AKENTEN APPIAH MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT, KUMASI

ASSESSING CONSTRUCTION EQUIPMENT MAINTENANCE PRACTICES FOR MEDIUM SCALE CONSTRUCTION FIRMS: A CASE STUDY OF TAMALE METROPOLIS

ABDULAI KAMARADEEN

SEPTEMBER, 2021

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A THESIS SUBMITTED TO THE DEPARTMENT OF CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, FACULTY OF TECHNICAL EDUCATION IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF CONSTRUCTION TECHNOLOGY (CONSTRUCTION OPTION) DEGREE

SEPTEMBER, 2021

DECLARATION

I, ABDULAI KAMARADEEN, declare that this Dissertation with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:…………………………………………………..

DATE:…………………………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba

NAME OF SUPERVISOR: DR. PETER KOFI YALLEY

SIGNATURE:……………………………………………………….

DATE:……………………………………………………………

DEDICATION

This thesis is dedicated to all my family members, especially my Father – Tali Dingonnaa (Abdulai Imoro), my younger brother – Mr. Taajudeen, my wife (Fatahiya), children – Abdul –Hakeem Wunnam, Abidatu Tipagya, Ismah Tungteiya and Adamu Nasara.

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ABREVIATIONS

1. MSCF – Medium Scale Construction Firms
2. EMI – Effective Maintenance Implementation
3. GDP – Gross Domestic Product
4. IASP – International Accepted Standard Practice
5. PP – Practice of Professionals
6. PPM – Planned Preventive Maintenance
7. PCM – Planned Corrective Maintenance
8. BM – Breakdown maintenance
9. PM – Preventive Maintenance
10. PdM – Predictive Maintenance
11. CBM – Condition-Based Maintenance
12. CM – Corrective Maintenance
13. MP – Maintenance Prevention
14. RCM – Reliability Centered Maintenance
15. FMEA – Failure Mode and Effective Analysis
16. FMECA – Failure Mode Effect and Critical Analysis
17. PHA – Physical Hazard Analysis
18. FFA – Fault Tree Analysis
19. OMF – Optimizing Maintenance Function
20. HAZOP – Hazard and Operability Analysis
21. PrM – Productive Maintenance
22. CMMS – Computerized Maintenance Management Systems

23. TPM – Total Productive Maintenance
24. WCM – World Class Manufacturing
25. RM – Risk Management
26. RoSPA – Royal Society for the Prevention of Accidents
27. SME – Small Medium Enterprises
28. GDHS – Ghana Demographic Health Survey

ABSTRACT

The role of construction equipment in the execution of construction projects can never be overemphasized. Construction equipment plays a very vital role in most construction projects execution as it is the bedrock for the success of project execution. Despite this, the continues increase in the size of Construction Firms also leads to increase in the use of Construction Equipment but does not match with a corresponding increase in its equipment maintenance. This, however, overstretches equipment usage with thin or no maintenance of these equipment resulting to the breakdown or low efficiency of the equipment. This research was to assess construction equipment maintenance practices of medium scale construction firms in the Tamale Metropolis. The study adopted a cross-sectional survey design. The target population of the study was management, staff and operators operating medium scale firms and in the Tamale Metropolis. Purposive sampling technique was used to select sixty respondents comprising forty Management and twenty staffs and operators of Medium Scale Construction Firms in Tamale for the study. Twenty-seven were retrieved but two were rejected during the analysis on the basis that it was incomplete responses. The major techniques or tools used in collecting data in this research were questionnaire, interview and observation as the study intends to examine the level of effectiveness of the recent available equipment maintenance systems applicable to Medium Scale Construction Firms and recommendations that would assist in improving safety and efficient firms in the Tamale Metropolis. The descriptive survey was found most appropriate. Twenty-five questionnaires were used for the analysis representing a response rate of 41.6%. The findings of the study revealed that some MSCF in the Tamale Metropolis do not practice equipment maintenance as it should have

been due to either financial constraints, inadequate data and lack of maintenance professionals. The study concluded by outlining a number of recommendations which were aimed at providing solutions to the premature breakdown of some equipment by some MSCF in the Tamale Metropolis. The provision of maintenance policies should be part of the criteria in the selection of the constructional firms for any project in the Tamale Metropolis, Monitors of constructional projects should insist on equipment maintenance practices and policies etc.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Shelter is one of the basic needs of man and ranks next only to air, food, water, sleep and constitutes the largest expenditure item of an average household (Kendra, 2022) . Here in our country, Ghana, the rapid rate of population growth and urbanization has made the demand for construction of all kinds of structures for various uses to become many and varied. With this, comes an increasing usage of complex construction equipment.

Increased Mechanization and Technology deployment has resulted in a wide plethora of construction equipment of varying design, capacities or capabilities been employed. Owing to the increase usage of construction equipment, the equipment maintenance is thin and mostly missing.

With the development of technologies and availability of various types of construction machineries, its use in the Construction Industry is increasing day – by – day.

Accordingly, equipment is one of the key factors for improving contractor‘s capability in preparing their work more effectively and efficiently(Day and Benjamin, 1991). With the advent of heavy construction equipment and the approach of large construction company of converting the construction sector to a more mechanized and in turn an organized sector, has made it mandatory for maintaining the fleet of equipment to perform to its optimum function (Subburaj, 2006). Good maintenance engineering is essential to the success of any Construction Firm 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 flows and recommend solid, practical solutions

(Dame Wood, 2010).Accordingly, since plants and equipment which have become an integral part of any construction activity, and plants and equipment now constitute a substantial portion of the construction cost in a project in the tune of 10 to 30 percent (%) of total project cost depending upon the extent of mechanization, they need to be maintained to turn the project into a profit making centre for any organization (Subburaj, 2006).

Underestimating the importance of equipment maintenance is taking a toll on your bottom line. The saying ―if it is not broke, don‘t fix it" is too often the way some view construction equipment maintenance (Bruketta 2018). Why would you pay for service on your equipment if there is nothing wrong with it? Believe it or not, there are several reasons (Bruketta 2019). Construction equipment is an investment — one that requires time and money to keep in optimal shape. When equipment runs efficiently, projects get done on or ahead of schedule, and your bottom line does well (Bruketta 2019). Keeping that optimal, like-new condition is key to maintaining that level of equipment efficiency. If maintenance suffers, so does efficiency. When efficiency suffers, so does your bottom line (Bruketta 2019).

According toTatori and Skibniewski (2006), construction equipment is one of the most important physical asserts in a construction firm. It plays an important role in construction operations and constitutes a major portion of construction projects. Research of an Effective Maintenance Implementation (EMI) has reported that the main problem faced by Developing and Developed Countries is the lack of proper maintenance culture (Martin, 2003).Preventive Equipment Maintenance is key to extending equipment life and ultimately saving you time and money. While the perception may be that paying for preventative maintenance is unnecessary spending, the reality is that without it, the company is often left with more expensive repairs. The importance of preventive maintenance is too huge and can never be overemphasized.

There is no equipment that can operate 100 percent (%) efficient and these buttresses the fact that only equipment, no matter its present or recent reliability status, can breakdown (Yannis and Mackwanzie, 2003). Maintenance is a system which requires investment and when properly implemented, will;

- Provide reliable equipment that are safe, well configured and able to achieve only delivery of orders to customers
- Minimize equipment life cycle cost.

Maintenance means to maintain and improve the quality of the elements involved in production process, continuously and cost – effectively through detecting and controlling the deviations in the condition of a productive process that is decided by production costs, working environment and product quality. In order to interface when it is possible to arrest or reduce component/equipment deterioration rate before the present condition and product characteristics are intolerable affected and to perform the required action to restore the equipment/process or a part to be good as new (Al- Najja, B, 1995).

In Ghana, Researchers and Industry Professionals identify construction resource to include time, capital, labour, equipment‘s maintenance and material. Recently, attention has been to information as being vital resource in construction operations. One of the most important construction resources that have been for long overlooked is equipment maintenance practices (Sharm, 2010). Accordingly, equipment maintenance practice has been the most neglected aspect in the Construction Industry in Ghana and the attitude of

Engineers and Contractors has been that it will be done as the project progresses. Stakeholders in the construction equipment business know the old sayings ―an ounce of prevention is worth a pound of cure" and ―a dime of routine and preventive maintenance is worth a dollar in repairs." (―Construction Equipment Maintenance," n.d). And then there‘s the adage, ―If it not broke, do not fix it." The first two are true, but the last phrase should be the furthest thing from a construction equipment service person‘s mind (―Construction Equipment Maintenance," n.d).

Routine maintenance and preventive maintenance go hand-in-hand (―Construction Equipment Maintenance," n.d).They are extensions of the same term. Both aim at keeping equipment running smoothly and avoiding costly repairs that suddenly take it out of service. The believe, is that preventive maintenance goes further than routine and scheduled tasks. Service technicians and mechanics often anticipate potential problems and nip them before serious damage occurs.Construction equipment maintainers look at repair work as proactive and reactive. They also call it scheduled and unscheduled repairs (―Construction Equipment Maintenance," n.d). Proactive maintenance is far more cost-effective than reactive, post-breakdown repair. Routine and preventive maintenance saves construction companies enormous sums compared to suffering expensive parts replacement and costly downtime when unexpected failure suddenly happens (―Construction Equipment Maintenance," n.d).There are many definitions of maintenance but a more comprehensive one given by British Standard Glossary of terms (3811: 1993), as cited in 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 activities.

The Technical activities are classified under Maintenance Engineering and deal with the actual tasks carried out on equipment while the Administrative activities are classified under Maintenance Management and basically deals with the management aspects of maintenance (Thomas, 2014). 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 organizations. (Telang and Telang, 2010).

According to British Standard Glossary of terms (3811: 1993), activities of maintenance function could be either repair or replacement activities, which are necessary for an item to reach its acceptable productivity condition or these activities, should be carried out with minimum possible cost.

1.2 Statement of the Problem

The construction industry is striving to keep up with the increasing demand for housing and commercial and industrial space while simultaneously protecting the physical environment and social well-being of the country – a challenge becoming known in the industry as ‗sustainable construction' (Kwaku Ahmed etal, 2014). The Construction Industry is classified as one of the largest industries in Ghana.

According to Ghana Web (Sun, 14 April, 2013), Tamale is one of the fastest growing cities in Ghana. It is a cosmopolitan city and as such it comprises of different people from different background hence leading to the establishment of so many Construction Firms in the city. Accordingly, the concept of construction equipment maintenance at the medium scale sector in Ghana is a crucial component of equipment practices. It is reported by the Ghana Statistical Service (2010) that the Construction Industry constitutes about 2.9% of Ghana‛s Gross Domestic Product (GDP).

The continues increase in the size of Construction Firms also leads to increase in the use of Construction Equipment but does not match with a corresponding increase in its equipment maintenance (Mohamed Ben-Dayaetal, 2009). This, however, overstretches equipment usage with thin or no maintenance of these equipment resulting to the breakdown or low efficiency of the equipment. Every operator and mechanic knows that catastrophic failure can set off a chain of events that damages other equipment parts. What could have been an inexpensive part replacement at an early intervention stage would have prevented a complete system failure like a blown engine or ruptured hydraulics. Expensive downtime always accompanies extensive downtime. Many experienced mechanics in the equipment maintenance field say repair costs and downtime length are directly proportional (―Construction Equipment Maintenance," n.d). When equipment suddenly fails, there is no choice but to pull it from service. That leaves the machine unable to perform its task and support other machinery on the job. It also leaves a paid operator sitting idle. Unavailable machinery costs money. It doesn‛t make money until it is fixed and back to work. Good preventive maintenance makes sure equipment is always available except for scheduled servicing.

Unexpected breakdowns neither planned events nor are they planned expenses. Every profitable heavy equipment company works with budgets. Scheduled routine and preventive work fits into a budget and it is anticipated that sudden breakdowns often go beyond budget allowances. Repair costs added to lost income due to equipment unavailability compound into pricey expenses that may have been avoided with routine maintenance. Equipment maintenance practice has been a greater challenge to most medium scale construction industries in Tamale to embark on. They hardly assess the status of their plants and equipment to ascertain the efficiency and other related problems associated to the equipment for better solutions. Accordingly, construction businesses fail at the rate of 1.4 times the national average and 37 percent (%) of these failures have been in the construction business for 10 years or more (CPWR, 1998). The high failure rate and extreme competitiveness of the construction business demands that contractors continuously looking for new but cheaper ways to reduce cost thereby spending more at the end .Reliable machines are safe machines. Making sure all construction equipment is routinely repaired and maintained in excellent condition significantly adds to its safety. Sudden component failure can cause dangerous conditions to workers as well as presenting unsafe environmental hazards (―Construction Equipment Maintenance," n.d).Keeping construction equipment safe is part of a preventive maintenance program.

It is imperative to carryout regular checks and problems associated with heavy construction equipment to increase productivity and decrease loss (Hartmann, 1992). Building/Civil researchers, Engineers and Developers have put in place policies and programs to promote maintenance policy systems throughout the world (Cook, 1999). Realization of these policies include specifications failures on heavy Constructional Equipment put in place by various countries for developers to follow in reducing premature breakdowns. Routine is the key word in every preventive maintenance program. Performing routine tasks like oil changes, lubrication and tire or track inspections are part of a regular heavy equipment maintenance program. There is more to a thorough and comprehensive maintenance plan. It involves detailing routine tasks on a construction equipment preventive maintenance schedule so they will not be overlooked at specific milestones (―Construction Equipment Maintenance," n.d).

Preventive maintenance takes a team approach to properly looking after equipment. It involves following the original equipment manufacturer's recommendations as well as applying what a specific company's experiences tell it about a particular piece of machinery. Effective preventive maintenance also includes input from operators and front-line mechanics. No one knows equipment better than the people who build it, run it and repair it. The Medium Scale Construction Firms (MSCF) in the Tamale Metropolis were observed to be owned quite amount of construction equipment but output comes to a standstill which is strongly believed to be caused by unplanned routine maintenance policies in place. By anticipating and preventing these unplanned events, a company can protect its equipment assets from production downtime, unscheduled loss or expensive failures, while improving safety factors (Hartmann, 1992). Accordingly, Skones and Littleman (2015) lament the paucity of literature on Equipment Maintenance in developing countries including Ghana. Owners of Construction Firms in Tamale accords little attention to equipment maintenance despite its usefulness to the Construction Industry. In considering this gap and the ultimate disastrous outcome of the aforementioned construction equipment maintenance challenge of some Construction Firms in Tamale, this dissertation seeks to address some of these equipment maintenance problems by assessing the current practices and challenges and identified the gaps between the globally accepted conventional practices and the practices of professionals in the area of study.

The importance of equipment in the construction industries can never be over emphased. Despite its importance, the attention researchers give to it leaves much to be desired. Skones and Littleman (2015) lament the paucity of literature on Equipment Maintenance in Developing Countries including Ghana. In view of this gap and the unfortunate and dire consequences poses to most Construction Firms for the lack of Construction Equipment Maintenance, this research attempt to address the problem by assessing the Equipment Maintenance practices and the challenges. The study will also identify the gaps between the International Accepted Standard Practices (IASP) and the Practices of Professionals (PP) in the area of study.

1.3 Purpose of the Study

The purpose of this study is to assess the practices of Equipment Maintenance by Medium Scale Construction Firms in the Tamale Metropolis of Ghana. The study aims at addressing the status of Equipment Maintenance practice employed by Medium Scale Construction Firms in the Tamale Metropolis, examine the level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms and also identify some recommendations that will improve Construction Equipment Maintenance practices on MSCF in the Tamale Metropolis.

1.4 Objectives of the Study

The following are set of objectives aided in achieving the purpose of the study;

- To assess the status of Equipment Maintenance practice employed by Medium Scale Construction Firms in the Tamale Metropolis
- To examine the level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms
- To identify some recommendations that will improve Construction Equipment Maintenance practices on MSCF in the Tamale Metropolis.

1.5Research Questions

In relation to the aforementioned problem statement, the following research questions were proposed;

- What is the status of Equipment Maintenance practice employed by Medium Scale Construction Firms?
- What is the level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms?
- What recommendations will improve Construction Equipment Maintenance practices on MSCF?

1. 6 Significance of the Study

The study was informed by the little attention given to Equipment Maintenance by Medium Scale Construction Firms (MSCF) in the Tamale Metropolis of Ghana.

The outcome of the study will be of significant benefit to the actors in the Ghanaian Construction Industry such as the Contractor, Site Engineer, Maintenance Engineer and all other workers of any construction project in this country. It will also provide relevant information on the assessment of current maintenance practices as part of construction processes. On the MSCF's, it will bring to bear the effectiveness and efficiency the current maintenance systems applicable to MSCF. Again, it will outline some factors that one has to consider to improve construction equipment maintenance practices which will significantly change the attitudes of Construction Site Engineers in relation to equipment maintenance practices on how it is conceived and implemented.

1.7 Limitations

Compared to any other research, this thesis has its own genuine limits and extents. The limits hopefully would serve as guidance for future research. The limitations included;

- No published data was obtained on the perceived respondents of the research hence population was undefined and thus the research may not be wholly representative.
- Limited funds were another challenge as researcher needed enough funds to accomplish this dissertation.

1.8 Delimitations

This research was limited to various stakeholders in the Medium Scale Construction Firms and Civil Engineering Companies within the Tamale Metropolis who operate with Plants and Equipment and with a good standing and have registered with the Ministry of Roads and Transport.

It is my fervent hope that this study will reflect in totality of the Construction Industry in Ghana at large.

1.9 General Layout of the Study

This thesis consists of five (5) chapters.

- Chapter one introduced the research conducted. The background of the study was discussed. This chapter also discussed the statement of problem, the purpose of the study, research questions, and objectives of the study, significance of the study, limitations, delimitations and general layout of the study.
- Chapter Two discussed the review of literature on the subject. The literature review was an account of related works published by researchers in the area of study. The literature review also discovered the effects of not maintaining construction equipment.
- Chapter Three described the research methodology. The process of the research, research design, research style, and research approach were discussed in this Chapter. The sample population, sample size, the sampling technique and the development of the questionnaire were also described. The chapter explains methods that were used to analyze the data.
- Chapter Four provided descriptive analysis on the data collected. The appropriate relevant statistics used in analyzing and interpreting the collected data were discussed in this chapter.
- Chapter Five concluded the research conducted. Recommendations, findings and areas for future studies were well discussed in this final chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is a review of the various works that are relevant to the study. It covers the maintenance concept, significance of maintenance, maintenance practices, effective maintenance systems, factors to consider in maintenance, safety and risk consideration, equipment related accidents as well as management principles.

The study was to assess Maintenance practices of Medium Scale Construction Firms (MSCF) in Tamale, Ghana. It outlines the Equipment Maintenance challenges confronting the Construction Firms in the Metropolis and the negative effects it has in the Construction Industry.

2.2 Maintenance Concept

According to Ciprian (2015) the concept of maintenance in the field of complex equipment was developed in the USA being quickly adopted by European countries and Japan. The American maintenance concept has the significance of creating a support system for industrial equipment functioning. Functional maintenance is one of the most frequent used methods in maintenance management for industrial enterprises.

In an article written by Cabral (2016) on the topic ―Practical Guide to Facilities Maintenance Management"defines Maintenanceas the set of activities developed to ensure proper running of equipment and systems, ensuring that technical intervention is taken at the right opportunities with the right scope and in accordance with good technical practices and legal requirements. In order to avoid loss of function or reduction of efficiency and, should any of these occur, ensure that they are returned to good operating conditions at the earliest possible delay, all at an optimized overall cost.

According to AlirezaIrajpour et al (2014), Maintenance activities are classified as shown in Fig. 1 below:

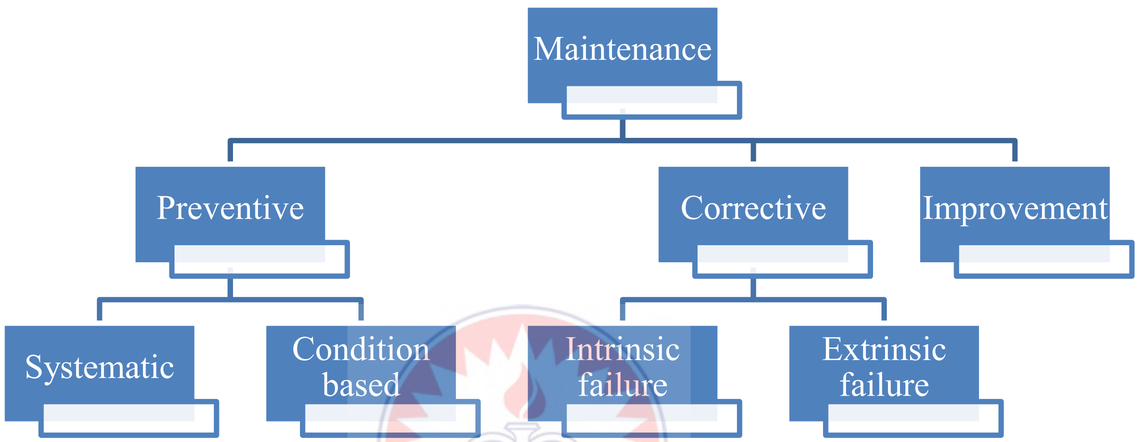


Fig 1.Maintenance Activities Hierarchy (AlirezaIrajpour et al 2014)

2.2.1 Preventive Maintenance

Preventive Maintenance is a schedulable type of maintenance that aims at preventing failures, loss or reduction of function. Prevention is always the prime objective of management. Preventive maintenance can be further classified in accordance with the nature of the originating conditions as:

- Systematic maintenance, also designated pre-determined maintenance, when the opportunity for the intervention is blindly determined, based on pre-defined frequency: calendar or running units (hours, km, cycles, etc). Typical title descriptions: Weekly inspection; Monthly lubrication; 10000 hours‘ overhaul; 20000 km service.

- Condition based maintenance, when the opportunity to carry out the work is based on symptoms detected along an inspection or running parameters, before loss or significant reduction of function. Typical title descriptions: Replace slack driving belt; Adjust valve; Replace bearing. (Kendall, 2017)

2.2.2 Corrective Maintenance

Corrective Maintenance is a non-schedulable maintenance action following a failure or unexpected loss of function which may have occurred as a result of:

- Intrinsic failure, a loss of function due to a cause intrinsic to the maintenance item: equipment broke down; pipe broke; overheated bearing.
- Extrinsic failure, a loss of function due to a cause external to the maintenance item: accident, collision, poor operation. Although penalizing the operational availability of the equipment this failure does not contribute to the theoretical maintenance indicators or intrinsic reliability of the item (WinWin, 2016)

2.2.3 Improvement Maintenance

Nowadays Improvement Maintenance is recognized and stimulated maintenance approach aimed at improving the performance of the equipment in its context (WinWin, 2016). It is schedulable. Typically, an improvement is identified and a modification is studied and planned to improve the running conditions, energy efficiency, and/or maintainability, among many others (WinWin, 2016)

Indeed, there is usually much scope for improvements in any industrial or facilities plant, as long as there is a basic positive attitude towards this approach: introducing automation; equipment monitoring; improving running efficiency; energy saving; reducing emissions; noise; improving accesses for maintenance; reducing maintenance necessities (WinWin, 2016).

Further to its strictly technical scope, maintenance covers nowadays a wide spectrum of activities related to the fulfillment of legal requirements, certification, safety, security and social sustainability – understood as the capability of the organization to exhibit and be in a position to demonstrate at any time that it runs its activities using practices that are safe, preserve the environment and are socially acceptable (WinWin, 2016)

These considerations and the technological profile of modern equipment explain why the maintenance function has become a first line activity requiring multi-disciplinary expertise, training of technicians and managers, involving a wide range of responsibilities in any organization. The times where maintenance was considered the poor partner in an organization and we had to convince the boss that managing it properly would bring significant advantage are far away. Neglecting maintenance management today may simply condemn the whole organization.

Accordingly, the idea of a maintenance concept and a resulting set of maintenance requirements build on the proven Systems Engineering approach. The systems engineering approach is recommended as the preferred method for developing Inteligent Transportation System (ITS) projects with Federal Highway Administration (FHWA's) Rule.Systems engineering is a structured technique for thinking about systems development and begins with a concept of operations (―Guidelines for Transportation

Management Systems Maintenance Concept and Plans" n.d). A "concept of operations" summarizes what the system is supposed to accomplish and under what conditions it will be done (―Guidelines for Transportation Management Systems Maintenance Concept and Plans" n.d). From this concept, a set of requirements can be developed. It is these requirements that drive the rest of system design and implementation.

A "concept of operations" is designed to articulate the vision, roles and responsibilities, practices, and procedures to be realized in a Transportation Management System (TMS) (―Guidelines for Transportation Management Systems Maintenance Concept and Plans" n.d). Likewise, the "maintenance concept" is designed to articulate the essential reliability and performance measures necessary to meet stated operational concepts. Just as the concept of operations drives the system functional requirements, the maintenance concept drives the Maintenance Requirements. These maintenance requirements then become enabling requirements for input into the system design phase and other implementation and operation phases in the TMS life-cycle (―Guidelines for Transportation Management Systems Maintenance Concept and Plans" n.d). The maintenance concept imposes a structured approach to the development of maintenance requirements that is traceable back to an operational concept.

According to Henze and Ashton (2002), Equipment maintenance is a science because it involves scientific and technical knowhow of different machineries involved and it is an art because for identical problem it may require different treatment or action process. We need equipment for technical and speedy construction and at the same time for economical and timely completion of project.

Wireman (2001) states that maintenance being an important support function in businesses with significant investment in plant and machinery plays an important role in meeting this tall order. Consequently, the equipment management has passed through significant changes in the recent times. In the present manufacturing scenario, the maintenance function has become an integral part of the overall profitability of an organization. The main purpose is to keep the equipment in good, serviceable condition. Therefore, equipment maintenance is a vital function in any contracting or plant hire company. This function includes all the activities such as daily and periodic inspection, lubrication, servicing, repairs and periodic overhauls.

Below are some of the usual maintenance practices adopted;

- Planned Preventive Maintenance (PPM)
- Planned Corrective Maintenance (PCM)
- Unscheduled or Unplanned Maintenance including repairs of breakdown maintenance.

Maintenance concept is a brief description of the maintenance considerations, constraints and plans for operations support of the system equipment under development. It is derived from the concept of operations (con ops) and is a major driver in system design and support. (Gits 2017). The primary process in an industrial organization is production in which the primary production input (material, energy and manpower) is transformed into the primary production output (the desired product). This transformation process makes use of technical systems. A technical system is a collection of physical elements fulfilling a specifiable function. The state of a technical system is the physical ability considered relevant to fulfillment of its function. External causes, ageing and use repair its state, inevitably leading to a secondary production output; maintenance demand. On being carried out, this leads to a secondary production input; that is potential production capacity. Maintenance is the total of activities required to retain the system in, or restore them to the state necessary for fulfillment of the production function.

Accordingly, maintenance is the act of preserving a particular asset in its original condition to prolong its useful life (Isermann, 1997). It is also the physical act of preventing, determining and correcting equipment or software faults. It includes all actions taken to retain the system/equipment/product in a useful serviceable condition (Guangyu 2012). It aims at ensuring plant availability, increasing production flow and outputs while decreasing failure of production equipment (Jarrell, 2001). The maintenance function is concerned with the aspect of decision – making that relates to effective maintenance, replacement and reliability of industrial equipment. These decisions relating to the maintenance of equipment often serves as guide towards ensuring proper maintenance implementation.

Just as it is done in product manufacturing, work maintenance should have scheduled inventories of spare parts at a maintained and prescribed level of maintenance quality (Isermann, 1997). The maintenance concept can tentatively be put forward as an idea or outline of the way maintenance will be conducted with supplemented information within the environment (Levis, 2003). This concept becomes the maintenance plan when the outline has finally been filled.

No one understands a machine or equipment batter than the manufacturer. Every single device in a machine or equipment is very important to the manufacturer or even the way a machine sounds during operation is crucial to the manufacturer. Machines are not just sold out to the general public or to Construction Companies unless it is thoroughly tried and tested its samples. A change of sound or a removal of a machine part means that machine no longer the way it was manufactured.

A continue or prolong use of an equipment is subjected to wear and tear and must be given proper attention it deserves. Not all machines or equipment are made by one manufacturer. There are a lot of manufacturers with different level of reputations. However, there are some common attentions that can be applied to all kinds of equipment of different brands.

A proper attention means, routine/regular inspection, cleaning, lubrication and systematic maintenance. When equipment runs efficiently, projects get done on or ahead of schedule, and your bottom line does well. Keeping that optimal, like-new condition is key to maintaining that level of equipment efficiency. If maintenance suffers, so does efficiency. When efficiency suffers, so does your bottom line.

2.3 Importance of Equipment Maintenance

According to mymbaguide.com (2021) Maintenance is a function which developed and progressed, knowingly or unknowingly, along with the operations of equipment. In early ages, maintenance was probably, not a separate identity but the job of maintenance was considered as part and parcel of operator‘s job. This was possible because of simplicity of machines and equipment.

In those days, nailing of a cracked wooden frame of a chariot or tying a broken or cracking piece with rope was done by the same person who was operating the chariot.

Thus, even the lubricator job which is basically a maintenance job, was done by the same person without giving the job a separate identity.

With the growth of industrialization, the complexity of the machines increased and the machines became less simple and less open. This started creating problems for the operating personnel and the concept of maintenance as a separate discipline was born. Further, the asset and equipment/component‘s replacement costs became so inflated that they necessitated a need to enhance the life of existing equipment and components, became the essential aspects of all management strategies.

The workforce and the materials must also be ‗maintained‘ through training, motivation, health care and even entertainment of the people and proper storage and handling of materials (**mymbaguide.com 2021)**. It is in this context that maintenance management assumes importance as an engineering function. It is made responsible for provision of a condition of these machines, buildings, and services that will permit uninterrupted implementation of plans requiring their use (**mymbaguide.com 2021)**.

According to **mymbaguide.com (2021)** Maintenance is an investment that fetches more production time. With the increase of complexity, sophistication and automation of equipment, a very serious burden now falls on the maintenance engineers regarding the quality and quantity of maintenance, maintenance aids and their documentation, etc. Problems of maintenance do not increase in linear proportions to the increase in production but increase in astronomical proportions. Accordingly, the major areas of maintenance are civil, mechanical and electrical.

2.3.1 Civil Maintenance

Civil Maintenance means the provision of all services required to maintain and preserve NCC physical infrastructures such as roadways, pathways, lights, fixtures and furniture, plumbing system. These includes maintenance service facilities such as water, gas, steam, compressed air, heating and ventilating, air conditioning, painting, plumbing and carpentry work. Also included in civil maintenance are janitor service, house-keeping, scrap disposal, fencing, landscaping, maintaining lawns, gardening, drainage and firefighting equipment (―Civil Maintenance Definition" n.d)

2.3.2 Mechanical Maintenance

In an industrial setting, it's important to keep machines operating at peak efficiency. And that's the goal of mechanical maintenance. These machines might include things such as a paper machine at a paper mill, a forming press, a robot, a forklift, a conveyor, or a palletizer--generally, any mechanical machine or tool used in an industrial setting.

Industrial plants often have a mechanical maintenance department, which is part of their overall maintenance unit and which will include one or more mechanical maintenance technician (―What is Mechanical Maintenance" 2020).

2.3.3 Electrical Maintenance

According to (Damewood, 2022) Electrical maintenance is the upkeep and preservation of equipment and systems that supply electricity to a residential, industrial or commercial building. It may be performed by the owner or manager of the site or by an outside contractor. The work is commonly performed on a schedule based on the age of the building, the complexity of the electrical system or on an as-needed basis.

The main areas of general electrical maintenance commonly include the power outlets and surge and protectors, generators and lighting systems. These supply sources are checked for structural integrity as well as internal stability. The maintenance plan normally includes the regular replacement of burned out fluorescent and incandescent lights. Many building managers in recent years have refitted their lighting systems with energy saving bulbs and elements.

Electrical generators, switches and circuit breakers are regularly checked for solid connections and intact wiring. If flaws are discovered, electricians normally make repairs. Depending on the condition of the wiring, the repairs are typically made by splicing wires together. In some situations, they are encased in metal tubing called conduit to protect them from wear. Keeping the wiring in good shape ensures a consistent flow of power to heating, ventilation and air conditioning systems.

2.4 Objectives of Maintenance

According to mymbaguide.com (2021) the main objectives of maintenance are as follows:

- To keep the factory-plants, equipment, machine tools, etc., in an optimum working condition.
- To keep equipment safe and prevent the development of safety hazards.
- To ensure specified accuracy to products and time schedule of delivery to customers.

- To keep the down time of machines to the minimum thus to have control over the production program.
- To keep the production cycle within the stipulated range.
- To modify the machine tools to meet the augmented needs for production.
- To improve productivity of existing machine tools and to avoid sinking of additional capital.
- To reduce the maintenance costs as far as possible thereby leading to a reduction in factory overheads.
- To minimize the total production or operating costs directly attributable to equipment service and repair.
- To prolong the useful life of the factory plant and machinery. Avoid postponing of incurring heavy capital expenditure involved in their replacement.
- To help management in taking decisions on replacement or new investment and to actively participate in specification preparation, equipment selection, its erection and commissioning, etc.
- Development of resources for equipment and spares and providing technical help for vendor development and rating and import substitution.
- Help in implementation of suitable procedure for procurement, storage and consumption of spares, tools and consumables, etc.
- Standardization of spares and consumables in conformity with plant, national and international standards and help in adoption of these standards by all users in the plant. Also help in variety reduction and inventory control.
- Help in training and development of skilled workmen and executives.

Furthermore, according to Gopalakrishnan and Banerji, (2004), Santiago (2010) and Telang and Telang (2010), the objectives of equipment maintenance are to;

- ❖ Ensure maximum availability of plant, equipment and machinery for productive utilization through planned maintenance
- ❖ Maintain plant, equipment and facilities at an economic level of repairs at all times to conserve and increase their lifespan
- ❖ Provide the deserved services to operating departments at optimum levels, through improved maintenance efficiency
- ❖ Provide management with information on the cost and effectiveness of maintenance and
- ❖ Achieve all the above - mentioned objectives as economically as possible

More so, 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 cost.

2.4.1 Minimization of Downtime

According to (―Five Ways to Minimize Manufacturing Downtime" (2013), minimizing manufacturing downtime means preventing machinery malfunctions. Outdated machines slow down the manufacturing process. Similarly, any machinery that continuously jams or breaks down has a huge negative impact on outcomes. Regular maintenance is important, as is installing new equipment.

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

2.4.2 Improvement in Total Availability of the System

According to (Mobley n.d) many confuse availability with equipment reliability. In reality, it is only one part of the calculation. Availability is the actual time that the machine or system is capable of production as a percent of total planned production time. Availability rate should not be confused with overall availability. The latter is calculated using total calendar time as the divisor, not planned production time.

Accordingly, increased availability usually leads to an increase in output and also improves in the quality of infrastructure. Increased availability and high reliability of well – mentioned machines which also improve the morale of workforce in the long run (Cooke, 2003; Mishra and Pathak, 2006).

2.4.3 Extended Useful Life of the Equipment

Useful life is ―an estimate of the average number of years an asset is considered useable before its value is fully depreciated (―An Introduction to Useful life and Depreciation: How to Calculate Depreciation for Equipment and more" n.d)

Accordingly, 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).

2.4.4 Safety of the Personnel

Jonathan, (2016) argues that the concern for health and safety is legitimate in every context of human enterprise. In schools, for teaching staff�if s safety to be guaranteed, the equipment available should be properly maintained and installation for nonexistent ones done according to the health and safety policies.

Accordingly, 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 compensation among others (Franklin, 2008).

2.4.5 Reduction in Cost

Cost reduction is the process of decreasing a company's expenses to maximize profits. It involves identifying and removing expenditures that do not provide added value to customers while also optimizing processes to improve efficiency. Cost reduction typically focuses on generating short-term savings (―Gartner Glossary" n.d).

Accordingly, good maintenance practices result in improved reliability of machines within the company. Improvement in reliability also leads to reduction in maintenance costs as breakdowns becomes fewer, maintenance spending in the area of materials, labour, contractor‘s equipment and plant.

The cost of regular maintenance is very low when it is compared to the cost of maintenance of a major breakdown of which time there is no productive purpose of maintenance. It is imperative to carryout regular checks of problems associated with heavy construction equipment to increase productivity and decrease loss (Hartmann, 1992). Building/Civil engineering researchers and developers have put in place, policies and programs to promote maintenance systems throughout worldwide (Cooke, 1999). Realizations of these policies include specifications failures on heavy constructional equipment put in place by various countries for developers to follow in reducing premature breakdowns.

Accordingly, the main purpose of regular maintenance is to ensure that all equipment required for production are operating at 100% efficiency at all times (http://linkedin.com, 2017).

2.5 Equipment Maintenance Practice Employed by MSCF

Every machine is thoroughly tested and inspected by the manufacturer before selling. When it is used, it is subjected to wear and tear and hence appropriate and due attention should be given to protect the machine and its components from undue wear and tear to avoid failure of the machine.

Accordingly, while it may seem like it does not make sense to spend the time and money to have equipment inspected or repaired when you‘re able to work around it, the reality in waiting is going to cost you even more. Bigger, more complex repairs come with a bigger price tag. A more complex problem will likely come with having to replace more and/or larger parts that are expensive, but it does not end there. Big problems often translate to more downtime, and more downtime means you are suddenly behind schedule and/or unable to take on a new project. If you have employees on the clock that were scheduled to work with that piece of equipment, now you are paying them despite the fact that they are unable to work temporarily due to equipment downtime. Obviously, if you get to this point, you will do what it takes to get the equipment back up and running as soon as possible, but that too comes with an additional set of costs. Expedited shipping for parts comes with a price tag. It all adds up. Bigger problems have a snowball effect. Do not wait for the bigger problem — invest in the small one.

Shin et al (2015) have provided the basic data-driven methods including off-line design and on-line computation algorithms; original idea, basic assumption/condition, and computation complexity were presented. Provided methods were implemented on an industrial benchmark.

2.5.1 Evolution of Equipment Management

To begin with, there is a requirement to improve an understanding of the basic perception of the maintenance role. Here, it is pertinent to note that the maintenance function has undergone serious change in the last three decades. The traditional perception of maintenance‘s role is to fix broken items. Taking such a narrow view, maintenance activities have been confined to the reactive tasks of repair actions or item replacement. Thus, this approach is identified as reactive maintenance, breakdown maintenance, or corrective maintenance. A more recent view of maintenance is defined by Gits as ―All activities aimed at keeping an item in, or restoring it to, the physical state considered necessary for the fulfillment of its production function." Clearly, the scope of this opinion also contains the proactive tasks such as the following:

- routine servicing and periodic inspection
- preventive replacement
- Condition monitoring.

According to Klaidman (2014), In order to maintain equipment, maintenance must carry out some further activities. These activities contain the planning of work, purchasing and control of materials, personnel management, and quality control. This variety of responsibilities and activities convert maintenance from a simple function to a complex function to manage.

Maintenance should ensure equipment availability in order to produce products at the compulsory quantity and quality levels. The scope of maintenance management includes every phase in the life cycle of technical systems (plant, machinery, equipment, and facilities), specification, acquisition, planning, operation, performance evaluation, improvement, and disposal.

2.5.2 Breakdown Maintenance (BM)

Breakdown maintenance is maintenance performed on a piece of equipment that has broken down, faulted, or otherwise cannot be operated. The goal of breakdown-maintenance is to fix something that has malfunctioned (―Maintenance Q &As/ types of maintenance" n.d).

This type of maintenance states the maintenance strategy, after the equipment failure equipment is repaired. This maintenance strategy was mainly implemented in the manufacturing organizations before 1950. In this stage, machines are serviced only when repair is required. This idea has some weaknesses such as the following:

- unplanned stoppages
- excessive damage
- spare parts problems

- high repair costs
- excessive waiting and maintenance time
- High troubles hooting problems.

2.5.3 Preventive Maintenance (PM)

This concept is a type of physical checkup of the equipment to prevent equipment breakdown. Preventive maintenance includes activities which are started after a period of time or amount of machine use. This type of maintenance depends on the estimated probability that the equipment will break down in the specified interval. The preventive works are as follows:

- equipment lubrication
- cleaning
- parts replacement
- tightening
- Adjustment.

2.5.4 Predictive Maintenance (PdM)

According to Irajpour, (2014), Predictive maintenance is often mentioned as condition-based maintenance (CBM). In this strategy, maintenance is started in response to specific equipment condition or performance deterioration. The analytic techniques are organized to measure the physical condition of the equipment such as temperature, noise, vibration, lubrication, and corrosion (Irajpour, 2014). When one or more of these indicators reach a set deterioration level, maintenance initiatives are assumed to restore the equipment to desired condition. This means that equipment is taken out of service only when direct evidence exists that deterioration has happened. Predictive maintenance is based on the same principle as preventive maintenance. The advantages of predictive maintenance are based on the need to perform maintenance only when their pair is really necessary, not after a specified period of time.

2.5.5 Corrective Maintenance (CM)

The main core of this concept is to prevent equipment failures. This type of maintenance system has been applied to the improvement of equipment; hence the equipment failure can be removed (improving the reliability) and the equipment can be simply maintained (improving equipment maintainability) (Irajpour, 2014). The main difference between corrective and preventive maintenance is based on the time of maintenance action. In the corrective action system, a problem must exist before corrective actions are taken. The corrective maintenance is following some purposes such as improving equipment reliability, maintainability, safety, reducing design weaknesses (material, shapes), reducing deterioration and failures, aiming at maintenance-free equipment (Irajpour 2014)

2.5.6 Maintenance Prevention (MP)

This type of maintenance system is based on the design phase of equipment. Equipment is designed such that they are maintenance free and an ideal condition of ―what the equipment and the line must be" is attained. In the development of new equipment, MP activities must begin at the design stage of equipment. Maintenance prevention often applies some earlier equipment failures and feedback from production areas to ensure equipment design for production systems (Irajpour 2014).

2.5.7 Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance (RCM) can be defined as an organized, rational process for improving the maintenance requirements of a physical resource in its operating context to understand its ―inherent reliability," where ―inherent reliability" is the level of reliability which can be attained with an effective maintenance program (Irajpour, 2014). RCM is a process implemented to determine the maintenance requirements of any machines or equipment in its operating context by recognizing their functions, the causes of failures, and the effects of the failures. RCM has seven basic steps:

- ✓ Identify the equipment/system to be analyzed;
- ✓ Determine its functions;
- ✓ Determine what constitutes a failure of those functions;
- ✓ Identify the failure modes that cause those functional failures;
- ✓ Identify the impacts or effects of those failures‘ occurrence;
- ✓ Use RCM logic to select appropriate maintenance tactics;
- ✓ Document your final maintenance program and refine it as you gather operating experience (Irajpour 2014).

The various tools employed for affecting maintenance improvement on these 6 steps include:

- Failure Mode and Effect Analysis (FMEA),

- Failure Mode Effect and Criticality Analysis (FMECA),
- Physical Hazard Analysis (PHA),
- Fault Tree Analysis (FTA),
- Optimizing Maintenance Function (OMF),
- Hazard and Operability (HAZOP) Analysis.

2.5.8 Productive Maintenance (PrM)

Productive Maintenance originates from Preventive Maintenance, and refers to the maintenance which includes Corrective Maintenance and Maintenance Prevention, and is performed to increase the broadly economic efficiency of production. In this maintenance, not only the comparison between them regarding the decrease in equipment control cost and production improvement, but also comprehensive integration of them are performed. These days the productive maintenance is advancing and turning into the next stage of all-hands-type "Total Productive Maintenance (TPM)", an autonomous maintenance based on small groups' activities (―Productive Maintenance" n.d).

The main aim of productive maintenance is to increase the productivity of a manufacturing unit by decreasing the total cost of the equipment over the whole life from design to equipment degradation (Irajpour, 2014). The significant features of this maintenance viewpoint are equipment maintainability and reliability focus, as well as cost reduction of maintenance actions. The maintenance strategy including all previous viewpoints to increase equipment productivity by applying preventive maintenance, corrective maintenance, and maintenance prevention is named productive maintenance.

2.5.9 Computerized Maintenance Management Systems (CMMSs)

Computerized maintenance management systems (CMMSs) are vigorous for the management of all activities related to the availability, productivity, and maintainability of complex systems (Irajpour 2014). Modern computational facilities have offered a dramatic scope for improved effectiveness and efficiency in, for example, maintenance. Computerized maintenance management systems (CMMSs) have existed, in one form or another, for several decades. CMMS can be used to mechanize the PM function and to help in the control of maintenance inventories and the buying of materials. CMMS can reinforce reporting and analysis capabilities. Accessibility and accuracy of information can provide more reliable decisions in CMMS because of closer working relationships between maintenance and production (Irajpour 2014).

2.5.10 Total Productive Maintenance (TPM)

This methodology is linked to the maintenance systems designed and perfected by ―Toyota family" companies including Denso and Aisin Seiki. TPM is an innovative approach to maintenance that optimizes equipment effectiveness, removes breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving total workforce (Irajpour 2014). A strategic approach to improve the performance of maintenance activities is to effectively implement strategic TPM initiatives in the manufacturing organizations. TPM brings maintenance into attention as a necessary part of the business. The TPM initiative is aimed at improving competitiveness of organizations TPM try to find to involve all levels and functions in an organization to optimize the overall effectiveness of production equipment. This method also tunes up existing processes and equipment by reducing mistakes and accidents. TPM is a World Class Manufacturing (WCM) initiative that pursues to optimize the effectiveness of manufacturing equipment.

2.6 Lean TPM and Maintenance Performance Framework

The integration of Lean Thinking and Total Productive Manufacturing (Lean TPM) applies the proven business models of ―world class" manufacturing enterprise. The maintenance performance conceptual framework proposed by Muchiri et al 2013 recognizes main processes that lead the maintenance function to delivery of performance required by manufacturing objectives. The conceptual framework supports alignment of maintenance objectives with the manufacturing and corporate objectives. The conceptual framework has three main sections that include maintenance alignment with manufacturing, maintenance effort/process analysis, and maintenance of results performance analysis. The first area of the conceptual framework pursues aligning the maintenance objectives with the manufacturing strategy. By studying the requirements of the stakeholders, the performance requirements of the manufacturing system can be well-defined. Cognitive mapping is a crucial tool for studying the cause and effect relationship between strategic essentials.

2.6.1 The Maintenance Performance Indicators

The Maintenance Performance Framework summarizes the main essentials that are central in the management of the maintenance function. The essentials make sure that the right work is recognized and effectively implemented for definite results that are in line with the manufacturing performance requirements. Each step is important for effective management of the maintenance function. Both the maintenance process (leading) indicators and maintenance results (lagging) indicators are vital for measuring the performance of the maintenance function. For each essential, the main encounter is to recognize the performance indicators that will express whether the essentials are managed well. Efficient indicators should cover control and monitoring performance and support maintenance actions towards achievement of objectives.

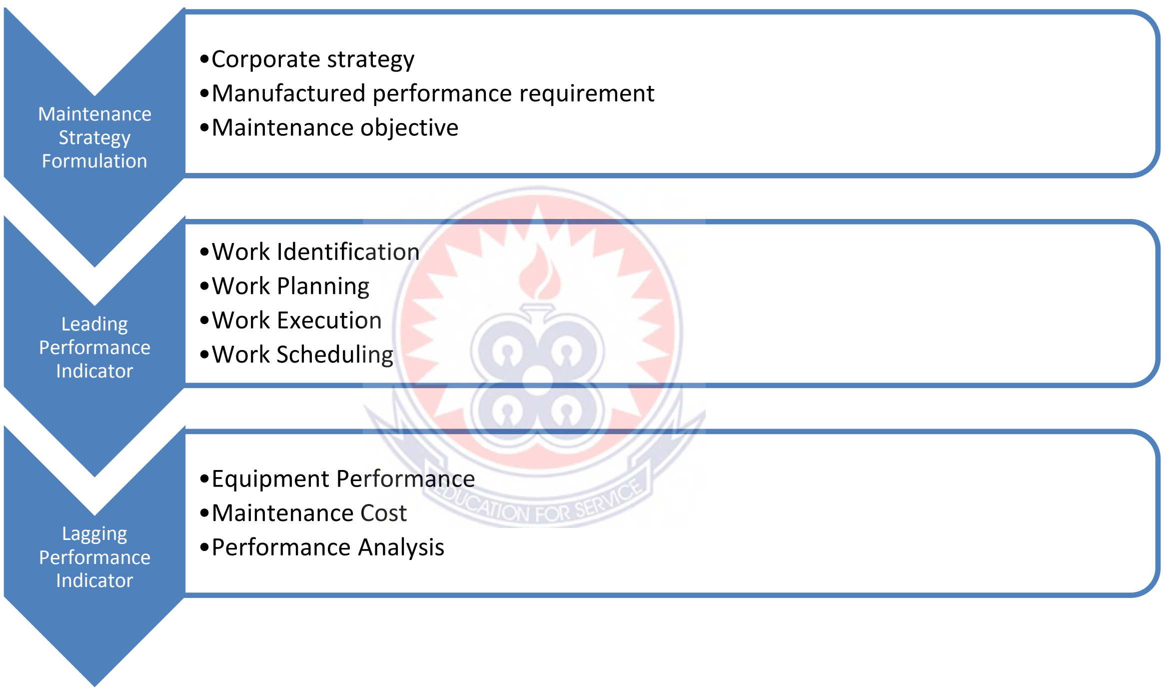


Fig.2: Performance Measurement Framework for the Maintenance Function (Irajpour 2014).

2.7 Preparing a Heavy Equipment Maintenance Checklist

According to a recent report byMacAllister Machinery Company (2021) checklists must be comprehensive and identify every crucial and not-so-crucial maintenance point that is unique to a particular equipment piece. They cover what should be done and at what recommended time. They also remind maintainers to anticipate developing problems so they can take counteractive measures before something fails.

Although checklists are designed for thoroughness, they are not meant to be how-to or instructional guides (MacAllister Machinery Company,2021). Rather, effective checklists have itemized points that remind a maintainer to pay attention to all details. Checklists do not have to be complicated, but they are indispensable in every construction equipment regular and preventive maintenance program. Here are common tasks found on a heavy equipment maintenance checklist:

- **Batteries:** Batteries notoriously lose charge or die on short notice. Checklists should include a battery‘s age, its voltage retention and acid ratio. Also important are the terminal and cable conditions.
- **Belts:** Most construction equipment has belt-driven components like compressors, alternators and pumps. Belt age, fraying, slackness and discoloration should be on an equipment list.
- **Body:** Inspect and record general body condition with a checklist. Note the damage, rust, looseness and paint conditions.
- **Brakes:** Brake condition should be near the checklist top. Pad and shoe status, as well as drum and disc health, are crucial observations. So are fluid levels, pressures and cable conditions.
- **Coolant:** Radiator and transmission coolants tell a lot about equipment‘s state. Aside from adequate levels and normal colors, coolants should have periodic analysis to check for internal problems that can‘t be detected by the eye.

- **Electrical:** Electrical component checkpoints go beyond battery conditions. Checklists should include voltage and amperage testing, cable examination and fuse conditions.
- **Exhaust:** Exhaust systems tell a lot about engine performance. Abnormal sound is one problem indicator but so is smoke. Exhaust connections like clamps and hangers should have their own checklist boxes (MacAllister Machinery Company 2021).
- **Filters:** Every filter on the equipment must have its own check-off. That includes oil, fuel, air and hydraulic filters. It could also be cabin filters. Checklist remarks can include whether filters were cleaned or replaced.
- **Fluids:** Checking equipment fluids is mandatory in every scheduled service inspection. Fluid analysis for engine oil, hydraulic oil, transmission fluid and engine coolant is like a blood test for humans. They reveal what is going on inside equipment.
- **Fuel:** Gasoline, diesel and propane fuel functions are extremely important to equipment operation. Without functioning fuel delivery systems, they are not going to run. Ensure there are checkmark spots for fuel pumps, lines and storage tanks.
- **Injectors:** Diesel engines rely on injectors for fuel delivery. Plugged or dysfunctional injectors impact power and economy. Injector cleaning or replacement belongs on an equipment maintenance checklist.
- **Lubrication:** It goes without saying that greasing and lubricating is on a check sheet. The list should also identify critical moving areas like joints and sleeves.

- **Safety:** Every safety device should have a checkbox. Include seatbelts, lights, horn, locks and energy lockout points. Other safety devices like fire protection and hazard warning belong on the list, too.
- **Steering:** Every part of the equipment steering system needs preventive maintenance checks. That goes for the tie rods, ball joints, idler arms and even the wheel condition (MacAllister Machinery Company 2021).
- **Suspension:** Preventive maintenance and proactive tasks always take in the equipment‘s suspension components. Note condition of springs, struts, shocks and undercarriage.
- **Tires:** If the equipment rolls on tires, it needs checklist mention. Record tire wear, tread depth and pressure. Balance is another item for the list.
- **Tracks:** Tracked equipment deserves special recognition on a maintenance checklist. Treads, cleats and idlers should have their box as well as general wear condition.
- **Windshield:** All glass should be inspected every time a checklist comes out. Chips can easily develop into sight-impairing cracks. Also look for mirror and light glass condition (MacAllister Machinery Company 2021).

2.7.1 Some Types of Equipment used by MSCF

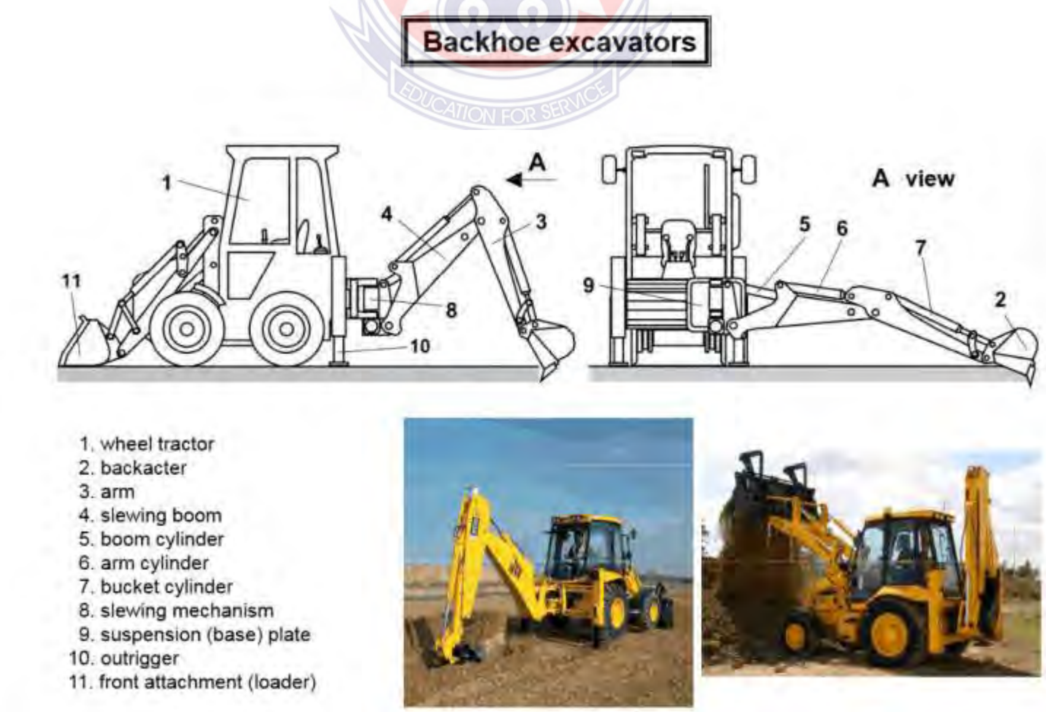
There are numerous and varied equipment used by Medium Scale Construction Firms. These equipment‘s are made from different Companies but usually perform the same functions depending on the purpose of such equipment is/are manufactured and the project or job.

Examples of such equipment are as follows;

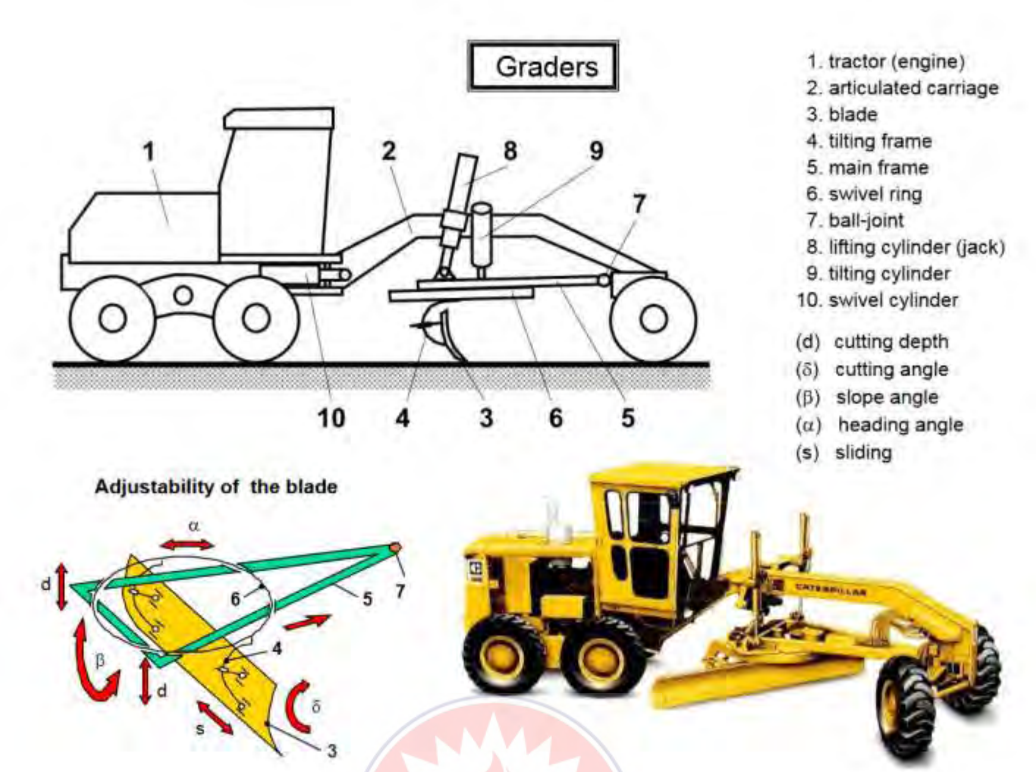
1. Excavators
2. Rippers
3. Bulldozers
4. Graders
5. Rollers
6. Tampers
7. Vibrators
8. Graders
9. Scrapers etc

Vattai, 2010

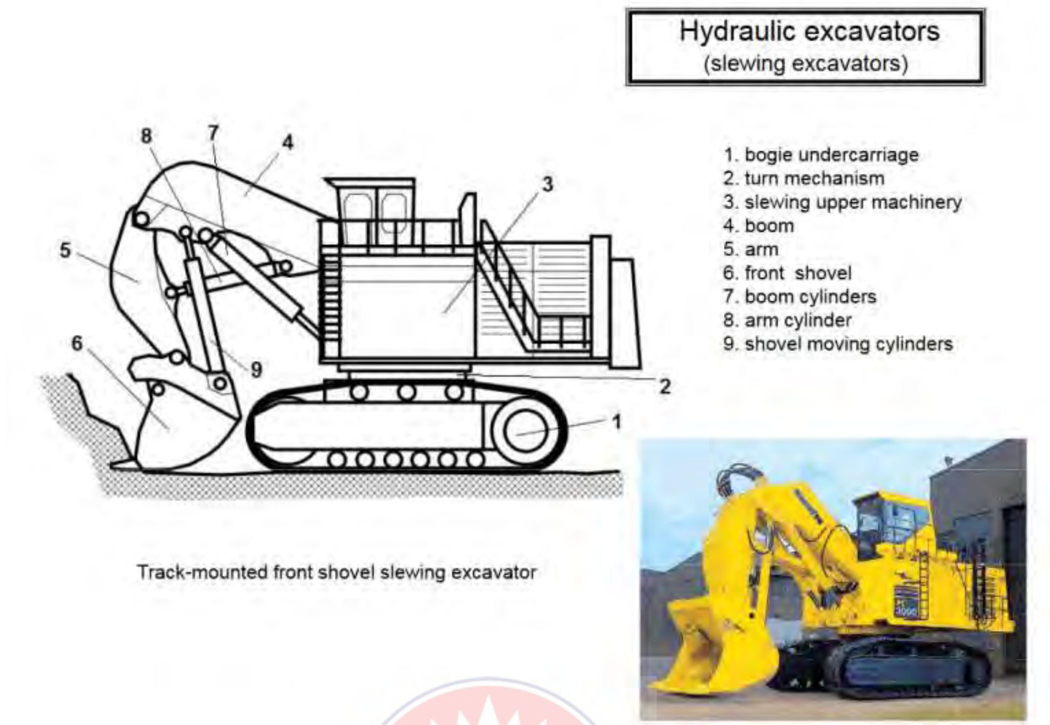
See some pictures below;



(Vattai, 2010)


Graders
1. tractor (engine)
2. articulated carriage
3. blade
4. tilting frame
5. main frame
6. swivel ring
7. ball-joint
8. lifting cylinder (jack)
9. tilting cylinder
10. swivel cylinder
(d) cutting depth
(δ) cutting angle
(β) slope angle
(α) heading angle
(s) sliding
Adjustability of the blade

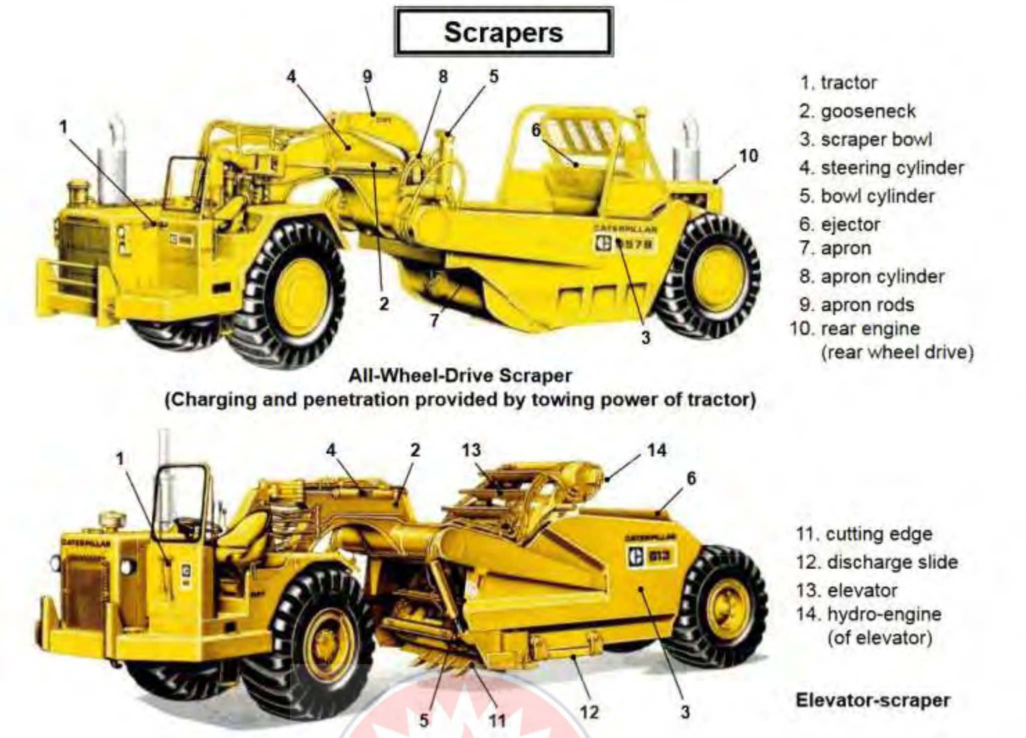
(Vattai, 2010)


Hydraulic excavators
(slewing excavators)
1. bogie undercarriage
2. turn mechanism
3. slewing upper machinery
4. boom
5. arm
6. front shovel
7. boom cylinders
8. arm cylinder
9. shovel moving cylinders
Track-mounted front shovel slewing excavator

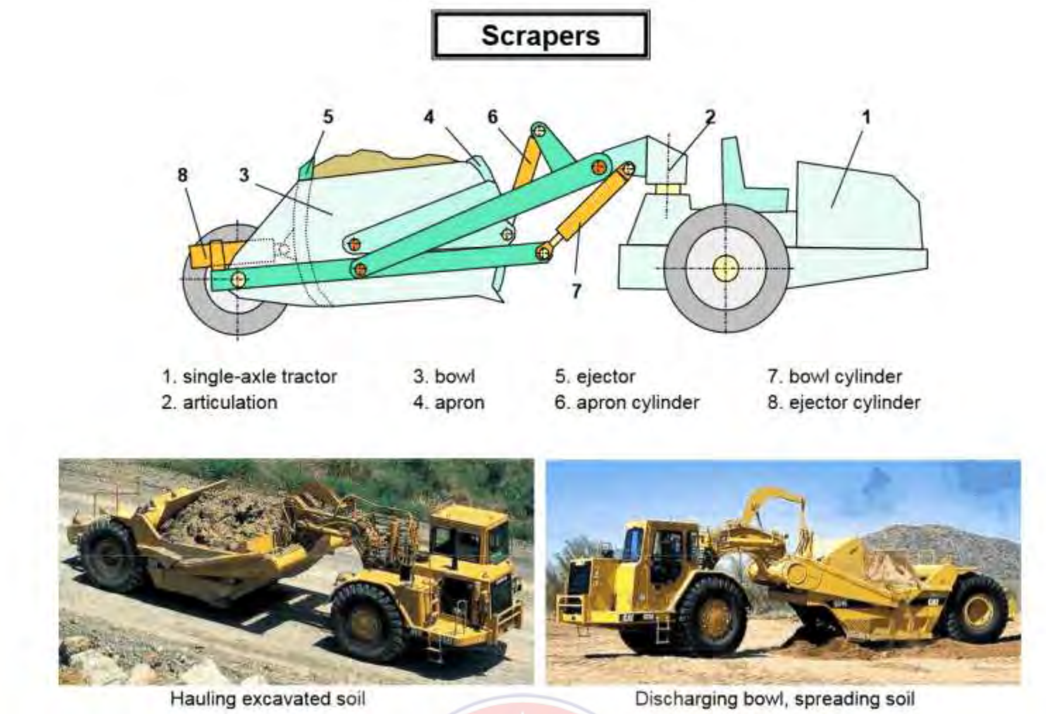
(Vattai, 2010)


Hydraulic excavators
(slewing excavators)
1. wheel-bogie
2. turn mechanism
3. slewing upper machinery
4. boom
5. arm
6. backacter
7. boom cylinders
8. arm cylinder
9. bucket cylinder
10. bucket moving rods
11. auxiliary attachment
12. outrigger
01_04_11.
Wheel-mounted backacter slewing excavator

(Vattai, 2010)


Scrapers
1. tractor
2. gooseneck
3. scraper bowl
4. steering cylinder
5. bowl cylinder
6. ejector
7. apron
8. apron cylinder
9. apron rods
10. rear engine (rear wheel drive)
All-Wheel-Drive Scraper
(Charging and penetration provided by towing power of tractor)
11. cutting edge
12. discharge slide
13. elevator
14. hydro-engine (of elevator)
Elevator-scraper

(Vattai, 2010)



(Vattai, 2010)

2.8 Safety and Risk Consideration in the use of Construction equipment

According to (Kendall 2017) Heavy equipment is a necessity on nearly every construction project. Unfortunately, they can be extremely dangerous when not used properly. Roll overs, struck by accidents and caught in or between accidents are common ways workers can be injured when working on or near heavy equipment.

What is considered the most effective safety and risk management programs ever developed, Procter and Gamble‘s key Element, has been able to achieve significant improvement in both health and safety. This remarkable association validates the key element approach, which are listed as follows;

2.8.1 Organizational Planning and Support

Organizational planning is the process of defining a company‘s reason for existing, setting goals aimed at realizing full potential, and creating increasingly discrete tasks to meet those goals (―Organizational Planning Guide: Types of Plans, Steps and Examples" 2020).

- Clear expectations
- Management and employee‘s involvement
- Goal setting and action planning

2.8.2 Standards and Practices

According to (―Maintenance Reliability" 2019), Standards are useful when applied to technological systems. For example, they can boost the development of interoperable systems that can exchange data and services to boost the replication of maintenance solutions. Such data exchange and sharing is key to sharing visualizations across stakeholders and supporting new cost-effective ideas for remote maintenance

- Standard implementation
- Safe Practices
- Planning for safe conditions

2.8.3 Training

There is probably no better return on construction equipment investment than training. Employees who know how to properly operate their machines and to watch for problems are invaluable. They are the front-line defenders of a company‘s mechanical assets (―Construction Equipment Maintenance Tips" n.d).

- Site training system
- Qualification of safety risk management resources

2.8.4 Accountability and Performance Feedback

- Safety sampling
- Behavior feedback
- Performance tracking (Olson, 1999)

Because this system effectively integrates risk management into the corporate fabric, it affirms that accidents cannot be simply dismissed as events that do not involve the management system. In addition to using Procter and Gamble‘s key element methods, management must realize reacting after the accident or event cannot accomplish effective risk control. In essence, reactive safety management focuses on the symptoms rather than the root causes while a proactive safety management approach searches for ways to measure system that produce results (Earnest, 1997). As illustrated in the following, successful industrial maintenance programs also rely heavily on root cause analysis and measurement of results to achieve continuous improvement.

2.9 Equipment Related Accidents in the Construction Industry

Working with heavy equipment is high – risk work. If an accident occurs, the result is often a life – altering injury such as a broken bone, head injury or in many cases loss of life as the machines or equipment are heavy ones. Incidents involving heavy equipment deeply affect not only the person who is injured but the person operating the equipment or the co – workers nearby (https://www.Ihsa. Ca).Occupational accidents frequently encountered in heavy construction equipment can be listed as follows;

- Struck – by: this kind of accident take place any time a worker is struck or hit by any type of equipment, moving load/material, attachment, and object (Hinzeet. Etal, 2005)
- Falling from vehicle (―Types of Construction Site Accidents" Steve Lee n.d)
- Caught or compressed in running equipment or machinery (―Types of Construction Site Accidents" Steve Lee n.d)
- Crushing (run – over); damage of operator or other person by heavy construction equipment (―Types of Construction Site Accidents" Steve Lee n.d)

Accordingly, where heavy construction equipment is used, the following safety precautions should be observed.

2.9.1 Communication

According to (―Construction Health and Safety Manual" n.d) a signaler must be a competent worker and must not have any other duties to fulfill while acting as a signaler. The signaler must maintain clear view of the path that the vehicle, machine, or load will be travelling and must be able to watch those parts of the vehicle, equipment, or load that the operator cannot see. Workers who are designated as spotters should stand where equipment operators can see them at all times and have a full view of the intended path of travel. They must not only stay out of the path of the vehicle they are signaling for, but also be aware of other moving machinery in the area.

2.9.2 Blind Spots

According to (―Construction Health and Safety Manual" n.d)the main problem with reversing vehicles and equipment is the driver or operator‗s restricted view. Around dump trucks and heavy equipment such as bulldozers and graders there are blind spots where the operator has no view or only a very limited view. The operator may not see someone standing in these blind spots. Anyone kneeling or bending over in these areas would be even harder to see. Consequently the driver or operator must rely on mirrors or signalers to back up without running over someone or into something.

Foot traffic should be minimized where trucks and equipment operate in congested areas such as excavations. Where feasible, a barricade can help to protect workers.

2.9.3 Improving Construction Equipment Maintenance Practices on MSCF

Construction Equipment Maintenance is dynamic. Almost day – in – day – out new ideas and innovations are created. The principles below explain how to improve equipment maintenance.

Principles of Equipment Safety and Risk Management

Over the past two decades, a number of Risk Management (RM) standards have been developed to meet new demands from industry and higher expectations from regulators for managing risks (e.g. AS/NZS 4360; FERMA; COSO; ISO 31000). Most RM standards share common principles and processes as they require systematic methods in safety oversight, understanding of acceptable risk tolerance (ALARP), formal risk assessment, and risk mitigation, communication of risks and review of safety investment.

The new ISO 31000: 2009 standard offers principles and guidelines for risk management (RM) and remains widely applicable to industry. It also serves to unite risk management processes with existing standards of quality and environmental management and offers a common approach to address risk without leading to a process of certification. The standard can be used by any public, private or community enterprise, association, group or individual. ISO 31000 provides general principles for risk management and processes for implementing a system for managing risks. It can be applied to both industrial safety and project risk management which provides a good basis for elaborating the principles of total safety management. In particular, the principles of effective risk management in ISO 31000 are as follows;

- Risk management should create and protect business values
- Risk management should be central to the organization's processes
- All decision making within the organization involves the explicit consideration of risk and the application of risk management to some appropriate degree
- Risk management should be based on best available information
- Continual communication with internal and external stakeholders, including comprehensive reporting of safety performance
- Risk management should be comprehensive and clear about accountability for risk, controls and risk treatment processes.
- It should be systematic, structured, and timely applied to critical activities
- It should take in to account of human and cultural factors
- It must be dynamic, iterative and responsive to change
- It must facilitate continual improvement of the organization.

The first three principles refer to what has been termed the ―Business value of safety" (CCPS, 2008) where all decision making and organizational process should involve the explicit consideration of risk while risk management provides a capability for creating value for business. The fourth principle suggests that risk management should be based on best available information about hazards, available methods and safety measures that have been implemented. This principle on the use best available risk information is elaborated by the NORSOK standard Z013 which proposes an inventory of risk information about hazards, risk acceptance criteria, risk contributory factors, risk assessment tools and uncertainties or assumptions related to such information. The fifth principle refers to the involvement of external and internal stakeholders in the risk management process as well as to their continual communication including the reporting of risk information. This is similar to the participative management approach pointed out by Strategic Safety Management and Total Quality Management.

A vital part of all safety standards concerns the risk assessment process, the people who will be involved, the techniques, the scope of analysis, and the context of work.

The next three principles (6, 7 and 8) refer to the allocation of safety responsibilities and the conduct of risk assessment that should take into accounts, the context of work (i.e. the technical environment and the human factor). In this regard, the organization should manage any valuable knowledge about risk (e.g. peoples view, standard procedures, audit reports, incident investigations) and make it available to the risk assessment process.

Finally, the last two principles refer to a feedback mechanism that monitors risk reduction measures, evaluates results and facilitates continual safety improvement.

Employers are required by legislation and by social responsibility to provide a safe working environment while also been required by stakeholders to deliver profit. For many years, process industries have viewed productivity as being at odds with safety. This is partly justifiable since investments in safety may not show short – term returns whilst major accidents may occur after long time periods; this can make managers quite skeptical in investing in safety and biased towards attending to pressing production issues to ensure economic survival in a competitive world. For this reason, many institutions and researchers have emphasized the need for risk management to demonstrate a business value to organizations.

For instance, in its HSG96 publication, the Health & Safety Executive (HSE, UK) provided some evidence that ―Good Health is Good Business”, since work accidents can occur at a high cost to the business. Other studies argued that the ―business case” of safety should be supplemented with an ―ethical case” of safety. Wright (1998) suggest that many managers are more likely to be motivated by factors such as company values, peer expectations and perceived threats to individual and corporate reputation. The Royal Society for the Prevention of Accidents (RoSPA, UK) supported the idea that the ethical case needs to be advanced as the primary reason for taking action on health and safety (Bibbings, 2003).

Accordingly, Small – Medium Enterprises (SME‘s) often ―care” about their employees but do not know how to turn this ―care” into practical action. In 2006, the Centre for Chemical Process safety conducted a benchmark study with the chemical processing and petroleum industries found that companies that implemented efficient safety management system achieved many returns from their investment such us, productivity increases, production and maintenance cost decreases, lower capital budgets and lower insurance premiums. It appears then that we should to set out a much broader ―business case" for safety showing how a proactive safety approach can benefit the business by improving quality and reliability, encouraging work force innovation and enhancing corporate reputation. Recent studies have shifted their emphasis and presented safety more in terms of improvement of effectiveness rather than simply avoiding accidents. In this respect, there has been an emphasis on how to relate safety to productivity, workforce morale and corporate culture, empowerment innovation and competitiveness.

There is the need for modeling aspect of safety, quality and productivity in a joint manner. In the past, ―Balance scorecards" have been used for integrating performance and indicators for safety, quality and productivity with some degree of success (Mearns and Havold, 2003). Balance scorecards takes a global approach but they are not very helpful in considering how specific interventions (e.g. modified task sequences) impact on quality, maintenance and productivity. Other methods from Total Quality Management can also be considered (e.g. Quality Foundation Deployment Diagrams) to examine how modifications in a critical task may affect Key Performance Indicators. Finally, Total Productivity Management approach may offer some insights as to how to achieve integration between safety, quality and productivity (Sumanth, 1997).

Traditionally, safety management has focused on correcting safety problems and on taking remedial actions to bring the system back to normal operation. Existing Safety Management System (SMS) seem to practice what is commonly known as feedback control where poor feedback guides further action. However, there are no predictive or anticipatory capabilities where organizations are able to anticipate future states of the system and foresee the effects of corrective actions in terms of effectiveness and cost.

Model – driven control enables safety practitioners to cope with information overload and directs attention to critical events in a timely manner. Safety practitioners should be able to monitor what could become a threat in the near term and what could impair their abilities to respond. This monitoring capability is supported by an ―internal model" of how the technical process works, how people organize their jobs and how the environment affects the process and the people. This internal model should also address how safety is measured and what performance indicators can be monitored to measure not only ―final outcomes" but also antecedent so that changes are made before undesired outcomes are produced.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter provides details on the approach that the study followed. It described the study area, research design, the study population, the sample size, the sampling technique, sources of data, data collection tools, ethical issues, data analysis and summary.

For years past, there were limited Construction Firms in Tamale but now due to the increasing population of Tamale, a lot of Construction Firms are emerging. MAWUMS, FUZAK, LIDRA, MIMA etc. are construction firms in Tamale.

According to Tamale, Ghana – Wikipedia, Tamale (Dagbani: {tamale}, officially called Tamale Metropolitan Area is the fastest growing city in West Africa. It is the capital city of Ghana. Tamale is Ghana‘s third largest city. It has a projected population of 950,124 according to the Tamale Metropolitan Assembly official Website. It is the fastest-growing city in West Africa.

According to the Website, the city is located 600km (370 mi) north of Accra. Most residents of Tamale are Muslims, as reflected by the multitude of mosques in Tamale, most notably the Central Mosques, Afa Ajura Mosque (Ambariyyah Mosque) and the Ahmadiyyah Muslim mission Mosque.

Tamale is located in the Northern Region and more precisely in the Kingdom of Dagbang. The local (neighborhood) chiefs and the district chief of Tamale are subservient to the Dagomba King in Yendi. The language of the people is Dagbani.

Due to its central location, Tamale serves as a hub for all administrative and commercial activities in the Northern Region, doubling as the political, economic and financial capital of the Northern Region. The centre of Tamale hosts regional branches of financial institutions and a considerable number of international non-governmental organizations.

Tamale has developed and transformed significantly in the last few years. The new dimension of Tamale‘s development is the rush by various companies to open branches in Tamale. The hospitality industry has grown significantly with new hotels and guest houses built around Tamale. Tamale grew from a conglomeration of towns where one could find an architectural blend of traditional mud houses and more modern buildings

Tamale‘s new and modern facilities include the newly constructed Tamale Stadium (now Aliu Mahama Sports Stadium named after the late Ghana‘s Vice-President, Alhaji Aliu Mahama), replacing the town‘s former principal football pitch, Kaladan Park, with a world-class venue.

Indeed, many improvements to Tamale‘s infrastructure occurred in the period leading up to the 2008 African Cup of Nations tournament. Furthermore improvement was made, particularly to Tamale‘s road system which has influence the emergence of Medium Scale Construction Firms.

3.2 Research Design

The researcher employed a descriptive survey method. According to Leedy (2002), descriptive survey involves the collection of data in order to answer questions concerning the current status of a problem.

The major techniques or tools used in collecting data in this research were questionnaire, interview and observation as the study intends to examine the level of effectiveness of the recent available equipment maintenance systems applicable to Medium Scale Construction Firms and recommendations that would assist in improving safety and efficient firms in the Tamale Metropolis. The descriptive survey was found most appropriate.

3.3 Study Population

The targeted population of the study comprised Management Staff of some Medium Scale Construction Firms operating within Tamale in the Northern Region of Ghana which have been registered with the Ministry of Works and Housing. Stratified random sampling was used to classify the population according to the financial sub – classification and professional background.

3.4 Sampling Technique and Sampling Size

Kumar (1999) explained that a sample is a sub – group of the population which is an ideal representative of the entire population. De Vaus (2001) ascertains that the process of sampling presents the opportunity to limit a study to a relatively small segment of the population. A sample thus becomes a representative selection of a population that is investigated into in acquiring statistical information of the whole.

For convenience purposes and the undefined nature of the population for the study a sample size of sixty (60) was used. 60 MSCF based on their experience regarding the number of years they have been operating. Survey questionnaires were then administered to Management level staff of Construction Firms in the Metropolis.

3.5 Sources of Data

This study employed the use of both primary and secondary data sources. The primary data were collected using questionnaire and observation. The primary data was analyzed quantitatively and the interviews conducted were qualitatively analyzed to give better understanding of the outcome of the study.

The secondary data was used by the researcher in diverse ways by reviewing literature selected for the study in both empirical and theoretical perspectives. These include: books, journals, reports, websites, articles, research works, newspapers and internet search engines.

3.6 Data Collection Tools

The researcher used administered a self-developed questionnaires of constructional equipment under study in gathering data from the respondents. The questionnaires were closed ended and were grouped into four sections with —A̋ presenting the respondents personal data, section -B” shows the general information about the construction, -C” for current maintenance practice and -D” shows effective maintenance systems applicable on construction firms.

The questionnaires were self- administered by the researcher to professionals such as project managers, civil engineers, schedulers/planners, contractors. In some instances the questionnaires were retrieved on the spot. After the administration of the questionnaires the researcher used two and a half weeks to retrieve the answered questionnaires. Retrieving the answered questionnaires was a great problem for the researcher in the sense that the researcher had to go several times to these professionals to retrieve the answered questionnaires. The interviews conducted were structured to follow the pattern of the questionnaires to get reliable data from the respondents. The researcher also observes how MSCF use their equipment in relation to maintenance.

3.7Ethical Issues

Permission was sorted from some MSCF in Tamale before field work began. The researcher before administering the questions introduced himself to the respondents to avoid impersonation. The purpose of the study was made known to the respondents. Participation in the study was not compulsory but based on the willingness of respondents. Anonymity of respondents was highly esteemed.

During the field work, all forms of identification including names, addresses and telephone numbers of respondents were avoided. The instruction for the completion of the questionnaires explicitly appeared on the instrument. Therefore no further instruction was needed during the distribution of the questionnaires.

3.8 Data Analysis

In the process of analyzing the gathered data, there was cleaning of the data, sorting and grouping them in their respective categories.

The categories include factors such as gender, age, education background, maintenance practices on equipment for construction firms and maintenance policies on equipment.

The questionnaires were quantitively analyzed. These were carried out by using descriptive statistics. The entries were coded and tested for their consistency, validity and reliability. The final results were presented in tabular, percentages and chart forms.

3.9 Summary

As noted, this chapter outlined key elements that were very primary in deciding a suitable research methodology to address any research objective. This chapter identified and explained, among other things, the area of study, research design, study population, sampling technique and size, sources of data, data collection tools, ethical issues, data analysis and summary. The chapter that follows presents the results of the study.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter examines the data gathered from the respondents. The analysis was done on research question basis. The chapter is organized into eight main sections which comprises; an introduction, Socio- demographic characteristics of the respondents, sex of respondent, age of respondents, designation/status, category of company, construction experience and level of education of respondents. Forty (40) questionnaires were distributed to forty (40) senior management staff, junior staff and some equipment operators of Medium Scale Construction Firms in Tamale. Twenty-seven (27) were retrieved but two were rejected during the analysis on the basis that it had incomplete responses. Twenty-five (25) questionnaires were used for the analysis representing a response rate of 41.6%.

4.2 Socio- Demographic Characteristics of the Respondents

This section briefly explains the background of respondents. It is imperative because, the background of the respondents help generate confidence in the reliability of data collected; and eventually the findings of the study. According to Adinyira and Anokye (2013) argue that it is always important to have a fair idea of the respondents so as to situate the responses within context. As a result, the relevant socio-demographic variables of respondents that this research covered included age, sex, level of education and employment (occupational status).

4.2.1 Sex of Respondents

It is a general perception of people that males are the main actors involved in Construction. Accordingly, the results from **Fig. 4.1** below confirmed this perception as 23 (92%) respondents out of the 25 responses retrieved were males and the remaining 2 (8%) respondents were females. This could be attributed to the nature of the cultural believes in Tamale where people consider females who are into construction as a strange behavior and not normal. However, administering the questionnaires was not gender bias; the sampling technique ensured inclusion of all members of the population being sampled for the study.

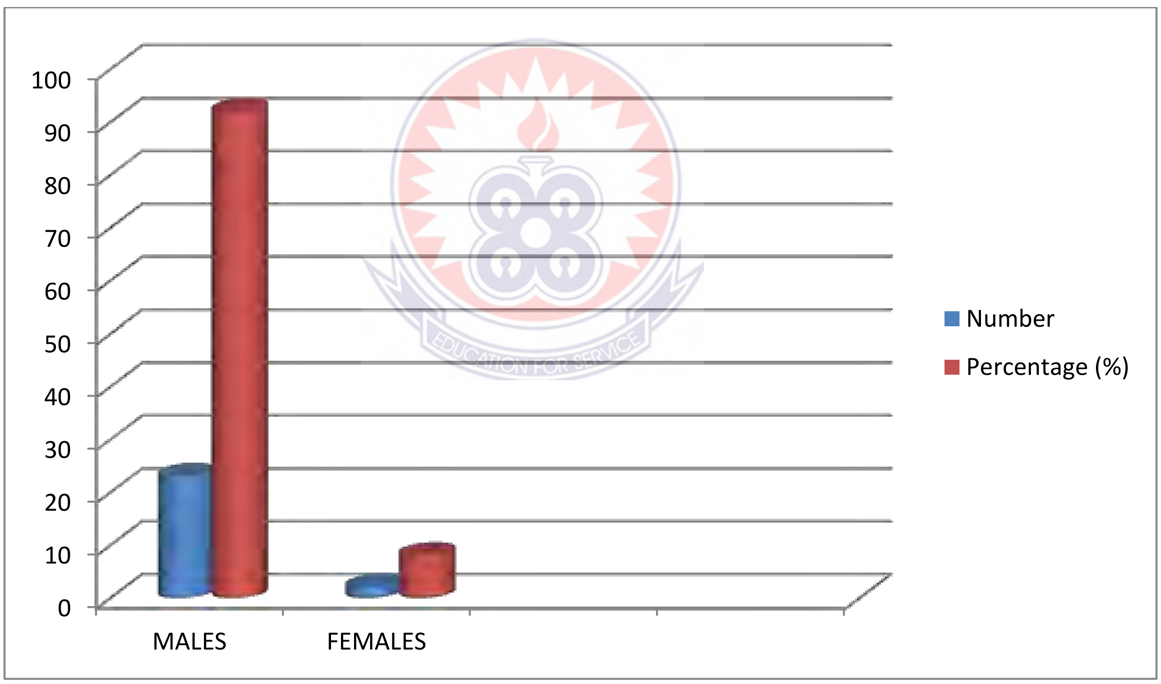


Fig. 4.1 Sex of respondents (Authors Field Data)

4.2.2 Age of Respondents

Age is an important variable to consider with respect to the main actors involved in the Medium Scale Construction Firms (MSCF). The respondents were asked to indicate their ages. The ages of the respondents were categorized in ranges in order to know the range that contains the majority of respondents. The categorization was in line with the 2008 Ghana Demographic and Health Survey‘s (GDHS) categorization of the age-groups of Ghana. **Fig 4.2** below shows that most of the respondents were 41 years above. Out of the 25 respondents, 8 were 41 years above representing 32%, the next was 31-35 years and 36-40 years which had 6 numbers of respondents in both ranges representing 24% each whiles 26-30 years had 3 respondents representing 12% and 20-25 years had 2 respondents representing 8%

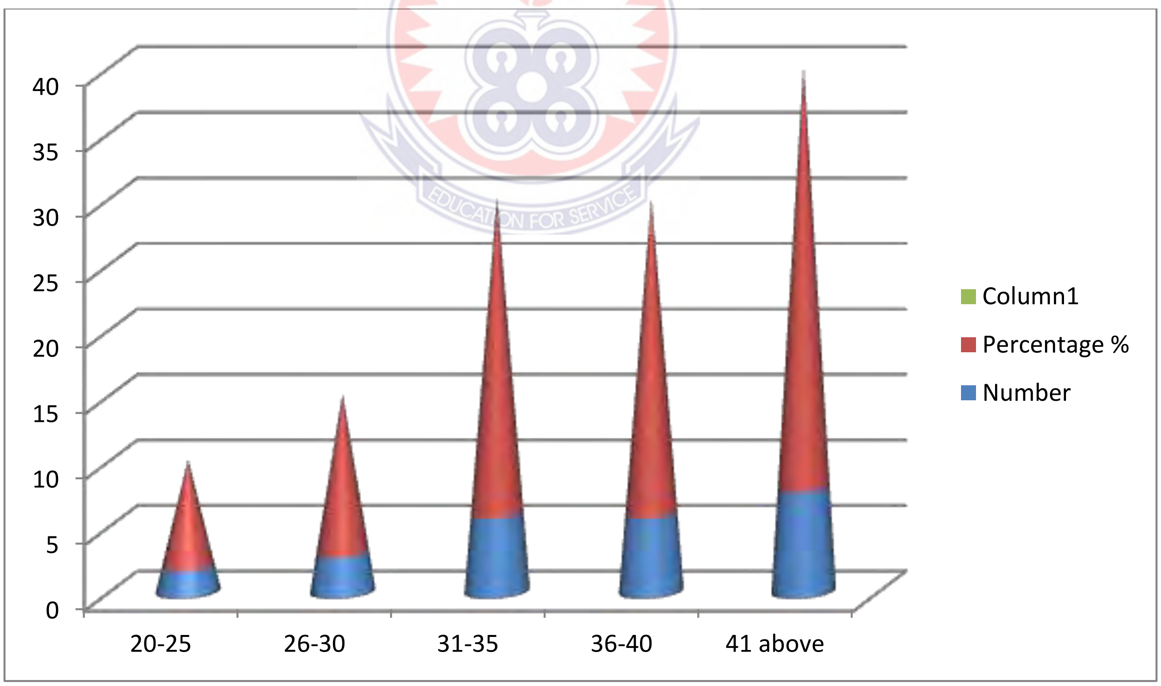


Fig. 4.2 Age of Respondents (Authors Field Data)

4.2.3 Designation/Status of Respondents

Figure 4.3shows the positions held by respondents in their various firms. Civil Engineers were 4 representing 16%, Project Engineers were 6 representing 24%, Site Engineers were 2 representing 8%, Site Foremen were 4 representing 16%. Mechanics/Fitters were 4 representing 16%, and Machine operators were 5 representing 20%

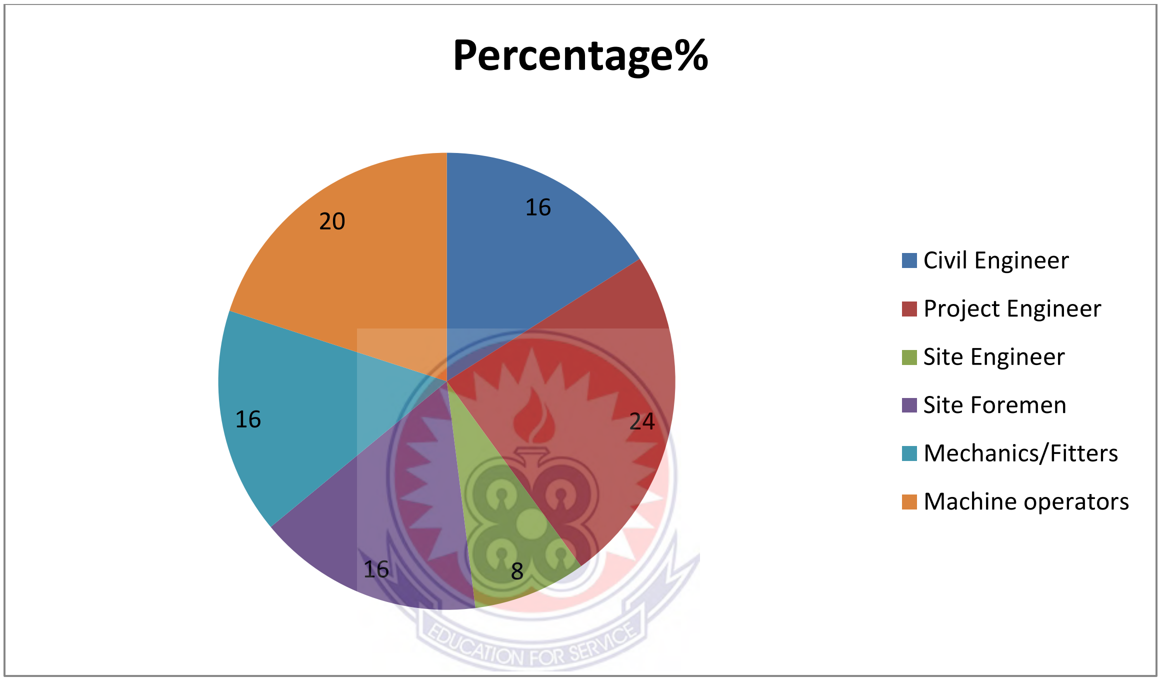


Fig 4.3 Positions/Status of Respondents (Authors Field Data)

4.2.4 Category of Company

According to Amartey, (2014) the Ghanaian building construction comprises large number of enterprises of various sizes as registered and categorized by the Ministry of Water Resources, Works and Housing (MWRW&H) as D1K1, D2K2, D3K3 and D4K4. Based on factors such as annual turnover, equipment holding, personnel, the D1K1 class of contractors are termed as larger firms, whereas D2K2 construction firms are medium and D3K3 and D4K4 are small firms (Edmonds et al., 1984). The larger firms according to MWRW&H are registered as financial class 1, capable of undertaking projects of any value, class 2 (the medium firms) are capable of undertaking projects up to US$500,000 or GH₵750,000.00 while the small firms (financial class 3) are also capable of undertaking projects up to US$200,000 or GH₵300,000.00 or class 4 to undertake projects up to US$ 75,000 or 112,500.00 (Danso, 2010).

Figure 4.4shows that out of the 25 responses retrieved, 2 were from the D1KI category representing 8%, 15 responses were from D2K2 category representing 60%, the D3K3 category were 5 representing 20% and the D4K4 category were 3 representing 12%. This means that the medium construction firms are more in Tamale. The construction firms in Tamale do not have large numbers of complex equipment.

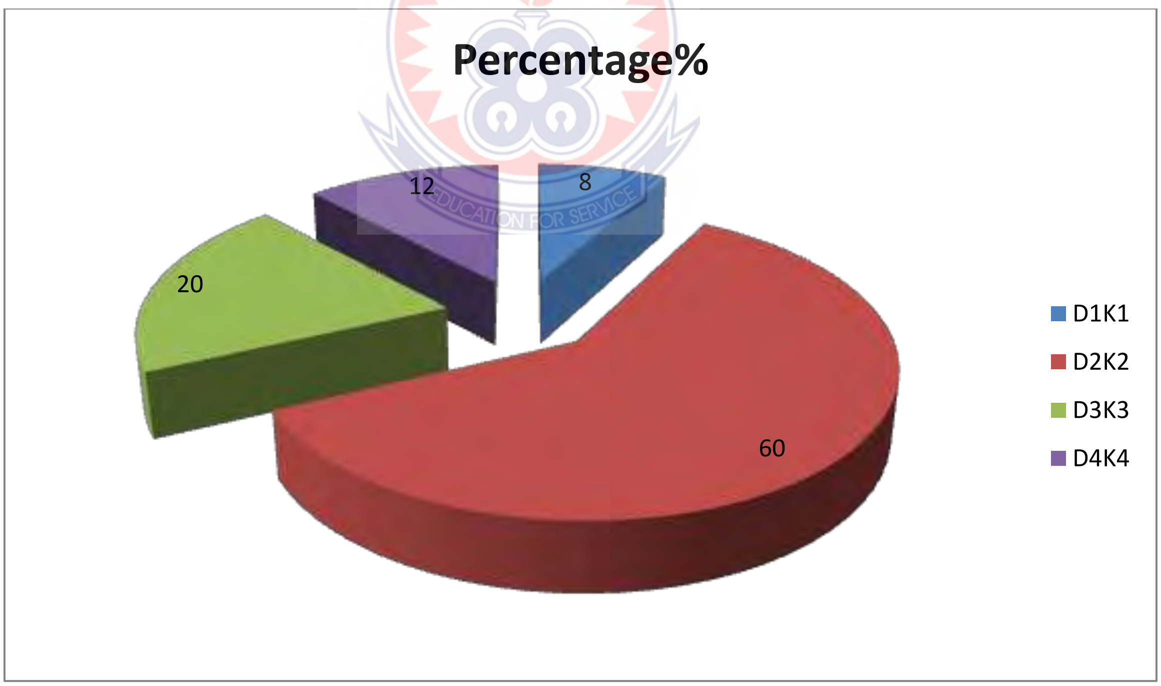


Fig 4.4 Company Category (Authors Field Data**)**

4.2.5 Construction Experience

Respondents were asked to indicate their experience in construction ranges from 1-4, 5-8, 9-12 and 13-16 and above. **Figure 4.5** shows the experiences of respondents as 1-4 were 2 respondents representing 8%, 5-8 were 6 representing 24%, 9-12 were 8 representing 32 and 13-16 were 9 representing 36%. Majority of the respondents were 9 and above which means that the responses they provided were quality.

Fig 4.5 explains more;

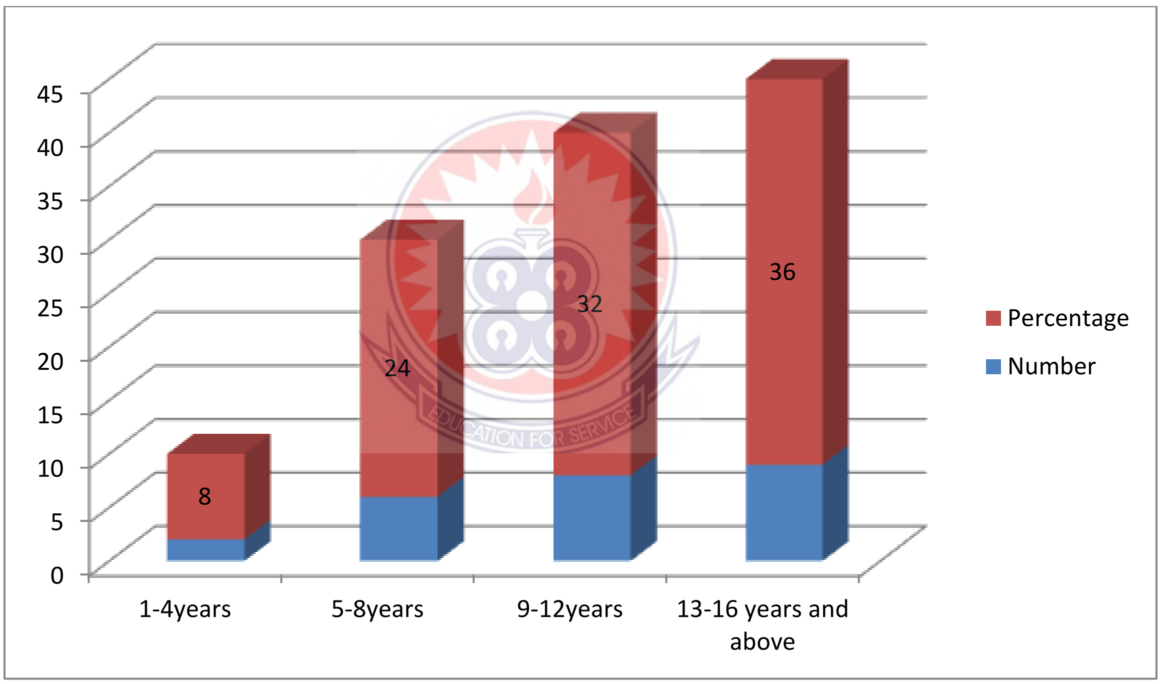


Fig 4.5 Construction Experience (Authors Field Data)

4.2.6 Educational level of Respondents

—We think one of the big causes for the worker shortages that we are experiencing now is that we have essentially dismantled a once robust vocational education system that existed across this country; so most high school students are not even getting exposed to the fact that construction is a career to consider" says Brian Turmail, senior executive director of public affairs for AGC.

The educational level of the respondents affirms what Brian Turmail said about vocational education system as most of the respondents were those whose level of education were secondary education but with very rich experience as a result of the long service in the field. **Table 1** shows that those with Master's Degree qualification are 2 representing 8%, Bachelor degree are 3 representing 12%, HND are 4 representing 16%, Technician (CTC I, II and III are 6 representing 24% and others are 10 representing 40%.

Table 1: educational qualification

Qualification	Frequency	Percentage%
MSc	2	8%
BSc	3	12%
HND	4	16%
Technician (CTC I, II and III)	6	24%
Others	10	40%
Total	25	100%

Authors Field Data

4.3 Extent at Which Equipment Maintenance is Carried Out

Table 2 shows that only 2 respondents representing 12% responded that construction firm maintains their equipment after use, 8 respondents representing 32% responded that equipment are sometimes maintain after use and 14 respondents representing 56% responded that equipment are never maintain after use. See table 2;

Table 2 Extent to which Maintenance is carried out

Always maintained after use	Sometimes maintained after use	Never maintained after use	Total
3	8	14	25
12%	32%	56%	100%

Authors Field Data

4.4 Employment of Emergency Maintenance Practices

Table 3 shows that 10 respondent representing 40% agreed that MSCF employed emergency maintenance practice, 11 respondent representing 44%, strongly agreed,2 respondent representing 8% disagreed, 2 respondents representing 8% strongly disagreed and no respondent representing 0% said somehow. This means that MSCF in Tamale employ emergency equipment maintenance.

Table 3 Emergency maintenance practices

Agreed	Strongly agreed	Disagreed	Strongly disagreed	Somehow	Total
10	11	2	2	0	25
40%	44%	8%	8%	0%	100%

Authors Field Data

4.5 MSCF Practices Only Breakdown Maintenance

Figure 4.6 shows that the common equipment maintenance practice by MSCF is the breakdown maintenance. They sometimes have no alternative but to maintain their equipment when it is broken-down because the want to use the machine to work.

Eleven (11) respondents representing 44% agreed that the only equipment maintenance practiced by MSCF in Tamale is the breakdown maintenance, 12 respondents representing 48% strongly agreed, 2 respondents representing 8% disagreed and 0 respondents representing 0% strongly disagreed.

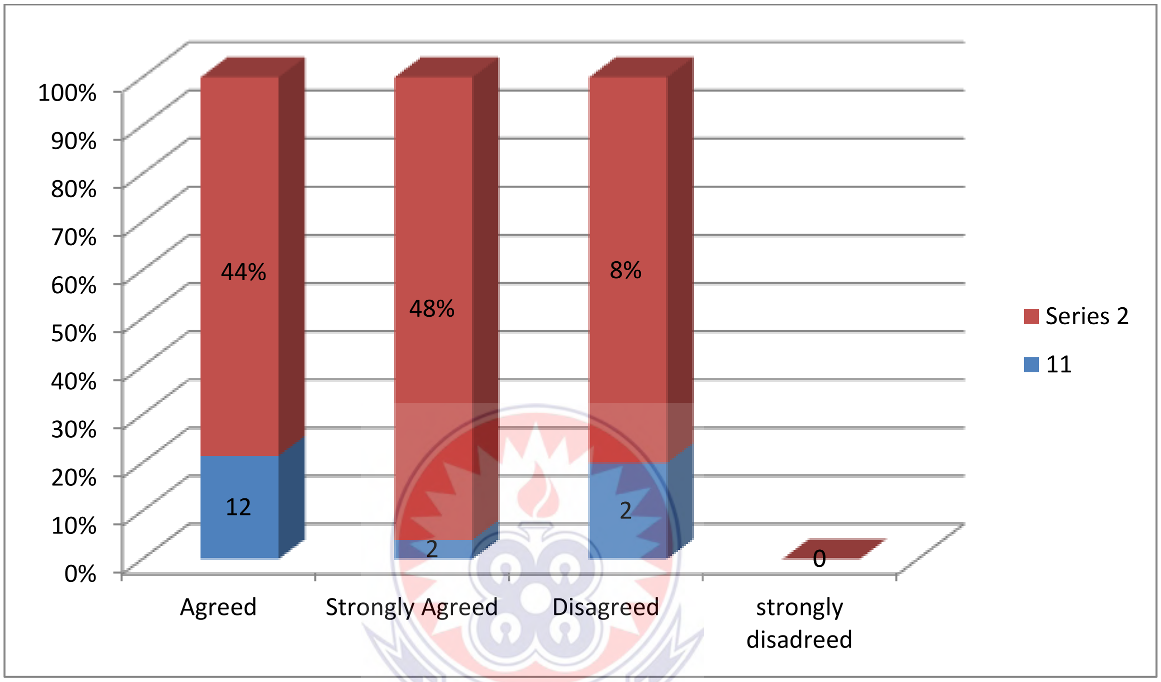


Fig. 4.6 Breakdown maintenance practices (Authors Field Data)

4.6 Corrective Maintenance Practices

The chart in Fig 4.7 below shows that 2 respondents representing 8% agreed that MSCF practices corrective maintenance, 1 respondent representing 4% strongly agreed, 8 respondents representing 32% disagreed and 14 respondents representing 56% strongly disagreed. This means that MSCF in Tamale does not practice corrective maintenance.

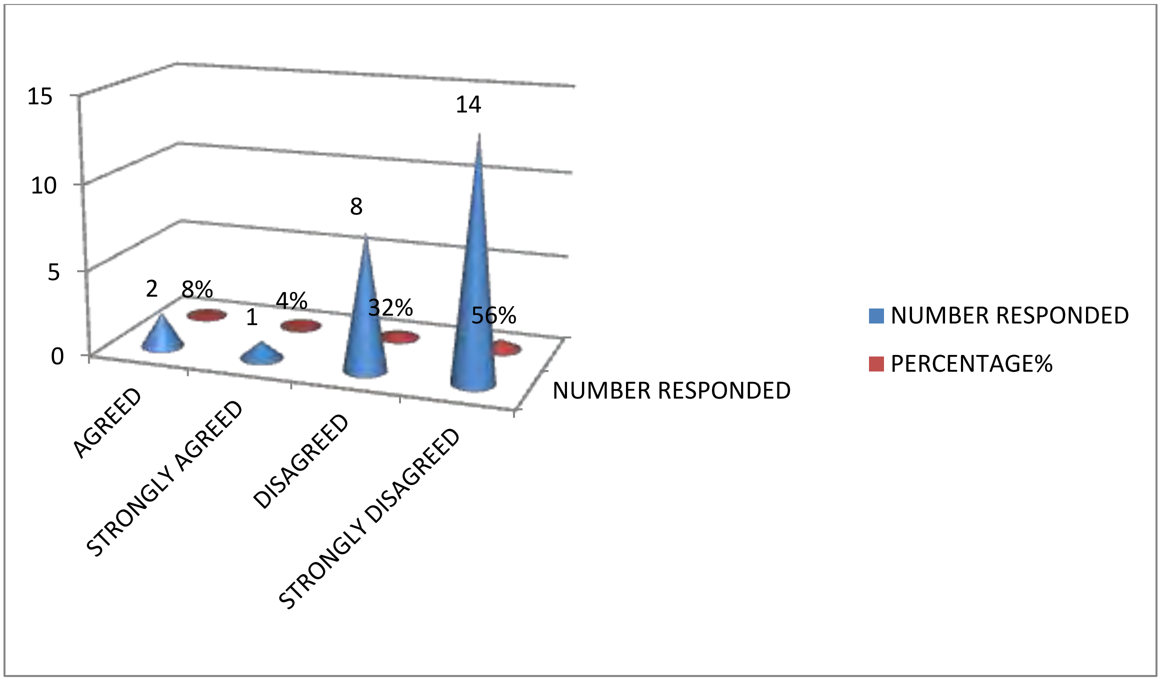


Fig 4.7 Corrective maintenance practice (Authors Field Data)

4.7 Planned Preventive Maintenance Practices

Figure 4.8 below shows that 1 respondent representing 4% agreed that MSCF practices planned preventive maintenance, no respondent representing 0% strongly agreed, 8 respondents representing 32% disagreed and 16 respondents representing 64% strongly disagreed. This means that MSCF in Tamale does not practice planned preventive maintenance.

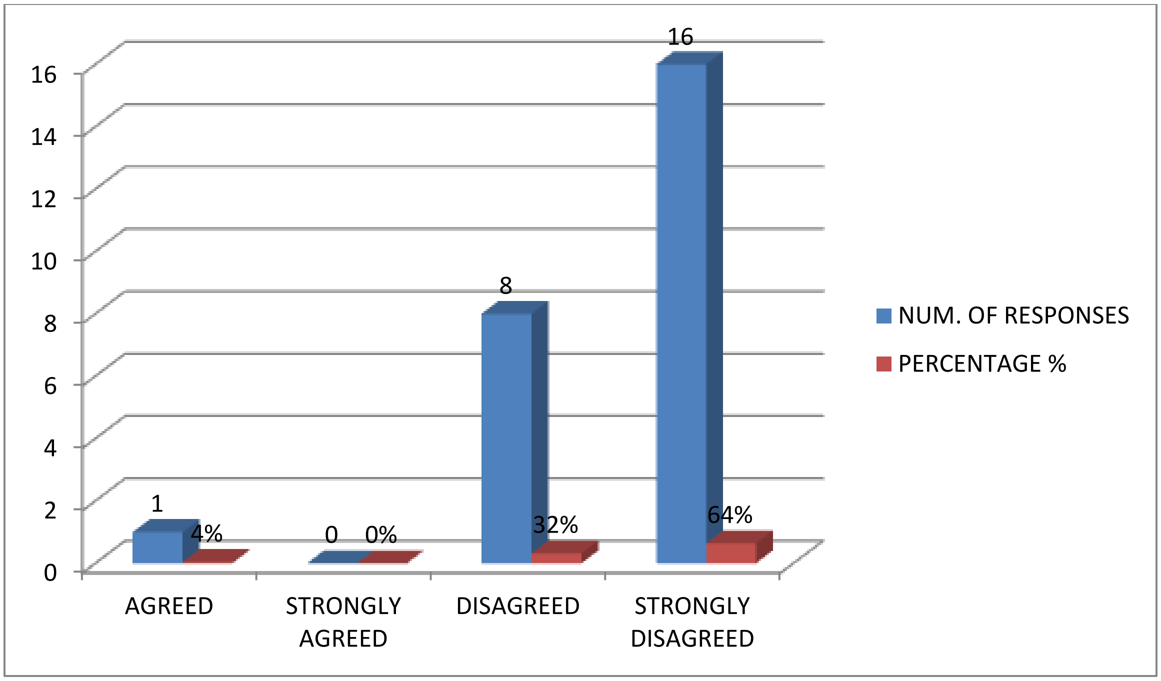


Fig 4.8 Planned preventive maintenance (Authors Field Data)

4.8 Improvement Maintenance Practices

Figure 4.9 below shows that no respondents representing 0% agreed that MSCF in Tamale practices improvement maintenance, no respondent representing 0% strongly agreed, 11 respondents representing 44% disagreed and 14 respondents representing 56% strongly disagreed. This means that MSCF in Tamale does not practice improvement maintenance.

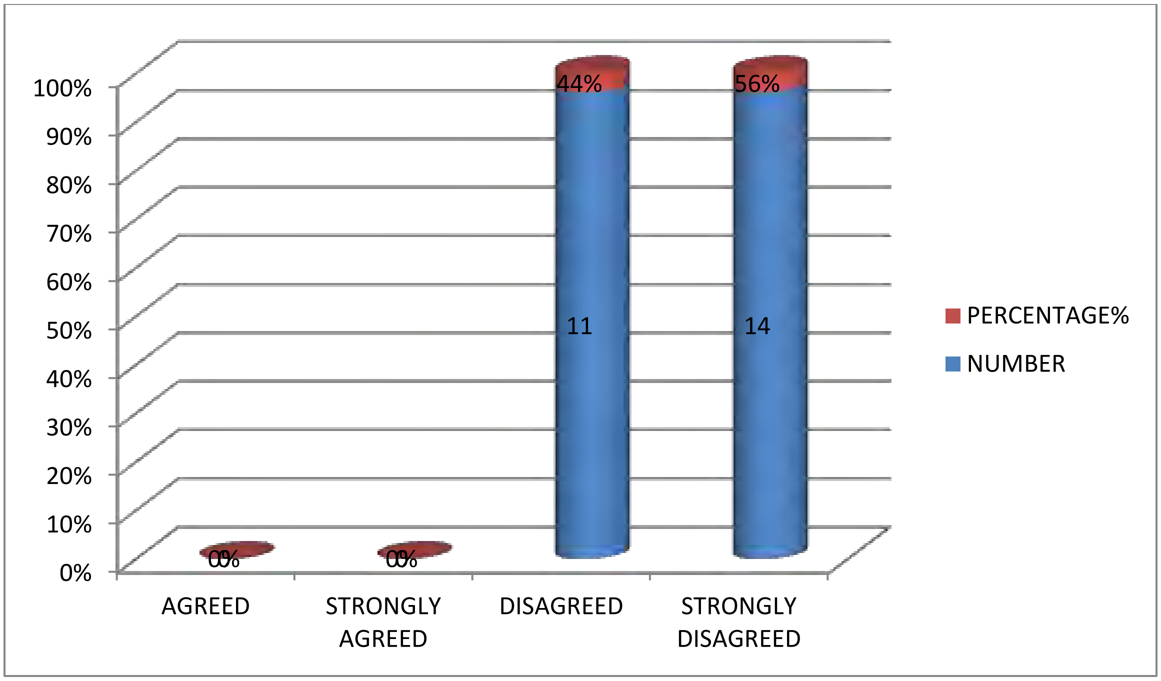


Fig 4.9 Improvement maintenance practices (Authors Field Data)

4.9 Increase of Manufacturing Productivity

Figure 4.10 below shows that no respondents representing 0% agreed that MSCF in Tamale practices productivity maintenance, no respondent representing 0% strongly agreed, 8 respondents representing 32% disagreed and 17 respondents representing 68% strongly disagreed. This means that MSCF in Tamale does not practice productive maintenance hence the production of most of their plants are low.

4.10 Equipment Maintenance for Contract Execution

Figure 4.11 below shows that 9 respondents representing 36% agreed that MSCF in Tamale only maintained their equipment when they have contract execute, 10 respondents representing 40% strongly agreed, 4 respondents representing 16% disagreed and 2 respondents representing 8% strongly disagreed. This means that MSCF in Tamale only put their equipment into good condition only when they have contract to undertake

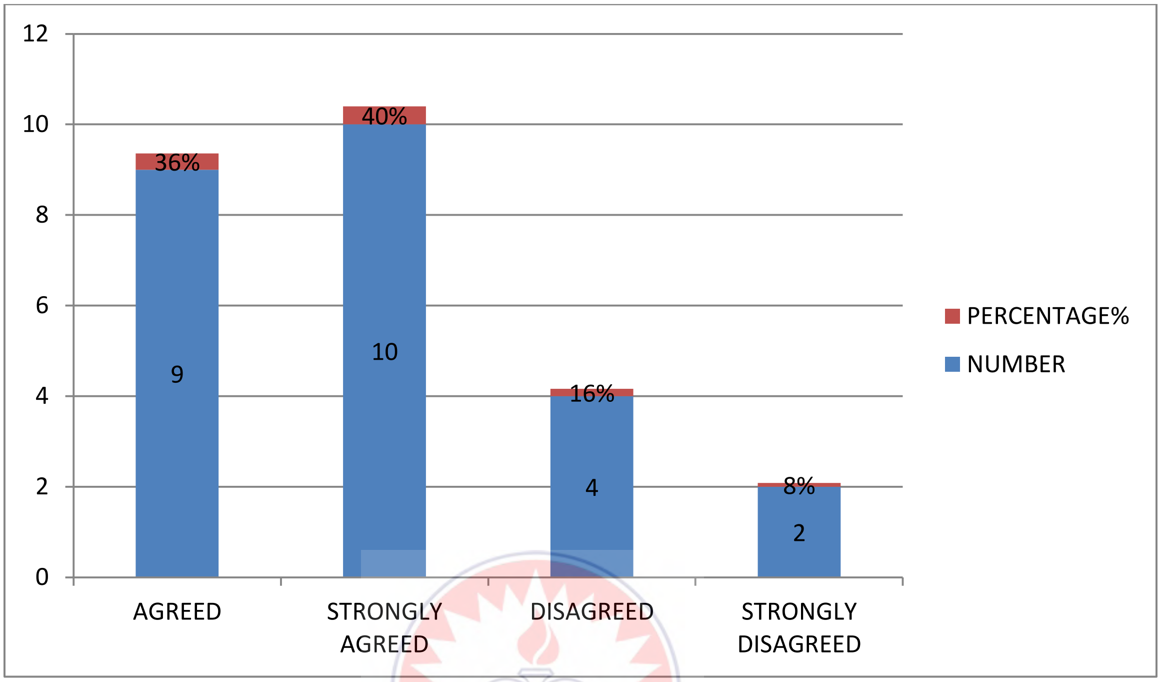


Fig 4.10 Equipment maintenance for contract execution (Authors Field Data)

4.11 reliability centered preventive maintenance practice by MSCF in Tamale

Figure 4.11 below shows that 2 respondents representing 8% agreed that MSCF in Tamale practices reliability centered preventive maintenance, 4 respondents representing 16% strongly agreed, 9 respondents representing 36% disagreed and 10 respondents representing 40% strongly disagreed. This means that MSCF in Tamale do not practice reliability preventive maintenance.

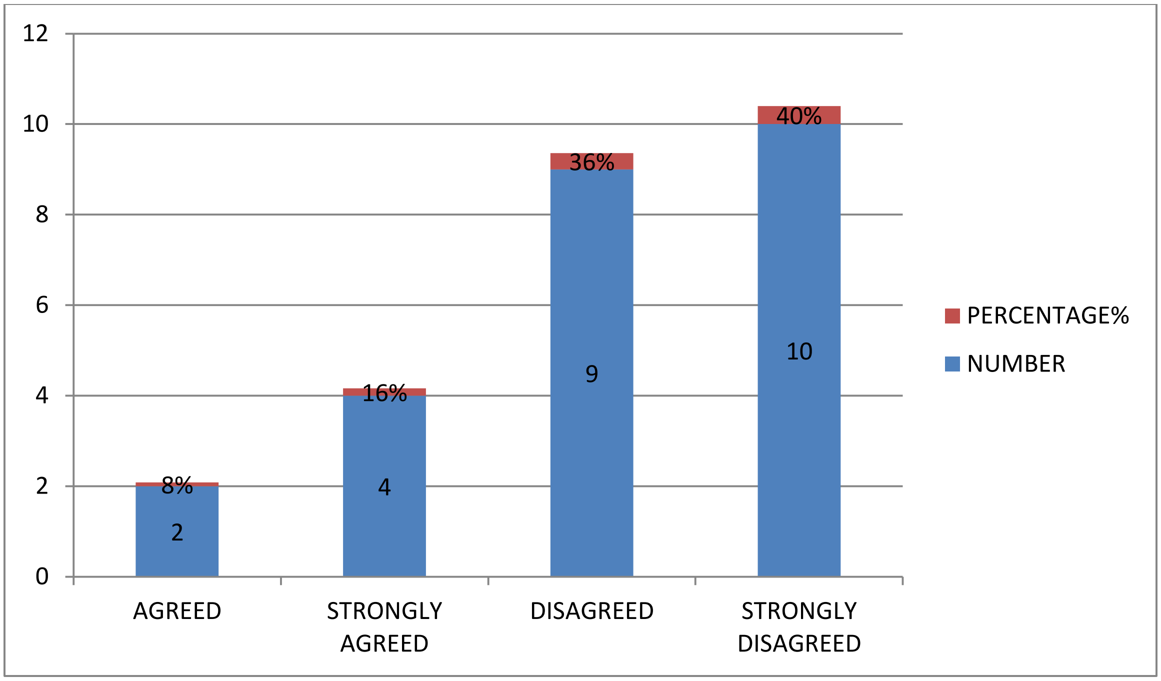


Fig 4.11 Reliability centered maintenance practice (Authors Field Data)

Table 4 shows questions and responses of respondents in relation to equipment maintenance.

Table 4: General responses

Questions	Responses							
	Agreed		Strongly agreed		Disagreed		Strongly disagreed	
	No.	%	No.	%	No	%	No	%
1. When damage plugs and cables of Electric Power Equipment are changed, it facilitates performance	11	44%	13	52%	1	4%	0	0%

2.	When Equipment are disconnected from the power source, it can damage the machine	13	52%	8	32%	3	12%	1	4%
3.	Electric Power Equipment shows signs of overheating which means that the equipment needs attention.	15	60%	10	40%	0	0%	0	0%
4.	The barrel of a loaded or unloaded Power Actuated Equipment is always pointed in a safe direction away from the operator's body	9	36%	7	28%	6	24%	3	12%
5.	Equipment or tools are equipped with protective shields or guards	7	28%	6	24%	6	24%	6	24%
6.	Air supply of equipment can be checked regularly	7	28%	6	24%	6	24%	6	24%
7.	Manufacturers inspect and test-equipment before sells to users	6	24%	7	28%	6	24%	6	24%

8. Some equipment or tools automatically goes off for sometimes after a long use	7	28%	9	36%	6	24%	3	12%
9. Fuses prevent a complete damage of equipment	9	36%	10	40%	4	16%	2	8%

Authors Field Data

For Question 1 on when damage plugs and cables are change, it facilitates the performance of Electric Power Equipment, 11 respondents representing 44% agreed, 13 respondents representing 52%, 1 respondent representing 4% and no respondent representing 0% strongly disagreed.

For Question 2, 13 respondents representing 52% agreed that when equipment are disconnected at power sources can damage the machine, 8 respondents representing 32% strongly agreed, 3 respondents disagreed representing 12% and 1 respondent representing 4% strongly disagreed.

For Question 3, 15 respondents representing 60% agreed that when electric power machine shows signs of overheating is an indication that the equipment needs attention.

For Question 4,9 respondents representing 36% agreed that the barrel of a loaded power actuated equipment is pointing at a safe direction away from the operator‘s body, 7 respondents representing 28% strongly agreed, 6 respondents representing 24% disagreed and 3 respondents representing 12% strongly disagreed. This means the operator is safe when operating the machine.

For Question 5,7 respondents representing 28% agreed that equipment are equipped with protective shields or guards, 6 respondents representing 24% each either strongly agreed, disagreed or strongly disagreed.

For Question 6,7 respondents representing 28% agreed that air supply of equipment can be checked regularly, 6 respondents representing 24% each either strongly agreed, disagreed or strongly disagreed.

For Question 7, 6 respondents representing 24% agreed that manufacturers inspect and test equipment before selling to users, 7 respondents representing 28% strongly agreed and 6 respondents representing 24% each either, disagreed or strongly disagreed.

For Question 8, 9 respondents representing 32% agreed that some machines or equipment automatically goes off after a long use, 10 respondents representing 40% strongly agreed, 4 respondents representing 16% disagreed and 2 respondents representing 8% strongly disagreed.

For Question 9, 9 respondents representing 32% agreed that fuses prevents complete damage of equipment, 10 respondents representing 40% strongly agreed, 4 respondents representing 16% disagreed and 2 respondents representing 8% strongly disagreed.

The **table 5** below shows recommendations and responses of respondents in relation to equipment maintenance.

Table 5: General recommendations

Recommendations	Responses							
	Agreed		Strongly agreed		Disagreed		Strongly disagreed	
	NO	%	No.	%	No.	%	No.	%
1. Warn/crack tires of plants must immediately be replaced with new ones before sent to site	10	40%	11	44%	3	12%	1	4%
2. Possible rusted and corroded equipment parts must be regularly checked for correction	11	44%	10	40%	3	12%	1	4%
3. Dirty and choked Air filter must be periodically cleaned	12	48%	11	44%	2	8%	0	0%

4.	Equipment must be periodically oiled/ greased for good performance	13	52 %	12	48 %	0	0%	0	0%
5.	Bolts and nuts of machine parts must be constantly checked and tightened	12	48 %	13	52 %	0	0%	0	0%
6.	Slaked bolts and nuts of machines must be replaced immediately	10	40 %	15	60 %	0	0%	0	0%
7.	Malfunctioning fuses of equipment must be replaced immediately	7	28 %	6	24 %	6	24%	6	24%
8.	Every MSCF must have an equipment or machine Inspector	8	32 %	8	32 %	5	20%	4	16%

Authors Field Data

For Recommendation 1, 10 respondents representing 40% agreed that warn tires must immediately be changed before sent to site, 11respondents representing 44% strongly agreed, 3 respondents representing 12% disagreed and 1 respondent representing 4% strongly disagreed.

For Recommendation 2, 11 respondents representing 44% agreed that possible rusted and corroded equipment parts must be regularly checked for correction, 10 respondents representing 40% strongly agreed, 3 respondents representing 12% disagreed and 1 respondent representing 4% strongly disagreed.

For Recommendation 3, 12 respondents representing 48% agreed that dirty and choked air filter must be periodically cleaned, 11 respondents representing 44% strongly agreed, 2 respondents representing 8% disagreed and 0 respondent representing 0% strongly disagreed.

For Recommendation 4, 13 respondents representing 52% agreed that equipment must be periodically oiled/ greased for good performance, 12 respondents representing 48% strongly agreed, 0 respondents representing 0% disagreed and 0 respondent representing 0% strongly disagreed.

For Recommendation 5, 12 respondents representing 48% agreed that bolts and nut machine part must be regularly checked and tightened, 13 respondents representing 52% strongly agreed, 0 respondents representing 0% disagreed and 0 respondent representing 0% strongly disagreed.

For Recommendation 6, 10 respondents representing 40% agreed that slaked bolts ants of machines must be immediately replaced 15 respondents representing 60% strongly agreed, 0 respondents representing 0% disagreed and 0 respondent representing 0% strongly disagreed.

For Recommendation 7, 7 respondents representing 28% agreed malfunctioning of equipment fuses must be replace immediately, 6 respondents representing 24% strongly agreed, 6 respondents representing 24% disagreed and 6 respondent representing 24% strongly disagreed.

For Recommendation 8, 8 respondents representing 32% agreed that every MSCF must have equipment or machine inspector, 8 respondents representing 32% strongly agreed, 5 respondents representing 20% disagreed and 4 respondent representing 16% strongly disagreed.

None of the respondents suggested any relevant information to what was contained in the questionnaire.

CHAPTER FIVE

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

In this chapter discussions and recommendations are concluded. Findings and observations drawn from the data analysis in chapter four of this study are also concluded in reference to the objectives of the study. The research sought to assess construction equipment maintenance practices for Medium Scale Construction Firms in Tamale Metropolis in the northern region of Ghana. This study has added up to work by researchers on the research topic. Three basic objectives relative to the construction industry were discussed in this study. The objectives of the study were to assess the status of Equipment Maintenance practice employed by Medium Scale Construction Firms in the Tamale Metropolis, examine the level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms and identify some recommendations that will improve Construction Equipment Maintenance practices on MSCF in the Tamale Metropolis. From this study, issues identified have been summarized which led to the conclusions and recommendation of the study.

5.2 Summary of Research Findings

This section summarizes the findings obtained from the research. This is based on the objectives of the research topic, assessing the construction equipment maintenance practices for medium scale construction firms which summary of findings can be deduced from the research objectives that served as a guide to the study.

5.3 Achieving the Research Objectives

The purpose of this research work is to assess how MSCF in Tamale, Ghana practices Equipment Maintenance. It outlines the Equipment Maintenance challenges confronting the Construction Firms in the Metropolis and the negative effects it has in the Construction Industry.

5.3.1 Objective One

Objective 1 was aimed at collecting factual information about the practices of equipment maintenance by MSCF.

The objective has been achieved by the views of experts' opinion on construction equipment maintenance which are considered by medium scale construction firms as maintenance practices that are supposed to be carried out or are carried out before the commencement of construction site operation. The findings revealed that most of the maintenance practices are not always carried out.

Most respondents believe that maintenance practices are not done the way should have been and few others think otherwise. The commonest maintenance practice by MSCF in Tamale is breakdown maintenance. This is so because; at this stage the firm has nothing to do than to maintain the equipment because it is needed to be used.

5.3.2 Objective Two

The maintenance practices of Medium Scale Construction Firms associated with specific categories of construction equipment was also assessed. The categories included; electric power operated equipment, powder actuated tools and pneumatic power tools.

In relation to electric power operated equipment; cables and plugs damaged were changed and such equipment are disconnected from power source after their use. For power-actuated tools, the barrels of such equipment operated following safety procedures ensuring they are free from obstructions. In the case of pneumatic power tool, procedures were in place to ensure the air supply checked regularly. The findings further suggest that workshop maintenance practices considered as important on the following; checking pressure of tires that may result in accidents, changing air filters that are dirty and clogged and repairs of malfunctioning gauges. The results agree with new safety standards (IS031000) highlighted in the important role of performance monitoring and operational feedback in safety control loop.

Most industries have realized a logging indicators (e.g. accident rate, lost time, injury rates etc.) to determine the reduction of risk as a result of safety intervention. The outcome of the research shows that the maintenance practices and policies have greater impact on the life of Medium Scale Construction Firms in the Tamale Metropolis.

5.4Conclusion

This research work was geared towards Assessing Construction Equipment Maintenance Practices for Medium Scale Construct Firms in the Tamale Metropolis of Ghana. In conclusion, the research findings seek to directly address the objectives of the study which are as follows: to assess the status of Equipment Maintenance practice employed by Medium Scale Construction Firms in the Tamale Metropolis, to examine the level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms and to identify some recommendations that will improve Construction Equipment Maintenance practices on MSCF in the Tamale Metropolis.

The study identifies that most contractors are not able to maintain their Equipment as per the police for maintenance of equipment indicated due to the unavailability of funds. The lack of equipment maintenance knowledge is also affecting MSCF. Change is not made without consequences, even from more awful to better.

When equipment maintenance are practiced prior, during or after construction work has been executed, the synergistic impacts of these maintenance can drastically influence project performance. Identifying and quantifying the cause and effect relationships between lack of maintenance and maintenance itself in order to mitigate or avoid their impact is vitally important to the construction industry. Maintenance practice greatly affects the execution of projects. The lack of this factor certainly makes it difficult to for maximum production and also affects life span of equipment/plants.

5.5 Recommendations

Reference to the above conclusion and findings from the Chapter four of this study, the following recommendations are proposed for review and improvement.

I. The provision of maintenance policies should be part of the criteria in the selection of the constructional firms for any project in the Tamale Metropolis

II. Monitors of constructional projects should insist on equipment maintenance practices and policies.

III. Stakeholders in the construction industry must take the initiative to educate professionals in construction on equipment maintenance practices and policies.

IV. Management of construction companies need to provide an expectation of minimum care standards to be used in the maintenance and repairs of Medium Scale Construction Firms' tools and equipment

V. Records of equipment/plants should be well kept to monitor the progress and life span of the plant/equipment on site

VI. Metropolitan, Municipal and District Assemblies (MMMDA'S) should have a register for a mandatory registering of all contractors in their jurisdictions.

VII. All lost history should be recalled and developed and maintained on all equipment owned by the various MSCF to enable owners of construction firms analyze the depreciation, improvement needs and value of equipment.

VIII. The following information of all equipment/plants should be recorded;

a. Age, cleanliness, and general condition
b. Addition, alteration and special modifications
c. Repairs, cost and mechanic performance
d. Accident involvement or other safety related problems
e. Number of equipment/plant assigned to a site

5.6 Limitation and Suggestion

All issues were not adequately exhausted due to the unavailability of time for the research. This was so because the study was an academic study. Data collection was limited to selected construction firms and construction projects in the Tamale metropolis hence the study is still constrained all though lots of efforts have gone into its planning and execution. In addition the undefined nature of the population has the potential of making this research not wholly representative. Due to this, further research can be conducted on the best equipment maintenance practices in the Tamale Metropolis and Ghana at large.

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APPENDIX

QUESTIONAIRE

Akenten Appiah Menka University of Skills Training and Entrepreneurial Development, Kumasi

This Questionnaire is in attempt to assess construction equipment maintenance practice for medium scale construction firms in the Tamale Metropolis. For the purpose of soliciting information for the writing of my thesis for the award of Master of Technology Degree from the **Akenteng Appiah Menka University of Skills Training and Entrepreneurial Development, Kumasi** .This questionnaire is prepared by me, a final year Master of Construction Technology (M-TECH) student.

Please be assured of your confidentiality and feel free to express your views.

Thank you for accepting to participate in this survey.

Please tick (√) the appropriate cell in response to the questions and write the necessary response or comment where applicable.

SECTION "A" PERSONAL DATA

1. SEX Male ( ) Female ( )
2. Age group 20 – 25 ( ) 26 – 30 ( ) 31 – 35 ( ) 36 – 40 ( ) 41 above
3. What is your designation/status in the company?.......................................
4. Which of the following categories does your firm classified under?

   a. D. K. ( ) b. D_2 K_2 ( ) c. D_3K_3 ( ) d. D_4K_4 ( )

5. How many years of construction experience are you in the following range of years?

    a. 1 to 4 years b. 5 to 8 years c. 9 to 12 years d. 13 to 16 years and above

6. What is your highest Education level?..

SECTION "B" MAINTENANCE PRACTICES BY MSCF IN TAMALE

Equipment Maintenance practice employed by Medium Scale Construction Firms in Tamale

Please tick (√) appropriately

7. To what extent is construction equipment maintenance in your firm carried out after use?

(a) Always after use (b) Sometimes after use (c) Never after use

8. Medium Scale Construction Firms in Tamale employed emergency maintenance practices

    (a) Agreed (b) Strongly agreed (c) Disagreed (d) Strongly disagreed (e) Somehow

9. The only practices by MSCF in Tamale is the Breakdown Maintenance

    (a) Agreed (b) Strongly agreed (c) Disagreed (d) Strongly disagreed

10. All MSCF in Tamale, practices Corrective Maintenance

    (a) Agreed (b) Strongly agreed (c) Disagreed (d) strongly disagreed

11. The most common maintenance practices by MSCF in Tamale is the Planned Preventive Maintenance

(a) Agreed (b) Strongly agreed (c) Disagreed (d) Strongly disagreed

12. It is common to see MSCF in Tamale practicing Improvement Maintenance

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

13. MSCF in Tamale increases their manufacturing productivity because they practice Productivity Maintenance

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

14. Most MSCF in Tamale do not maintain their equipment unless they have contract to execute

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

15. Only few MSCF in Tamale practices Reliability Centered Preventive Maintenance

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

SECTION "C" EFFECTIVENESS OF MAINTENANCE SYSTEMS

- Level of effectiveness of the recent available Equipment Maintenance systems applicable to Medium Scale Construction Firms.

10. When damage plugs and cables of Electric Power Equipment are changed, it facilitates performance

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

11. When Equipment are disconnected from the power source, it can damage the machine

(a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

12. Electric Power Equipment shows signs of overheating which means that the equipment needs attention.

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

13. The barrel of a loaded or unloaded Power Actuated Equipment is always pointed in a safe direction away from the operator‘s body

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

14. Equipment or tools are equipped with protective shields or guards

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

15. Air supply of equipment can be checked regularly

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

16. Manufacturers inspect and test-equipment before sells to users

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

17. Some equipment or tools automatically goes off for sometimes after a long use

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

18. Fuses prevent a complete damage of equipment

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

SECTION "D" RECOMMENDATIONS TO MSCF IN TAMALE

- Some recommendations that will improve Construction Equipment Maintenance practices on MSCF in the Tamale Metropolis.

9. Warn/crack tires of plants must immediately be replaced with new ones before sent to site

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

10. Possible rusted and corroded equipment parts must be regularly checked for correction

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

11. Dirty and choked Air filter must be periodically cleaned

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

12. Equipment must be periodically oiled/ greased for good performance

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

13. Bolts and nuts of machine parts must be constantly checked and tightened

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

14. Slaked bolts and nuts of machines must be replaced immediately

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

15. Malfunctioning fuses of equipment must be replaced immediately

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

16. Every MSCF must have an equipment or machine Inspector

    (a) Agreed (b) strongly agreed (c) disagreed (d) strongly disagreed

Please suggest any relevant Equipment Maintenance plan (if any)

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