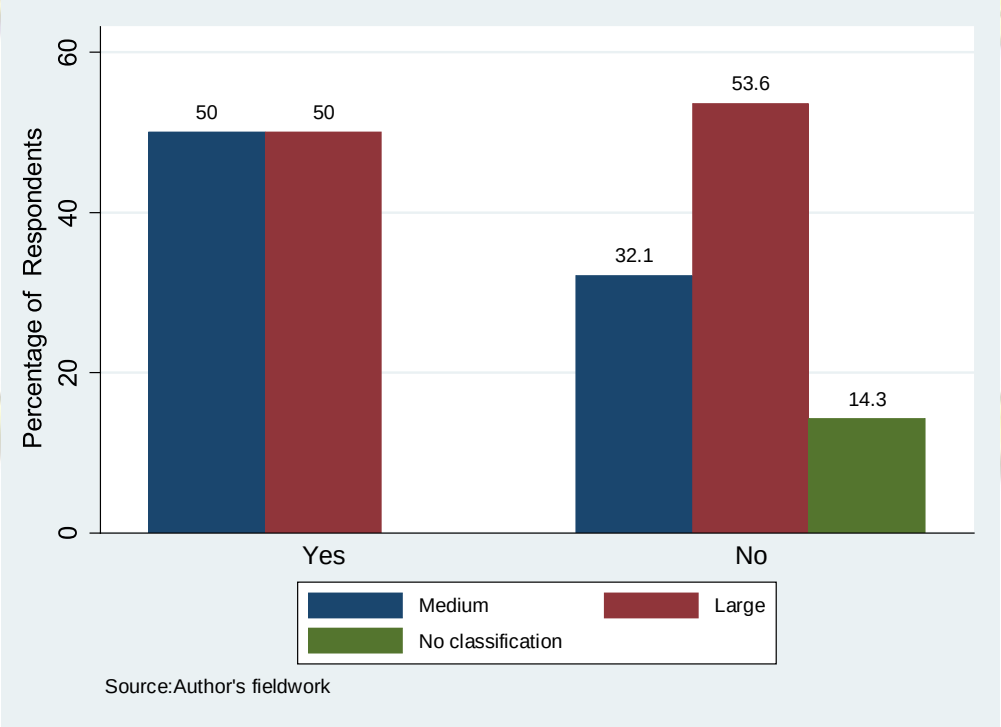

Figure 4.27 Distribution of Respondents Who Utilize Total Productive Maintenance (TPM)

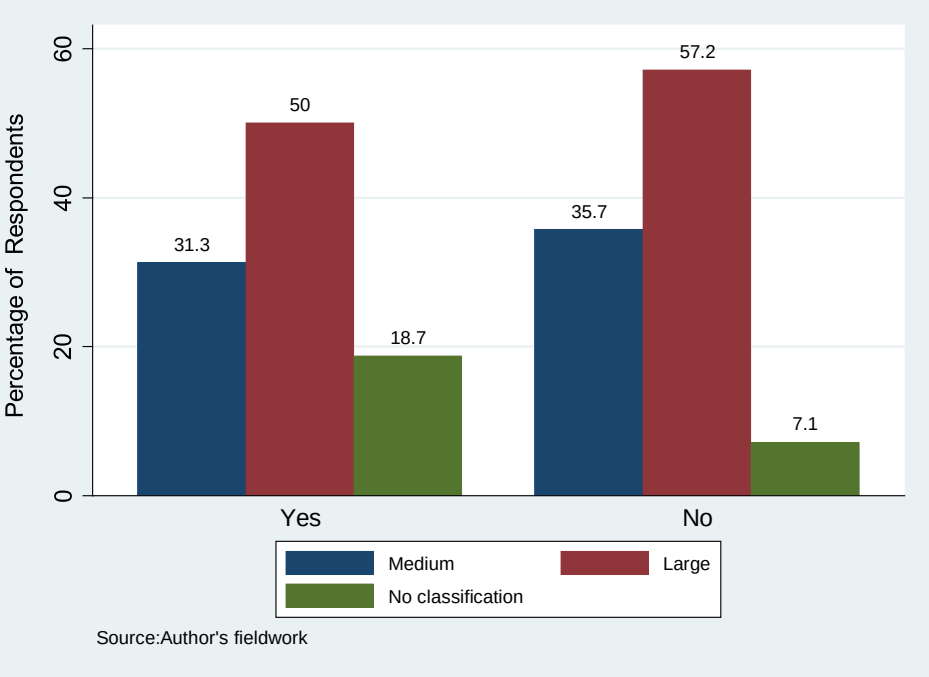

Figure 4.28 Distribution of Respondents Who Utilize Contract Maintenance

4.6.2 Geographical Location of Maintenance Contractors

Sixty three point three percent of the respondents have their maintenance contractor stationed in Ghana while 3.3% have their maintenance contractor based abroad. Twenty three point four percent have maintenance contractors based both in Ghana and abroad. A total of 10% do not use contractors. Of the percentages of respondents mentioned a summary of results based the preferences of medium and large scale enterprises are shown in Figure 4.29.

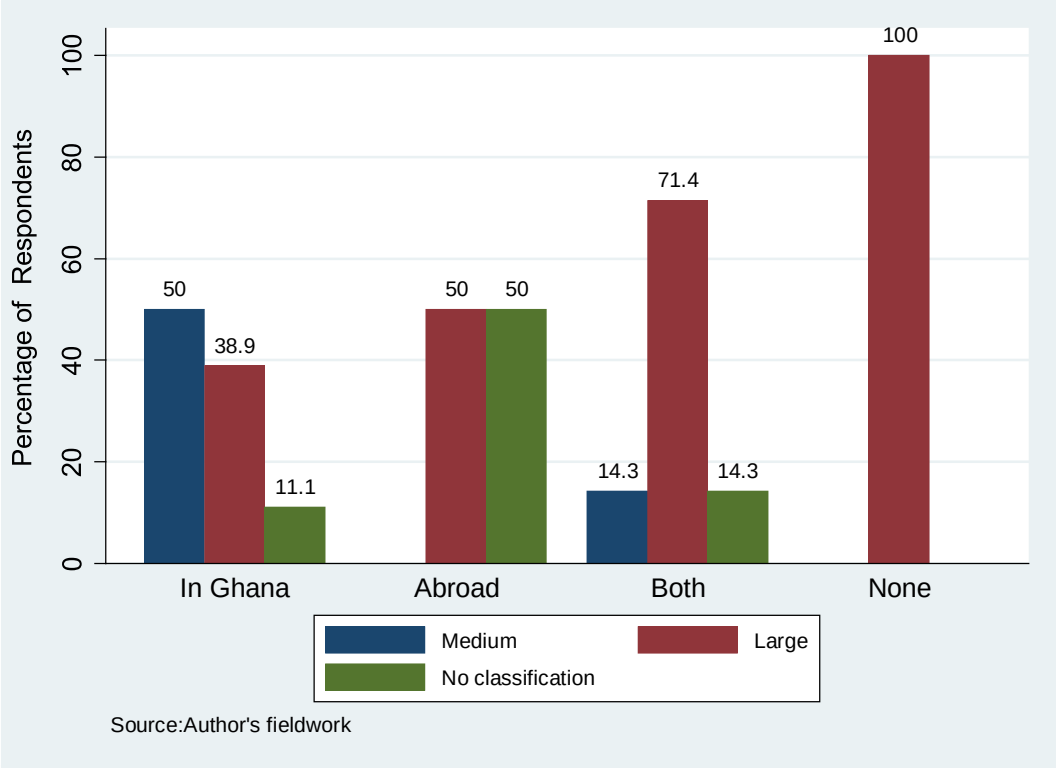

Figure 4.29 Distribution of Respondents According to Geographical Location of Maintenance Contractors

4.6.5 Devices Used for Maintenance

A list of modern devices used for maintenance and repair activities were presented to the respondents. They were then asked to indicate which ones they use. Table 4.3 shows the results obtained.

Table 4.3 Devices Used for Maintenance

Device	% of respondents
Boroscope	6.7
Flexiscope	13.3
Liquid dye penetrant	26.7
Ultrasonic corona detector	3.3
Ultrasonic Hardness tester	13.3
Creep tester	10
Tension checker	16.7
Laser beam source and detector readout	10
Pistol grip static meter	3.3
Portable sonic resonance meter/tester	3.3
Eddy current tester	6.7
Pencil probe leak detector	10
Thermopile heat flow sensor	10

4.6.6 Techniques Applied

A list of modern techniques for maintenance and repair activities was presented to the respondents to indicate which ones they apply. Table 4.4 shows the results obtained from the analysis of data collected.

Table 4.4 Maintenance Techniques Employed

Technique	% of respondents
Magnetic particle detection	16.7
Radiography	13.3
Thermal testing	30
Acoustic emission testing	3.3
Holography	3.3
In situ metallography	10
Strain monitoring	6.7
Vibration monitoring	20
Spectrometric Oil Analysis Procedure (SOAP)	23.3

4.7 STAFF TRAINING AND BENEFITS

Regarding training,Figure 4.30 shows that 10% of respondents train maintenance staff every six months, 23.3% train staff yearly while 63.4% indicated other training frequencies mainly on the job or whenever there is installation of new equipment. Three point three percent undertake no training at all.

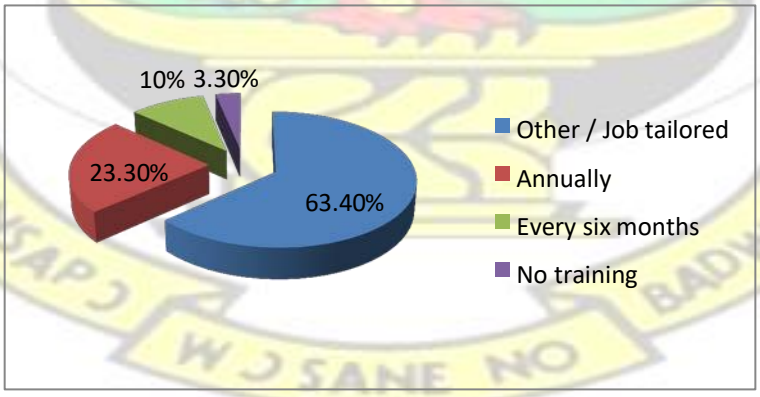

Figure 4.30 Frequency of Training of Maintenance Staff in Respondent Firms

The training regimes adopted by the companies (Figure 4.31) shows that 66.7% of those who train their maintenance staff every six months are large scale enterprises while 33.3%

are medium scale enterprises. Of those who train their staff annually 50% are medium scale enterprises while 25% are large scale enterprises.

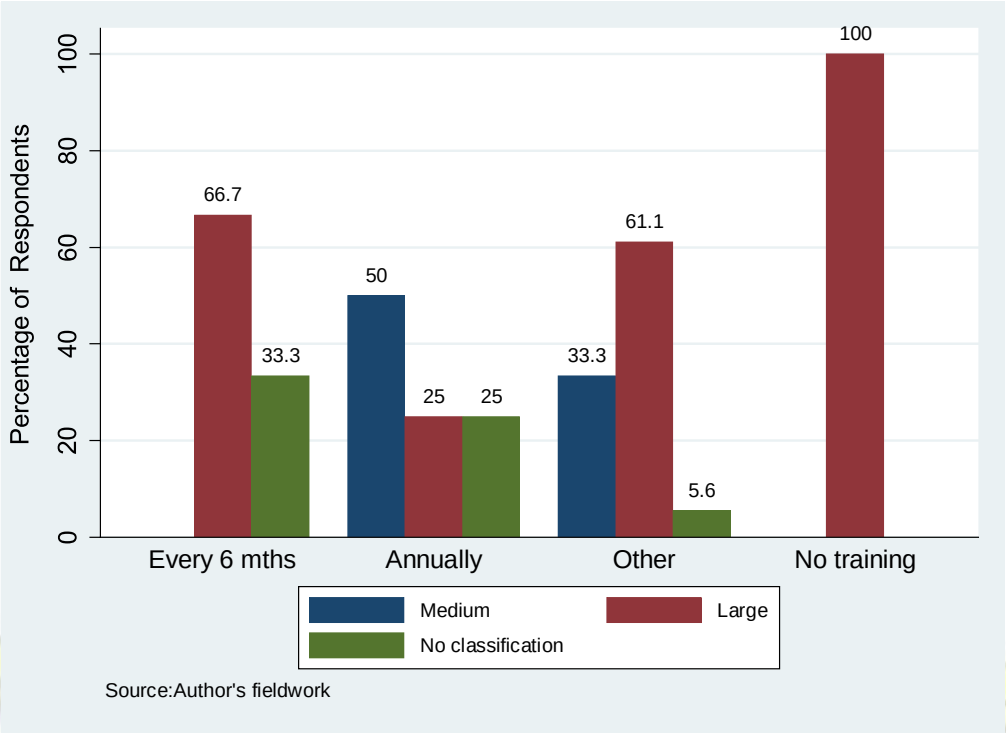

Figure 4.31 Frequency of Training of Maintenance Staff Organized by Firm Size

4.8 INFRASTRUCTURE AND SPARE PARTS

It is seen from the analyses of data collected that 80% of respondents operate maintenance workshops. Of this percentage 56% are large scale enterprises while 32% are medium scale enterprises (Figure 4.32). In addition, of the total number of respondents who retain workshops, 33.3% utilize request forms as means to regulate and document activities, 45.4% of which are large scale enterprises while 36.4% are medium scale enterprises (Figure 4.33).

It is observed that 93.3% of respondents have stores for spare parts used by the maintenance department.Fifty seven point twopercent of these respondents are large scale enterprises while 32.1% are medium scale enterprises (Figure 4.34). Only 23.3% use CMMS to procure spare parts for maintenance. This percentage, as shown in Figure 4.35, consists of 42.9% of large scale and medium scale enterprises respectively.

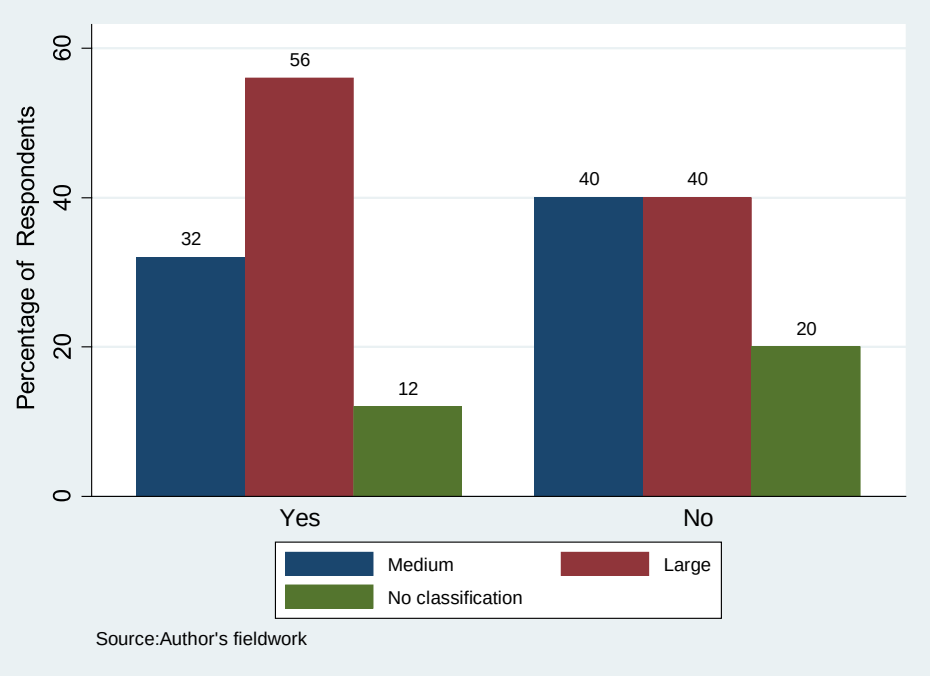

Figure 4.32 Distribution of Respondents Who Retain Workshops

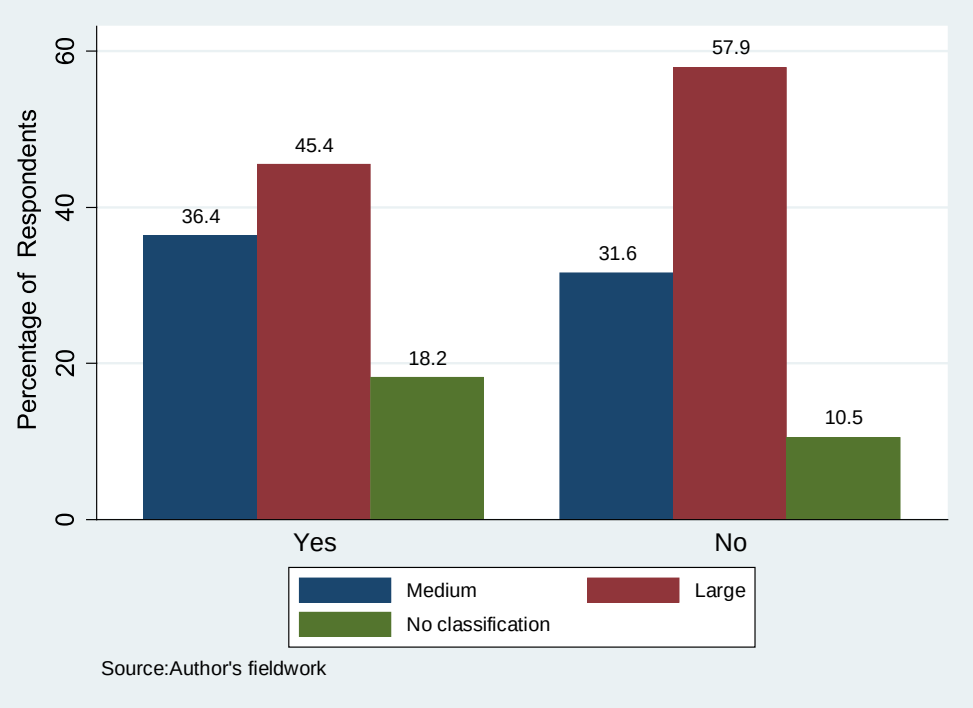

Figure 4.33 Distribution of Respondents Who Use Request Forms

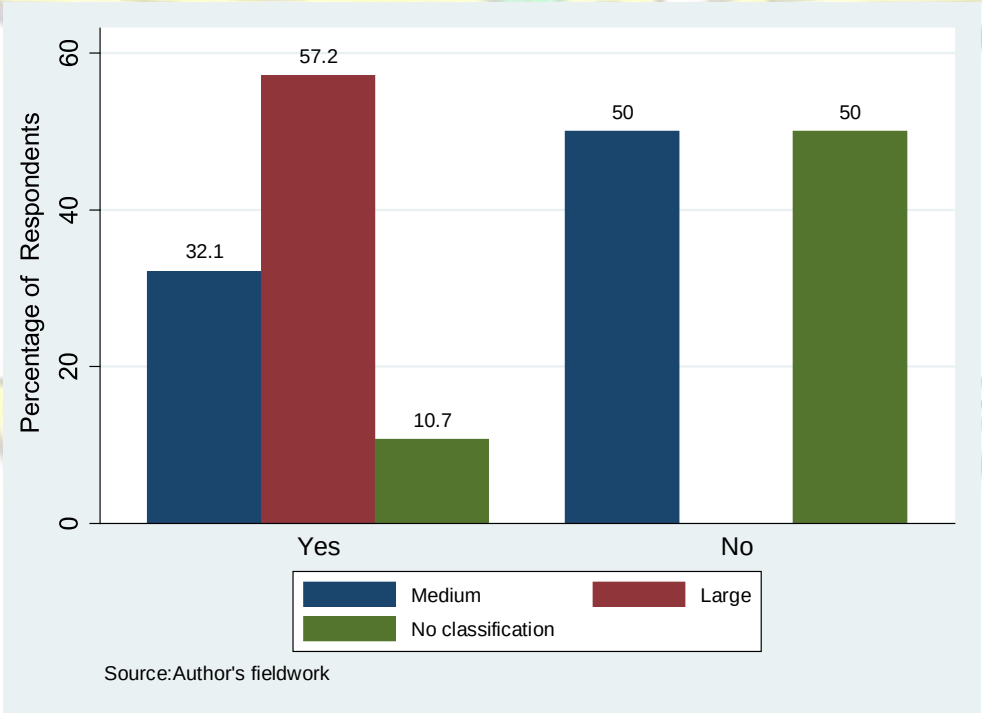

Figure 4.34 Distribution of Respondents Who Have Stores for Maintenance Activities

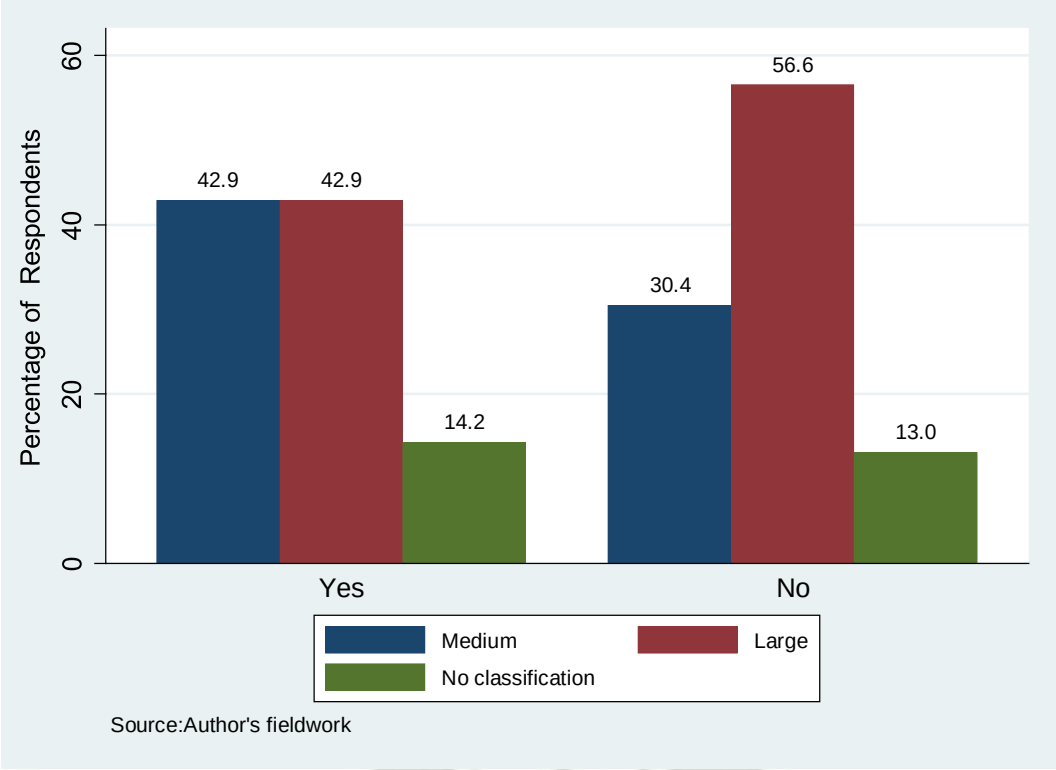

Figure 4.35 Distribution of Respondents Who Use CMMS in Stores for Maintenance Activities

Respondents indicated the amounts of spare parts they procure in Ghana. Twenty three point three percent of respondents procure between 0-25%, 30% procure between 2555%, 36.7% procure between 55-85% and 10% procure between 85-100% of their spare parts in Ghana. A summary of these results organized by size of enterprise is shown in Figure 4.36.

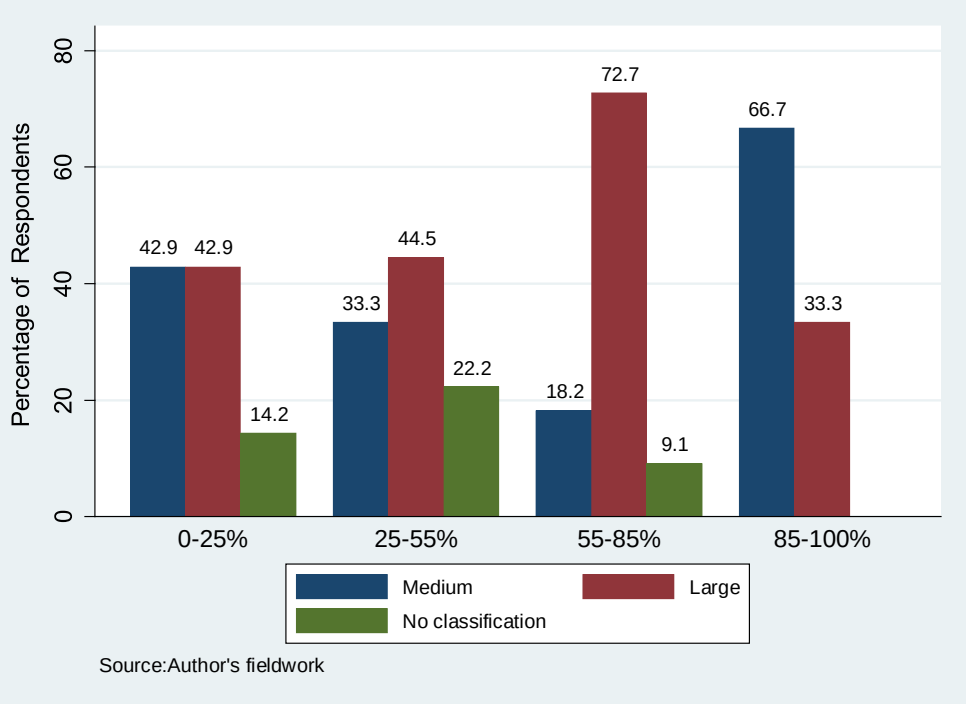

Figure 4.36 Distribution of Respondents and Percentage of Spare Parts Purchased in Ghana Organized by Enterprise Size

The results also indicate that 66.7% of respondents purchase their parts brand new. Sixty six point seven percent of these respondents are large scale enterprises while 33.3% are medium scale enterprises (Figure 4.37). Ten percent purchase used parts (50% of which are large scale enterprises while 35% are medium scale enterprises) and 23.3% purchase a combination of both; fifty seven point one percent of which are large scale enterprises while 28.6% are medium scale enterprises (Figure 4.37). Firms were asked to indicate delivery times when parts needed are ordered. Sixteen point seven percent confirmed that it takes a week. For 20% of respondents it takes less than three weeks. Delivery takes a month after ordering for 23.3% of respondents. Forty percent indicated delivery times outside those provided.

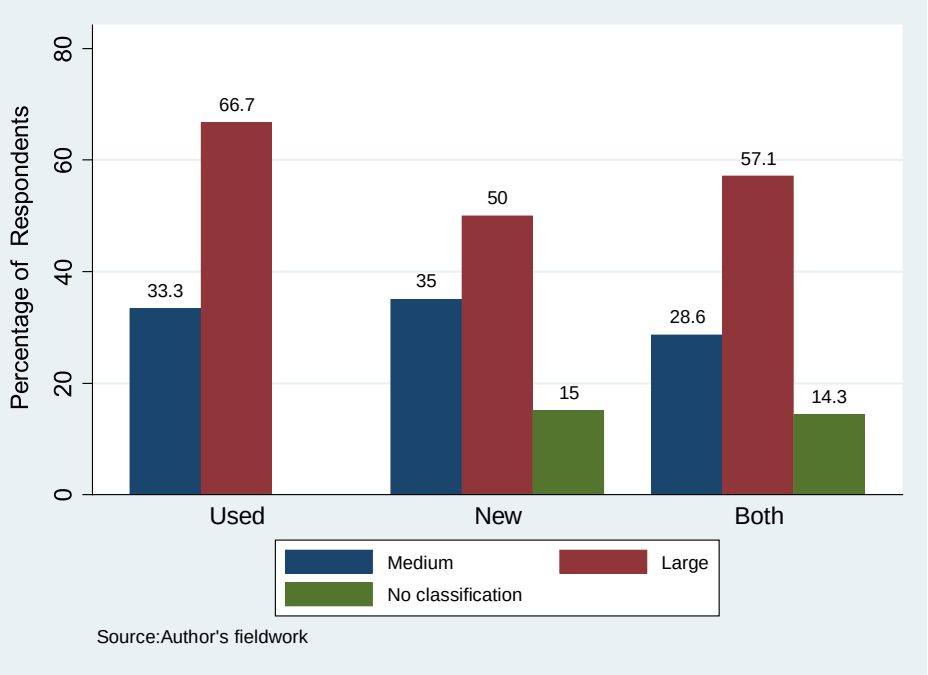

Figure 4.37 Distribution of Respondents according to Quality of Spare Parts Purchased in Ghana Displayed by Firm Size

Further, the results also show that 63.3% practiced "cannibalism" within the workshops during maintenance. Of this percentage 61.1% are large scale enterprises while 33.3% are medium scale enterprises (Figure 4.38).

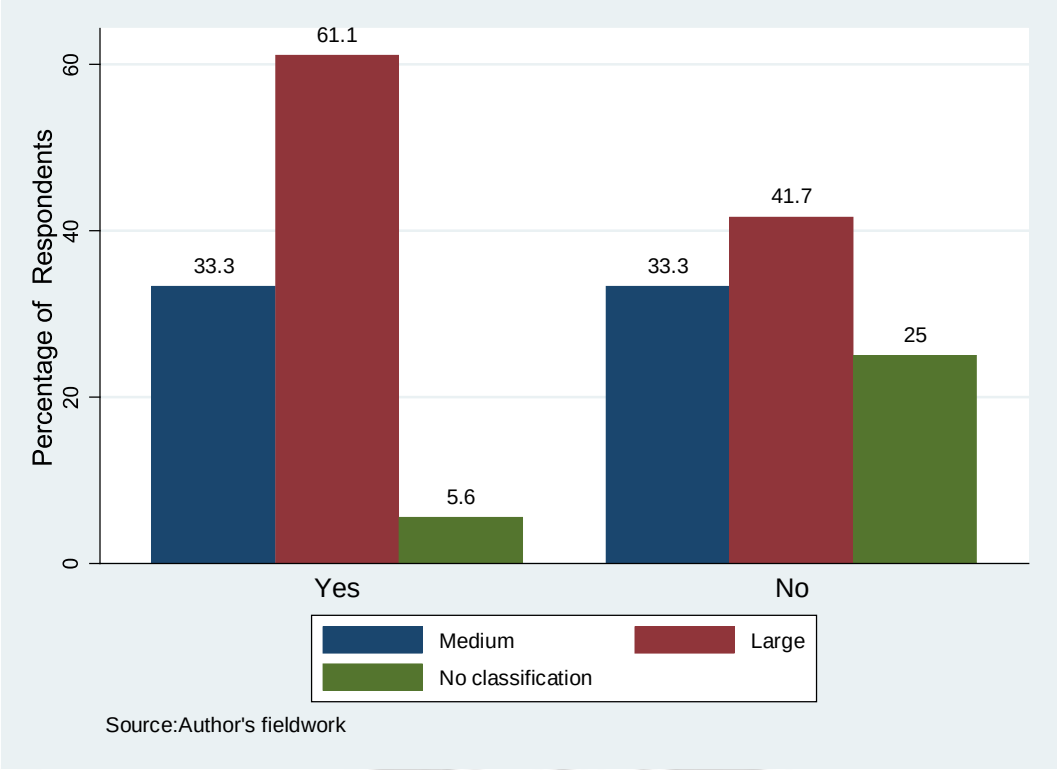

Figure 4.38 Distribution of Respondents Who Practice Cannibalism

4.9 SAFETY MANAGEMENT

96.7% of respondents maintain a safety policy. Fifty five point two percent of these respondents are large scale enterprises while 31% are medium scale enterprises (Figure 4.39). Of those who maintain a safety policy, 93.4% enforce wearing of protective clothing and equipment at all times during maintenance operations by workers; 53.6% of which are large scale enterprises while 32.1% are medium scale enterprises (Figure 4.40) and in 84.6% of firms punitive measures in place to check those who do not adhere to the policy. Of those who have punitive measures 52.4% are large scale enterprises while 33.3% are medium scale enterprises (Figure 4.41).

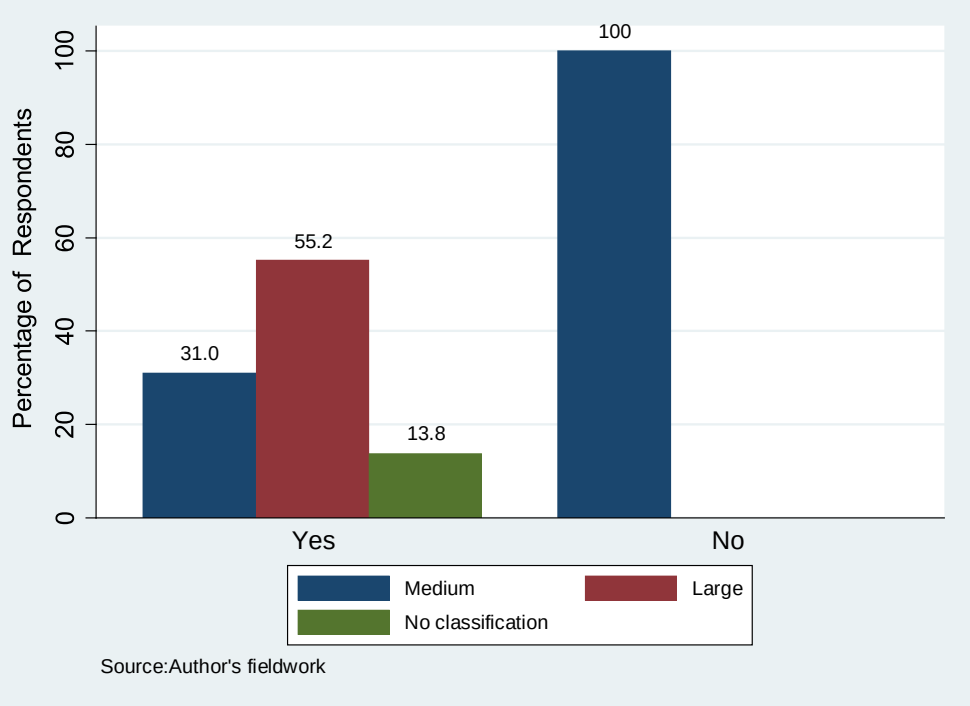

Figure 4.39 Distribution of Respondents According to Safety Policy

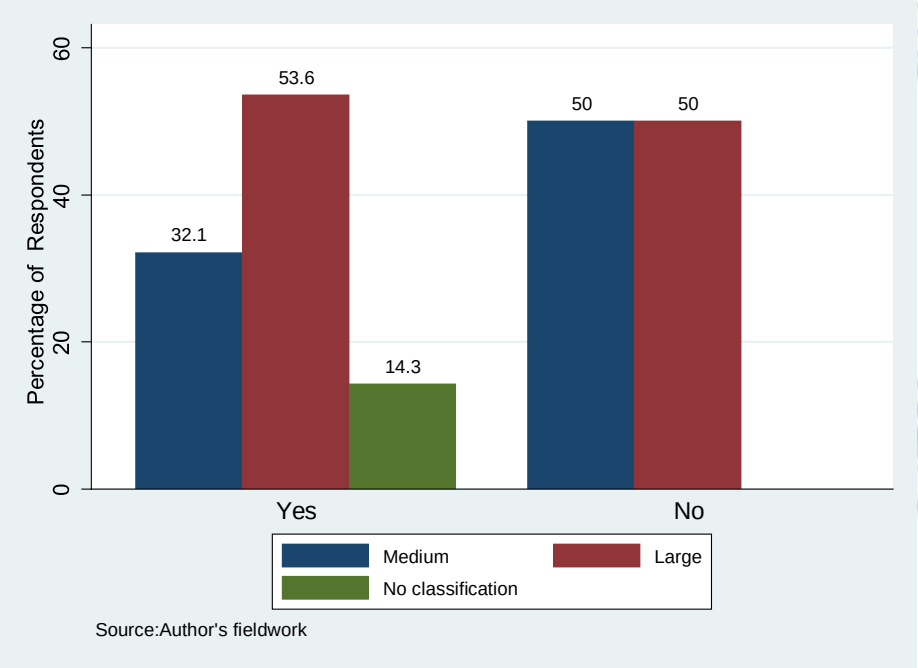

Figure 4.40 Distribution of Respondents Who Have Made Use of Personal Protective Clothing and Equipment as a Requirement for Maintenance Activities

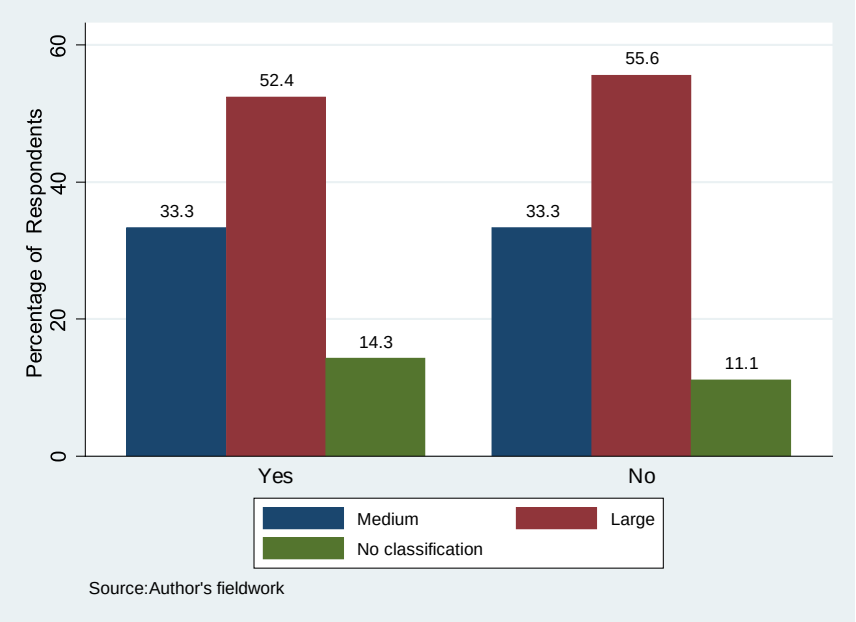

Figure 4.41 Distribution of Respondents Who Utilize Punitive Measures to Enforce Use of Personal Protective Clothing and Equipment

4.10 MAINTENANCE PERFORMANCE MEASUREMENT

Respondents were asked to indicate the frequency with which they perform maintenance evaluation. Twenty percent of the respondents undertake maintenance performance measurement weekly while 36.7% and 26.7% do this activity monthly and yearly respectively. 16.6% undertake it at other times (quarterly and bi-monthly) (Fig.4.42).A summary of the results showing maintenance performance activities of large and medium scale enterprises is as shown in Figure 4.43.

The results revealed that 36.6% utilize maintenance performance measurement to measure the value created by maintenance and to justify investment, 30% use it to revise resource allocations, 33.3% to adapt to new trends in operation and maintenance strategy, 56.7% to

effectively monitor and improve maintenance activities, 46.7% toreduce maintenance cost, and 23.3% to make changes in health and safety and environmental policy.

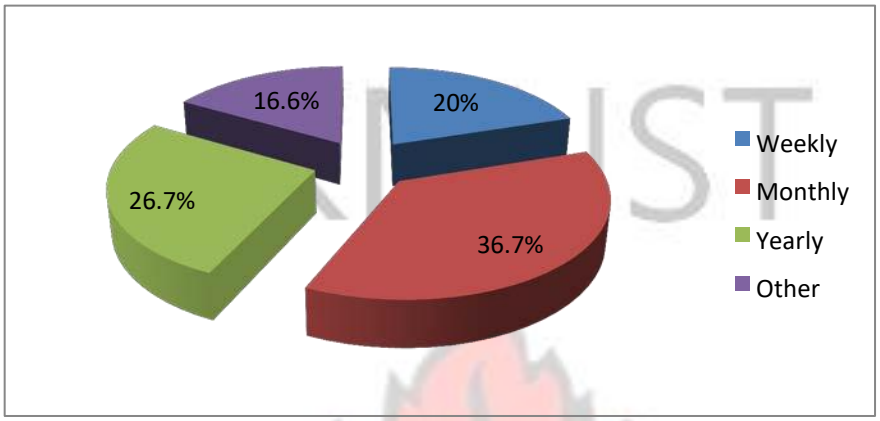

Figure 4.42 Time Intervals at which Maintenance Performance is Evaluated

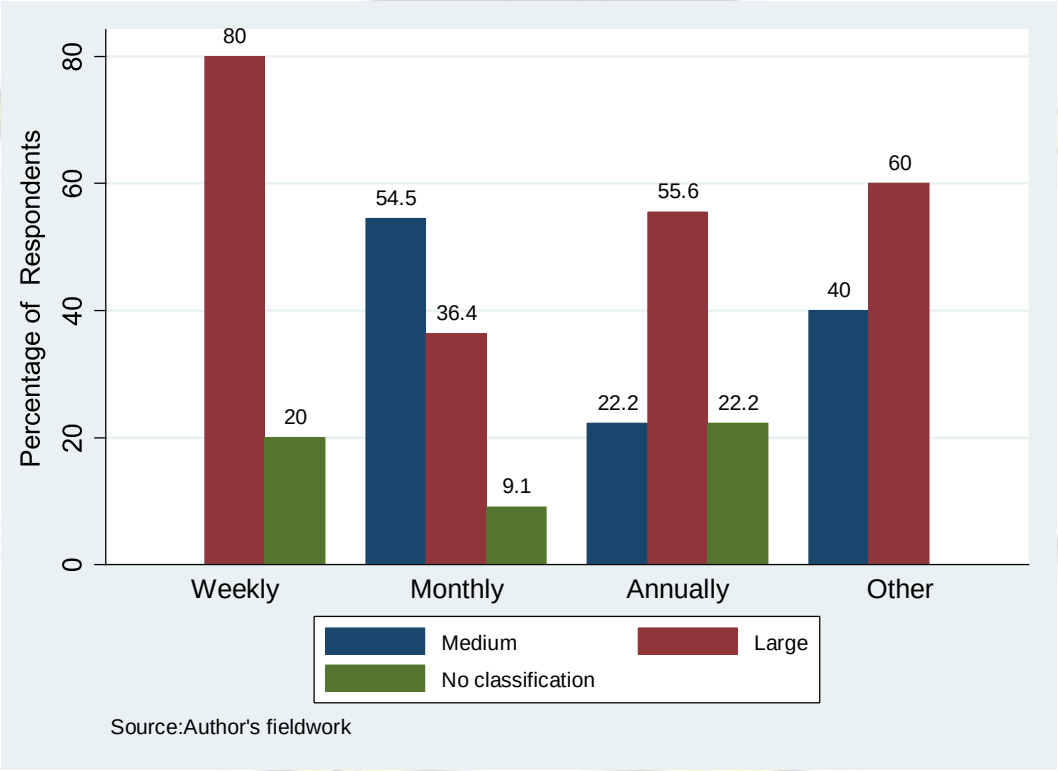

Figure 4.43 Distribution of Respondents Who Undertake Maintenance Performance Measurement

CHAPTER FIVE

5.0 DISCUSSION

5.1 CHARACTERISTICS AND PROFILE OF RESPONDENT COMPANIES

5.1.1 Geographical Location of Respondents

The research covered companies within the formal sector (companies registered with the Registrar General's Department) in Kumasi, Accra and Tema. This choice was made because these cities have the highest concentration of manufacturing companies in Ghana (Frimpong, 2007). Majority of the respondents were from the Greater Accra region, precisely from Tema. The least number of respondents came from Kumasi in the Ashanti Region. It was observed that most companies within the Ashanti region are only subsidiaries of mother companies in the Greater Accra region. In addition, Figure 4.2 makes it clear that of the respondents from the various cities majority are large scale enterprises.

5.1.2 Industrial Sector of Respondents

Majority (26.7%) of the respondents specified categories outside the major sectors provided. These included manufacturing of industrial and medical gases, plastic packaging, oil and gas, aluminium products, wood processing and cement manufacturing. There was no response from the textile, automotive and strictly chemical manufacturing sectors. Three and point three percent of the companies manufactured a combination of food and chemical products. The results also show (Figure 4.4) that with the exception of the metal working sector large scale enterprises dominated the other sectors.

5.1.3 Ownership Structure of Respondent Firms

Majority of the respondent companies are private-owned and interaction with designated contact persons within these companies revealed that majority of the owners are foreigners. Further, the results showed that state-owned companies, public liability companies and Ghanaian joint ventures captured within the survey are large enterprises. Within the private-owned (Ghana-foreign) ventures there are more medium scale enterprises than large scale ones (Figure 4.6).

5.2 EFFECTIVENESS OF MAINTENANCE ORGANIZATION

Heisler (2008) suggests a good organization is one with effective people working constructively together towards a common goal. In his view, one cardinal point is for these organizations to have a balance between policy and practice. The results obtained and interactions with maintenance staff attest to the fact that majority of respondents have achieved a degree of this balance. This is because the managements of respondent companies consider maintenance as a core function of their activities and have properly organized it. As evidence of this the results obtained show that majority (83%) of the respondents operate reliable maintenance departments and have structures and staff within the premises to facilitate the detection of systematic flaws and recommend solutions as suggested by Damewood (2008). Of the respondents who have workshops large scale enterprises are in the majority as shown Figure 4.7. For respondent firms who answered "no" to whether the company operated a workshop, the major reason given for the answer was that their managements did not consider a workshop as a priority and as such did not retain one.

In addition, the maintenance departments are organized with a majority (66.7%) of respondents using a centralized maintenance organization. This category is followed by partially decentralized and decentralized maintenance organizations respectively. Ten percent of respondents were found to apply neither of the above types of maintenance organizations. Observations made from Figure 4.9 reveal that of the percentage of respondents who utilize centralized maintenance organizations large scale enterprises form the majority. Though information was not readily made available it could be inferred from interaction with respondents within the firms that that these large scale enterprises operate this maintenance organization because their maintenance operations mostly occur within their premises. Again, only large scale enterprises use the decentralized maintenance organizations in accordance with observations made by Corder (1976). According to him, this means that these enterprises have maintenance staff on site and also at all locations of operation and the maintenance management at all locations are independent of each other. For the partially decentralized maintenance organization, both medium and large scale enterprises shared equal percentages. This means that these enterprises have main maintenance staff within their premises and send out teams to handle maintenance activities in other branches depending on the nature of the maintenance expertise required. Interaction with the respondents revealed that majority adhered to maintenance organizations described.

Also, majority of respondents (90%) are consulted in their maintenance departments before equipment is acquired. Of this number the phenomenon is most prevalent in the large scale enterprises as shown in Figure 4.10. Though it occurs mostly in large enterprises a fair percentage of medium scale enterprises also follow the same approach. This is evidence that the heads of maintenance department have been grafted into the

organizational decision-making mechanism and play active roles in the management of the companies. It is further evidence that top management recognize the importance of departmental interrelationships.

Further interactions revealed that most respondents organize their maintenance such that maintenance staff could quickly respond to and provide quality support for emergency and preventive maintenance, as well as periodic rebuilds and overhauls which according to Heisler (2008) is a minimum requirement for effective maintenance organizations. These indicators show that maintenance organization in manufacturing firms in Ghana is effective.

5.3 MAINTENANCE PROCEDURE AND DOCUMENTATION

5.3.1 Work Order System Employed

The work order system contains information pertaining to specific work for a piece of equipment or facility. It facilitates future maintenance planning and implementation by answering standard questions pertaining to what, how, when, where, why, how much and how often a piece of work is to be done (Gober, 2008). The results (Figure 4.11) show that generally majority (50%) of respondents apply the standing order system to implement maintenance while 26.7% utilize work order. It was also observed that while 6.6% use both, 16.7% apply neither of the systems and execute maintenance activities based on instructions from the maintenance manager.

From Figure 4.12 it is also evident that the work order systemisin use more in large scale companies than in medium scale ones. However as many large scale enterprises as medium scale enterpriseuse both work order systems.

It is clear from above that within the manufacturing sector majority of companies have adopted work order systems for maintenance and are able to adequately document maintenance procedures for current and future reference.

5.3.2 Integration of CMMS into Maintenance Management System

Only 26.7% or respondents have integrated CMMS into their maintenance management system. Of this percentage, results shown in Figure 4.13 confirm that large scale companies form the majority. It can be inferred from the results that generally the documentation processes are handled manually in many of the companies and only a few companies are reaping the full benefits of using the software.

On interaction with respondents, reasons given for the lack of use of the software include cost of acquisition of the software and the fact that management has not seen the need to acquire it for use despite its advantages. They also identified the requirements of implementation, for example nature of data collection, time for coding, information for work orders, etc as a major challenge. Respondents who were using it responded positively regarding its contribution to improving their documentation procedure for maintenance activities. However, they cited the huge amount of work load involved in the collection of the data and its input into the software as a challenge.

5.4 MAINTENANCE COST

Though respondents offered little information to determine maintenance costs in manufacturing in Ghana it could be observed that the major elements which constitute total maintenance cost include labour, electricity, outsourcing, spares and water. The decreasing order for cost elements for maintenance in Ghana is labour, outsourcing of maintenance and repair work, electricity, spares and others.

5.5 INCENTIVES TO MAINTENANCE STAFF

Corder (1976) cites incentives as one of the critical tools management of organizations can use to enhance the effectiveness of maintenance activities in industries. The trend from Figure 4.14 shows that of the 40% of respondents who give incentives to maintenance staff, majority (41.6%) are medium scale manufacturing companies,and that majority of the incentives given are financial in nature. Equal numbers of medium and large scale companies administer this policy. Again, only medium scale companies were observed to administer non-financial incentives to maintenance staff. Generally, it could be observed that medium-scale enterprises consider incentives for maintenance staff critical to their operations and are enjoying more benefits from its implementation than large-scale enterprises.

5.6 MAINTENANCE SYSTEMS AND STRATEGY

5.6.1 Organization of Maintenance and Repair In-House

Respondents were asked to indicate percentages of maintenance and repair activities conducted in-house. The results showed that only 36.7% of respondents conduct between 98-100% of their maintenance and repair operations in-house. Majority of the respondents in this category are large scale enterprises (Figure 4.17). They claim that they do maintenance and repair in-house as a cost reduction strategy. On interaction, majority of the respondents showed technical knowledge of the maintenance systems and subsystems. Also from Figure 4.17, it is observed that companies which implement 50% and 100% of their maintenance and repair in-house are all medium scale and large scale enterprises respectively. Of those implementing 70% of their maintenance and repair in-house there are more large scale enterprises than others. All respondents use a mixture of the systems to suit the production equipment.

It is evident from the results that contract maintenance has made in-roads in maintenance management in Ghana. Much information could not be obtained to determine the criteria for selection of contractors. Respondents, however, expressed satisfaction at services offered by contractors.

5.6.2 Levels of Production Process Automation

The research reveals that majority of the respondents (70%) use semi-automated production processes. The trend observed is that large-scale manufacturing companies

form the majority of respondents implementing various levels of automation (Figure 4.19). Many medium scale enterprises are also semi-automated.

Haroun and Duffuaa (2009) assert that contemporary management considers maintenance as an integral function to achieving productive operations and high quality products, while maintaining satisfactory equipment and machines reliability as demanded by the era of automation. The results obtained show that the era of automation has caught up with Ghanaian manufacturing companies and it is possible that this has forced management of these companies to undertake effective maintenance management activities to achieve the benefits summarized by Haroun and Duffuaa.

5.6.3 Maintenance Systems and Strategies Employed

Majority of manufacturing companies use the preventive shut down maintenance system. They also use preventive (routine), predictive (condition-based) and contract maintenance schemes in decreasing order respectively. The least implemented maintenance scheme, from the results, is total productive maintenance strategy. A discussion of the individual maintenance strategies adopted according the NBSSI categorization for companies in Ghana is done below.

Unplanned Maintenance Systems

On individual maintenance strategy basis, it is observed from Figure 4.20 that more large scale enterprises utilize emergency run-to-failure strategy than medium scale enterprises. When it comes to breakdown maintenance system the same number of large scale

companies as medium scale companies utilize it. The major reason given for their choice is the cost – effective nature of the maintenance strategy.

Planned maintenance

Planned Predictive Maintenance

It is observed from Figure 4.21 that equal numbers of medium and large scale enterprises use statistical-based predictive maintenance while large scale enterprises form the majority of those who employ the condition-based maintenance activities.The main factor which has influenced their choice is cost reduction. The respondents claim that application of the maintenance schemes allows them plan better and schedule conveniently such that maintenance operations are performed only when warranted. In their opinion, better planning and scheduling generate benefits which include reduction of their spare parts inventory, increased plant safety and machine life. These benefits as well as increased production levels increase their profits.

Planned Preventive Maintenance

It is observed that respondents employ both running and routine preventive maintenance schemes. Figure 4.22 shows that large scale enterprises form majority of respondents who implement running and routine preventive maintenance schemes. The same trend is observed in Figure 4.23. Respondent firms employ both opportunity and shut down preventive maintenance schemes and large scale enterprises form majority of respondents who implement them. Interaction with contact persons from respondent firms revealed

that theyemploy running, routine and opportunity maintenance schemes because they are best suited to the equipment which operate round the clock.

Planned Improvement Maintenance

Figure 4.24 shows that majority of respondents who apply design out and shut down improvement maintenance are large scale enterprises. Medium scale enterprises prefer the shut down maintenance strategy. Respondents who employ design out improvement maintenance schemes disclosed that they buy and use customized equipment for production and regularly consult with the manufacturers to integrate new designs and new parts which would improve their efficiency and ease maintenance and repair work. Respondents also iterated that they employ the shut down strategy mainly because it enables them to replace old and worn out parts with new and or used as well as improved machine parts which are of higher quality to increase machine life and enhance production.

Planned Corrective Maintenance

As many large scale enterprises as medium scale ones employ the deferred corrective maintenance strategy (Figure 4.25). For respondents who utilize remedial corrective maintenance strategy medium scale enterprises form a majority. For shut down corrective maintenance large scale enterprises form a majority of the respondents utilizing it (Figure 4.26).

Total Productive Maintenance

The Total Productive Maintenance (TPM) is the least implemented maintenance strategy. Figure 4.27 further reveals that the small percentage of respondents implementing is made up of equal numbers of medium and large scale enterprises. Reasons cited by respondents who do not use it include cost of implementation and the nature of documentation required. TPM is considered as an important tool in efforts needed to attain world-class manufacturing status; a status which enables companies to gain competitive advantage (McKone et al., 2001; Ahuja and Khamber, 2007) and facilitates cost reduction while improving quality and delivery of maintenance (McKone et al., 2001). Majority of manufacturing companies in Ghana are not thus experiencing the benefits that could be derived from total productive maintenance.

Contract Maintenance

Telang and Telang (2010) report that contract maintenance has made deep in-roads in the maintenance field. Results from the research confirm this observation on the Ghanaian manufacturing landscape. Both large and medium scale enterprises employ the services of maintenance contractors but of the two large scale enterprises form a majority (Figure 4.28). The contractors employed originate from both Ghana and abroad but majority of respondents prefer contractors stationed in Ghana. From Figure 4.29 some large scale enterprises strictly employ the services of contractors in Ghana; others prefer those abroad while a section employs local and foreign contractors. A greater percentage of large scale enterprises employ both local and foreign contractors. Medium scale enterprises on the other hand mainly utilize local contractors.

Challenges Encountered During Implementation of Maintenance Strategies

The general challenges facing respondents in implementing the various maintenance strategies include the following: cost of shut down, cost of spare parts, failure of maintenance staff to retain knowledge and skills acquired, lack of funds for maintenance, replacement of non-performing parts by contractors, techniques and tools used and staff training and benefits.

Cost of Shut Down

Respondents explained that shut down maintenance is a challenge because the quality of products produced for the market depends on the temperature at which the machines operate. Shut down maintenance allows the machines to cool. After maintenance, production is begun with equipment operating below their required temperatures. From their experience, resources are wasted because a significant number of products, produced within the first few hours, are of inferior quality generating losses for the company.

Cost of Spare Parts

Respondents also cited increasing cost of spare parts as a challenge as well as their delay in lead times of delivery.

Failure of maintenance staff to retain knowledge and skills acquired

Respondents cited the retention of knowledge and skill of maintenance staff as a challenge. In their account, maintenance staff failed to repair some machines on which they had been given training because they had forgotten the skill and knowledge acquired by the time it was needed. They attributed the failure of the maintenance staff to the nature of training they received. This phenomenon buttresses assertion by Barr (2000) that the time at which Ghanaian enterprises most actively accumulate knowledge is when they invest in physical capital. He also asserted that firms usually receive technical training and support when they import new equipment. To solve the problem, the companies resort to contractors, an action which adds to their maintenance costs.

It can be recalled from the results that only 10% of respondents train staff every six months, majority (63.4%) train them on the job mainly during installations and 3.3% give no training at all. It is the inefficient method of training implemented by companies ,within the survey, that is generating the problem and hence revision of the nature of training of staff is required. Lack of expertise is necessitating the need for contract maintenance.

Lack of Funds for Maintenance

Some maintenance heads also complained of lack of and sometimes late release of funds for maintenance from management. They attributed this to management's lack of understanding of how the maintenance systems work.

Replacement of Non-Performing Parts by Contractors

Respondents who employ the services of contractors revealed that contractors in Ghana are usually representatives of foreign companies abroad. The major challenge faced by respondents is that representatives are often reluctant to replace non-performing parts due to the extra expenses they incur. When they agree to replace the faulty part the time taken is prohibitive. Down time generated by this delay increases production cost.

Techniques and Tools Used

It is evident from the low percentages from the results that manufacturing companies generally do not use the common high end technological techniques and tools for maintenance activities. Where they are used the results show that they are mostly used by the large scale enterprises.

Staff Training and Benefits

Manufacturing companies in Ghana train maintenance staff during scheduled periods fixed for the maintenance department. However, training is not regular, does not follow any specified schedule and has no means of evaluation. Training mainly occurs on the job or whenever there is an installation of new equipment or spare parts. It is observed from Figure 4.31 that large scale enterprises form the majority of respondents who train maintenance staff every six months and at other times (mainly on the job, i.e. during installations). Again, medium scale manufacturing companies also train on the job and prefer to train maintenance staff annually. It is bad practice that some large scale companies give maintenance staff no training at all.

Information from the firms indicate that companies still have problems with expertise despite having maintenance staff. This is reflected in the number of respondents who use contractors. Haroun and Duffuaa (2009), in providing a solution to the problem, assert that solving performance problems and capitalizing on opportunities could be attained through selection of the right persons, with the appropriate capabilities, supported by continuous training and good incentive schemes, in order to achieve organizational success in terms of performance effectiveness and efficiency. They further assert that the increasing complexity and importance of maintenance engineering warrants a marked increase in training of machine operators and maintenance craftsmen through formal school courses reinforced by informed instruction by experienced supervisors. In addition they suggest that employers not only select and place personnel but should also provide facilities for their further training so as to increase individual proficiency and recruits for supervisory and senior grades. For senior staff, refresher courses comprising of lecturer on specific aspects of their work can be adopted while they are also encouraged to interchange and discuss ideas. Finally, they enjoin all organizations to develop well defined training and evaluation programs for each employee.

5.7 INFRASTRUCTURE AND SPARE PARTS

Workshops play an important role in maintenance of production equipment. Eighty percent of respondents have maintenance workshops with required machines. However, some workshops are not utilized as they are supposed to. It was also observed that most maintenance activities take place on faulty or broken-down equipment. Only minor works

take place within the workshops. Further, much attention is not paid to regulation and documentation of activities in the workshops possibly because major activities do not occur there.

Further, majority of the respondents consisting mainly of large scale manufacturing enterprise (Figure 4.34) operate stores for the maintenance. However, only a few (23.3%) use CMMS to procure spare parts for maintenance. Results (Figure 4.35) show that this percentage is comprised of equal numbers of both medium and large scale manufacturing companies. Interaction with respondents revealed that the documentation in the stores is done manually. The benefit of utilizing the CMMS software is lost to most manufacturing companies.

The research also shows that most respondents (36.7%), majority of which are large scale enterprises (Figure 4.36), purchase majority (55-85%) of their spare parts in Ghana. Further, medium scale enterprises purchase 85-100% of their spare parts in Ghana. Again, majority of respondents (66.7%) purchase their needed spare parts new. From Figure 4.37 the trend shows that the large scale enterprises form the majority of the respondents who use used, new and both new and used spare parts and an especially large majority of those who purchase used spare parts. It can be inferred from the information obtained that maintenance activities in Ghana have provided employment opportunities in the area of provision of services and equipment.

In addition, it was observed that "cannibalism", a system where parts from old and nonfunctional equipment are used to service a working equipment to facilitate the reduction of maintenance cost exists in manufacturing industries. Sixty three point three

percent of the respondents practice it as a cost reduction and time saving measure and large scale enterprises form the majority of the practitioners of this system (Figure 4.38).

5.8 SAFETY MANAGEMENT

Most (96.7%) of the respondents have safety policies. From Figure 4.39 all large scale companies have safety policies. Of companies with safety policies, it was found that, it is a requirement for all workers to wear protective clothing and equipment during maintenance. Majority of respondents have some punitive measures to ensure compliance. The punitive measures take the form of queries, suspensions and small deductions in salaries. From Figure 4.41, large scale enterprises formed a majority of this category of respondents with punitive measures.

The major challenges companies have implementing safety management policies mainly came from the workers who constantly and deliberately refuse to wear personal protective equipment and complain of discomfort. Some (57%) respondents also cited high cost of equipment as a challenge. From the complaints given it is evident that most companies have the policies but punitive measures are not stringent enough to ensure compliance.

5.9 MAINTENANCE PERFORMANCE MEASUREMENT

From the results obtained, manufacturing companies within the survey undertake maintenance performance management and majority (36.7%) do it monthly. The large scale enterprises form the majority of respondents who undertake performance measurement annually and at other times but especially do it weekly. Medium scale enterprises mainly prefer to undertake theirs monthly as shown in Figure 4.43. The major

benefit derived by companies within the survey is the ability to effectively monitor and improve maintenance activities. Reduction in maintenance cost is the next major benefit being derived. It was observed that respondents do not use the measurement to revise resource allocations.

According to Coetzee (1999) the main purpose for undertaking maintenance performance measurement is to assist strategic management in identifying trends and using them for directing the company and also to assist them to take corrective action where necessary. The results from the research show that this purpose is being achieved.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This research has focused on the status of maintenance management of production equipment in manufacturing companies in Ghana. The researcher employed a survey of 30 companies in Kumasi, Accra and Tema to enable him collect data. Stata 10, a general-

purpose statistical software package was used to analyze the results. From the results obtained the following conclusions are made.

1. Majority (60%) of respondents in the survey are private and use semi-automatic processesfor production.
2. Companies undertake regular maintenance and most have adopted a combination of maintenance strategies to suit the different equipment and machinery used for production. However, on an individual basis, the most common maintenance system (60%) being utilized by respondents is preventive shut down. This is closely followed by preventive routine (56.7%) and contract maintenance (50%) systems respectively. The trend observed is that more large scale companies undertake regular maintenance activities than medium scale companies.
3. Maintenance activities among respondents are organized and documented. Majority (66.7%) of respondents operate centralized maintenance organization. Majority (83.3%) of respondents also retain maintenance departments which use request forms. The major maintenance procedure employed is standing order. Again, companies document the maintenance procedure and activities manually. The concept of integrating computer maintenance management software as a facilitating tool is yet to catch up with manufacturing companies in Ghana. It is however used on a low scale for documentation in stores procedures for the management of spare parts.
4. Maintenance activities incur cost and this can be a significant factor in an organization's profitability. Maintenance cost as a percentage of turn-over could not be determined due to lack of input from respondents.However, from other

pieces of data collected, it can be concluded that among labour, electricity, outsourcing, etc, labour stands out as the major cost element of maintenance.

5. Despite delays in release of funds for maintenance there is a good working relationship between management and staff of the maintenance department promotes good maintenance.
6. Within the manufacturing industry, companies train maintenance staff mainly on the job especially during installations and repair of faults. This, from the results, has proved to be an inefficient method of training and has not contributed to effective and efficient maintenance of production equipment.
7. Contract maintenance has made in-roads into maintenance management in Ghana. Majority (50%) of respondents give out at least 30% of their maintenance to contractors, majority (63.3%) of who are based in Ghana. Twenty three point four percent utilize both Ghanaian and foreign contractors.
8. Maintenance activities are not characterized by the use of modern tools and techniques. Only a few (30%) respondents utilize them. Reasons attributed to this include lack of relevance to maintenance activity, cost, expertise to calibrate, expertise to use the techniques and time spent in waiting for results (users of SOAP).
9. There exists adequate infrastructure to support maintenance activities within the manufacturing industry. Firms, however, do not actively use their workshops for maintenance because maintenance is mostly carried out on the equipment. Spare parts are acquired new most of the time and most firms procure majority of their spare parts in Ghana. In addition, "cannibalism" is actively practiced in the manufacturing industry.

10. The research shows that none of the companies within the survey have achieved the ISO 18001 status. Respondent companies utilize internal safety policies and offer protective clothing and equipment to staff but lack strong stringent measures to ensure compliance by staff.
11. Firms measure their maintenance performance with most of them doing it monthly. Further, most (56.7%) respondents undertake performance evaluation in order to effectively monitor and improve their maintenance activities.

6.2 RECOMMENDATIONS

Based on the results obtained from this work the researcher would like to make the following recommendations:

1. One of the objectives of the research was to determine the cost of maintenance as a percentage of turn-over. Determination of this value would have gone a long way to give a picture of how much manufacturing industries are spending on maintenance. This could not be achieved due to lack of cooperation between the respondents and the researcher. As a result no effective measures could be suggested. The researcher experienced at first hand the barrier that exists between academia and industry. It is therefore recommended that the university increases its efforts at bridging this gap to facilitate research.
2. The research work focused on companies within the formal sector (registered with the Registrar General's Department). Therefore the results apply only to manufacturing companies within the formal sector of Ghana. To gain a more complete picture of maintenance management in manufacturing industry in Ghana,

it is recommended that further research be conducted to include those in the informal sector.

3. On interaction, it was observed that respondents are satisfied with the maintenance system they operate. Apart from one respondent who was actually implementing TPM, only one other was initiating the process. In addition to the fact that they exhibited some knowledge of TPM further education and encouragement is required to draw their attention to its objectives, benefits and experiences companies in the Western world have gained from implementing it.
4. Training of maintenance staff within manufacturing industries was observed to be below expectation. They were therefore losing benefits including reduction in maintenance they could have derived from training. It is therefore recommended that manufacturing industries develop standard and current maintenance training modules and train staff regularly to enhance their effectiveness.
5. It is recommended that management of manufacturing companies in Ghana increase their efforts to ensure compliance with safety regulations and policies to prevent unnecessary injury and death. In addition, they should make it a priority to attain the ISO 18000 certification.

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APPENDIX RESEARCH INTO THE ENGINEERING MAINTENANCE OF PRODUCTION
EQUIPMENT IN GHANAIAN MANUFACTURING INDUSTRY SURVEY QUESTIONNAIRE

The researcher is a postgraduate student at the Mechanical Engineering Department of the Kwame Nkrumah University of Science and Technology. This questionnaire seeks to gather information to help determine the status of engineering maintenance of production equipment in manufacturing industries in Ghana. It is hoped that the research would unearth maintenance-related challenges facing Ghanaian industries so that remedies could be sought.

A. COMPANY INFORMATION

1. Name: ……...
2. Region: ……
3. Your industrial sector: please tick below (√)

Industrial sector	
Textile	
Metal working	
Food processing	
Consumer goods	
Pharmaceutical goods	
Automotive	
Chemical	
Other (please specify):	

4. How many employees does your company have? ……
5. What is the annual turnover of your company? GH¢……
6. Form of ownership of company: please tick (√) below as appropriate

State-owned	
Private ownership	
Joint-venture (Ghanaian-foreign)	
Joint –venture (Ghanaian)	
Public limited company	

Other (specify)	

B. EFFECTIVENESS OF MAINTENANCE ORGANIZATION

Please tick (√) where relevant

1. Do you have a maintenance department? ☐ Yes ☐ No
2. If no, why
   ……
   ……..
3. Which type of maintenance organization does your company use? Partially decentralized
4. Is ☐ Centralized ☐ Decentralized ☐ the maintenance department normally involved in or consulted in the selection of new or replacement equipment? Yes No
5. If no why……..
   ……..
   ……..

C. PLANNED MAINTENANCE PROCEDURE AND DOCUMENTATION

1.	Which type of work order system does your company utilize?		Standing		Direct work
2.	Has your company integrated a computerized maintenance management system (cmms)?		Yes		No
3.	If yes, has the integration of CMMS improved the documentation and procedure of maintenance activities?		Yes		No

D. MAINTENANCE COST

1. What is the annual maintenance cost incurred by the company? GH¢									
2. What proportion of the maintenance cost can be attributed to the following?									
Spare parts	%	Labour	%	Electricity	%	Outsourcing	%	Other :	%

E. MAINTENANCE INCENTIVES

1.	Does your company have an incentive policy for maintenance staff?		Yes		No
2.	What form does the incentive take?		Financial		Non-financial
3.	Does the implementation of the incentive policy result in improved maintenance output desired by your company?		Yes		No

F. MAINTENANCE SYSTEMS AND STRATEGY

1. Please tick (√) below to indicate which maintenance system(s) are employed by your company

Maintenance category	Maintenance system or strategy	Sub system	Aware of	Adopted
Run to failure	Emergency			
	Breakdown			
Planned maintenance	Predictive	Statistical-based		
		Condition-based		
	Preventive	Running		
		Routine		
		Opportunity		
		Shut down		
	Improvement	Design out		
		Shut down		
	Corrective	Deferred		
		Remedial		
		Shut down		
	Total productive			
	Contract			

2. What are the major challenges your company faces in applying the chosen maintenance strategy / strategies? ……..
3. What is the level of automation of the manufacturing process of your company? Manual ☐ Semi – Automated ☐ Fully Automated
4. What proportion of your total maintenance and repair operation is conducted inhouse? 0% ☐ 20% 50% 70% 100% Other: ….% ☐

5. What is the location of the maintenance contractor performing the other maintenance activities? ☐ In Ghana ☐ Abroad

6. Please indicate by ticking (√) the testing devices and techniques used for maintenance operations whether by contractors or by the company's own technicians

Device	Function	Used
Boroscope	Aids visibility of inaccessible parts	
Flexiscope	Aids visibility of inaccessible contoured surfaces and u-bends	
Liquid dye penetrant	Aids detection of surface cracks and porosity	
Ultrasonic corona detector	Aids listening to the "carona" in the voids in the cables which can damage insulation	
Ultrasonic Hardness tester	Used to read surface hardness in Rockwell C	
Creep tester	Measures changes in dimensions of equipment	
Tension checker	Used to check tension in driving belts of equipment	
Laser beam source and detector readout	Permits alignment of shafts	
Pistol grip static meter	Measures electrostatic charge on surfaces	
Portable sonic resonance meter/tester	Measures thickness and soundness of wood or concrete	
Eddy current tester	Detects tiny discontinuities on or under the metal surface	
Pencil probe leak detector	Detects Freon leaks	
Thermopile heat flow sensor	Aids determination of heat loss due to insulation	

Technique	Function	Used
Magnetic particle detection	Locates surface and sub-surface discontinuities	
Radiography	Facilitates location of defects	
Thermal testing	Measures of temperature indicating abnormal working conditions	
Acoustic emission testing	Detects minute increasing flaws such as cracking development	

Holography	Detects debonds within honeycomb core structures	
In situ metallography	Monitors metallurgical changes such as intergranular cracking	
Strain monitoring	Monitors parts subject to strains during operation	
Vibration monitoring	Facilitates pin-pointing the causes of vibrations	
Spectrometric oil analysis procedure (SOAP)	Aids monitoring of the condition of machines by analyzing the concentration of metal elements in oil samples taken	

7. What are the major challenges associated with the use of testing devices and techniques adopted?……

G. STAFF TRAINING

1. How regularly are maintenance staff trained?

☐ Every six months ☐ Annually ☐ Other (specify):

2. Which of the following benefits of maintenance training can you claim?

☐ Improved efficiency ☐ Reduction in maintenance cost
☐ Reduction in level of supervision ☐ Other:……

H. INFRASTRUCTURE AND SPARE PARTS

1.	Does your company have a maintenance workshop?		Yes		No				
2.	Does the company use request forms for the use of the workshop?		Yes		No				
3.	Does your company have a store for the maintenance department?		Yes		No				
4.	Do you use information from the CMMS to determine the time and parts to procure?		Yes		No				
5.	Is it the practice to use parts from old or unused machines		Yes		No				
6.	What percentage of spare parts do you procure in Ghana?								
	0-25%		25-55%		55-85%		85-100%		
7	Describe the quality of spare parts purchased in Ghana?								
	Used parts				Brand new parts				
8.	What is the lead time for delivery of parts to your company?								
	A week		Less than 3 Weeks		A Month		Other (specify):		

I. SAFETY MANAGEMENT

1.	Does your company have a safety policy?		Yes		No
2.	Is it a requirement for all workers to wear protective clothing and equipment during maintenance?		Yes		No
3.	Is there some punishment for workers who do not adhere to the safety policy?		Yes		No

4. What challenges do you face in executing the safety policy during maintenance?……..……
……..
……..

J. MAINTENANCE PERFORMANCE MEASUREMENT

1. How often is maintenance performance evaluated or measured? ☐ Weekly Monthly ☐ Annually ☐ Other (specify):
2. Which of the following has been the outcome of maintenance performance measurement? Please tick (√) where applicable.

	Measuring the value created by maintenance and justifying investment
	Revising resource allocations
	Adapting to new trends in operation and maintenance strategy
	Effective monitoring of and improvement in maintenance activities
	Reduction in maintenance cost
	Changes in health and safety and environmental policy
	Other (specify)