Assessment of heavy construction equipment management practice on road projects: the case of Oromia Construction Corporation

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DECLARATION

I hereby declare that this Master Thesis "Assessment of heavy construction equipment management practice on road projects: the case of Oromia Construction Corporation is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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We, the undersigned, members of the Board of Examiners of the thesis by Yibas Hailu lema have read and evaluated the thesis entitled "Assessment of heavy construction equipment management practice on road projects: the case of Oromia Construction Corporation" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Specialization in Construction Engineering and Management).

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ABSTRACT

Highway construction business is a sector that relies primarily on high utilization of machinery. Equipment is thus one of the key factors for improving contractor's capability in performing their work more effectively and efficiently. The purpose of this study was to assess the heavy construction equipment management practices on construction projects: case study of Oromia Construction Corporation. The study was done using mixed research method with a target population of three public road projects. 47 questioners were distributed to the projects and 45 questioners were completed and returned. Descriptive, inferential and relative importance index analysis methods were used to analyze the collected data. By using Statistical package for social science software version 23 Questionnaires reliability was estimated by calculating Cornbrash's Alpha. The findings indicated that unexpected equipment breakdown & down time, idle time, poor maintenance practice and Non availability of spare part are the major equipment management problems. The study also indicate that: Equipment breakdown, Delay in payment for obstruction, Lack of training, Spares not available, Equipment efficiency, Lack of proper maintenance, Rework, Routine checking overall productivity of equipment, Two or more groups sharing an equipment, and Delay in allocating the equipment are the top factor from different groups those needs highly emphasis to improve equipment efficiency affect the productivity of equipment on those projects. The study advise that using currently developed software and GPS tracker those helps to manage inventory, maintenance schedule and equipment tracking. Also the study forward that the client should have to pay high attention before starting the construction of the project to decrease Delay and Cost Overrun of project happened due to delay of payment for obstruction (right of way) which increase idle hour and rework for equipment's.

Key word: Equipment management, productivity, problems, factors, effect, best practice

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LIST OF ABBREVIATIONS

CBM	Condition-Based Maintenance
CE	Construction Equipment
CEM	Construction equipment Management
CM	Corrective Maintenance
GPS	Global positioning system
LCC	Life Cycle Cost
MCDM	Multi-criteria decision-making
OCC	Oromia Construction Corporation
PM	Preventive Maintenance
QR Code	Quick response code
RII	Relative Importance Index
SPSS	Statistical package for social science
TPM	Total Productive Maintenance

CHAPTER ONE

INTRODUCTION

1.1. Background of Study

In construction operations on a large scale require the standard Equipment's for Effective operations especially in the area of infrastructural development. This is the true picture of large construction companies whose physical successful activities depends on men, materials and sophisticated machineries that will produce output of operations during a particular period use (Jaijith & Fazil, 2020).

Modern construction characterized by effective and efficient utilization of construction equipment to accomplish numerous construction activities. Equipment may range from simple hand tools or apparatus to heavy-duty construction equipment (Abebaw, 2014).

The existence of heavy equipment currently plays a very important role in carrying out various kinds of construction activities, especially those that are mostly carried out by mechanical means. In line with the rapid development of technology, the use of heavy equipment in construction activities will be very helpful in achieving several goals, such as saving time in carrying out work, saving work execution costs, labor efficiency, and obtaining results in accordance with standards (Irriene & Maulvi, 2021).

According to Yisa & Tsado (2014) construction business relies primarily on high utilization of equipment to carry out most of their projects, like construction of highway and other sophisticated structures. Equipment is thus one of the key factors for improving contractor's capability in performing their work more effectively and efficiently. Through the utilization of equipment, an extensive volume of work can be completed in a shorter period of time or within the project schedule. However, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investments in the requisition phase, which usually constitutes a major financial burden to them.

According to Jaijith & Fazil (2020) Construction firms are also often faced with problems related to high rate of equipment failure or breakdown and accident resulting from unskilled

operator’s abuse. Poor training of equipment operators is often claimed as a major cause of equipment related accidents.

Depending on the level of mechanization, the cost of equipment in a project ranges from 10% to 30% of the entire cost of the project. The cost of equipment increases by 30% when working on fully automated projects in the present era. For the project to be completed successfully, proper planning, selection, procurement, installation, operation, maintenance, and equipment replacement policy are crucial (Mohane & Ambare, 2019).

The construction industry currently plays a significant role in short-term trends in Ethiopia, with more frequent development, not only for the industry itself but also for other economic activities. It is therefore widely accepted that the construction industry requires an efficient resource management strategy to maintain profitability and keep making a significant contribution to the nation's growth (Mekdim, 2017).

Oromia Construction Corporation (OCC) is a public company that was just recently founded on July 2020, Four formerly autonomous public enterprises—Oromia Water Works Enterprise, Oromia Road Construction Enterprise, Oromia Construction Works Enterprise, and Oromia Drilling Enterprise—were amalgamated (merged) to establish the organization. The company is divided into three sectors: buildings, roads, and water, each of which has its own set of operational duties. The corporation's headquarters are situated in Addis Ababa City, next to "Kality Square (*Occ Profile*, 2021).

1.2. Statement of the Problems

Construction equipment is very important to the construction business and can cost up to 30% of the whole cost of a project. However, because equipment maintenance has not received the proper attention, the cost of a project has increased by roughly 40% overall (Yisa & Tsado, 2014).According to (Balaji & Venugopal, 2017) 70 % of delay in execution by equipment is due to operators, who operated equipment without training in it and 20% of construction accidents were due to ineffective handling of equipment. Inadequate supervision of equipment accounts for about 30–40% of construction cost overruns (Ranjithapriya & Arulselvan, 2020).

Oromia Construction Corporation is a public corporation that builds massive irrigation and hydraulic infrastructure, buildings, and roadways. It is a grade one contractor. It employs a variety of heavy construction equipment to complete such duties. The management of construction equipment and measuring its productivity are essential to the success of

corporation. Construction companies typically suffer significant losses as a result of inadequate manual equipment management methods and the arbitrary judgments of equipment managers.

According to Ethiopia Erena (2021) the utilization and management strategy for heavy equipment was not fully fulfilled in the 2020–2021 year owing to idle hours (6.9 percent) and downtime (25.12 percent). When these downtimes and idle time were assessed in birrs rather than dollars, the firm lost around 203 million Birrs in that year. This shows that management places a high priority on daily operations rather than factors affecting equipment productivity and equipment management issues that make it difficult for them to complete their work within a given project's budget and timeframe and maximize the organization's profitability. In addition, the company uses spreadsheets for equipment management rather than currently available software. An inquiry of these facts is necessary, coupled with an improvement intervention.

Therefore, the purpose of this study is to evaluate the practice in which construction equipment management is used in road projects, to identify the main problem associated with managing construction equipment, to identify the variables influencing equipment productivity, to evaluate best practices for managing construction equipment, and to provide recommendations.

1.3. Objective of the Study

1.3.1. General objective of the Study

The general objective of this study is to assess the heavy construction equipment management practices on road projects: a case study of Oromia Construction Corporation.

1.3.2. Specific Objectives of the Study

The specific objectives of this study are: -

- To assess the major problems of managing construction equipment.
- To identify the various factors affecting equipment productivity on road construction.
- To evaluate the effect of poor equipment management on road projects.
- To examine best practices for construction equipment management on road projects.

1.4. Research Questions

With the research questions, this study seeks to answer the following questions:

- What are the major problems with managing construction equipment?
- What are the various factors affecting equipment productivity in road construction?
- What is the effect of poor equipment management on road projects?
- What are the best practices recommended for Construction Equipment Management on road projects?

1.5. Significances of the Study

The study would give an overview of the situation in the area for other researchers by providing useful information about construction equipment management and productivity. The study would also enable awareness for a contractor about the current practices of construction equipment management, which helps the contractor to obtain a concept about its weakness and strengths in equipment management activity of construction projects. The study could also be used as an initiation for those who are interested to conduct a detailed and comprehensive study regarding the practice of construction equipment in Ethiopia.

1.6. Scope of the Study

The main objective of study is to evaluate how the contractor (Oromia Construction Corporation) manages its construction equipment and the elements that have an impact on it on three public projects. This study concentrated on the various construction equipment management aspects practiced on-site, major problems with managing construction equipment, factors affecting equipment productivity, and best practices for construction equipment management on road projects due to the broad and complex nature of construction equipment management practice aspects.

1.7. Limitations of the Study

This study was carried out under the limitation of very few previous researches published on equipment management on the local context, limited access and availability actual historical data and the project were far apart. Moreover, the common time and financial limitation are taken as consideration.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Highway construction projects are the yardstick to measure the development of the country. The projects to build new highways are currently evolving. For a project to be completed successfully, proper planning, selection, procurement, installation, operation, maintenance, and equipment replacement strategy are crucial. Construction engineers now need to be quite knowledgeable about the construction applications and maintenance of a large variety of contemporary machinery due to the expanding usage of machinery (Mithilesh & Nagavinothini, 2016).

The effective use of personnel, materials, and equipment must be aggressively pursued in good project management in the construction industry. The improvement of worker efficiency ought to be a top priority for anybody in charge of keeping construction facility costs under control. Material handling, which includes procurement, inventory, shop fabrication, and field servicing, requires special attention for cost reduction (Manikandan et al., 2018).

Different types of construction tasks are presently carried out with the aid of heavy equipment, especially those that rely heavily on mechanical methods. The employment of heavy equipment in construction activities are highly beneficial in attaining several goals, including reducing time while carrying out work, lowering job execution expenses, improving labor efficiency, and getting outcomes that are in line with standards (Irriene & Maulvi, 2021).

2.2. Concept of Construction Equipment Management

2.2.1. Construction Equipment

Construction equipment" refers to heavy-duty self-propelled vehicles, specially designed for executing construction tasks. Its use has significant importance in the successful realization of civil projects; it, therefore, represents a major capital investment for the construction industry. In this research, the term CE refers to the machinery that is used especially for earth-moving

operations (excavators, dump trucks, loaders, compaction rollers, graders, scrapers, etc.). Those earthworks mainly consist of four basic processes: excavating, hauling, spreading, and compacting (Naskoudakis & Petroutsatou, 2016).

Construction equipment is one of the three major inputs of construction practice along with labor and materials. The use of construction equipment makes the process more economical and helps in achieving high standards. A wide range of portable or movable items starting from hand tools to heavy equipment like cranes; trucks etc. are classified as machinery or equipment. Effective use of construction types of equipment reduces construction costs and increases productivity. It also reduces the wastage of construction materials during handling and placing. Effective equipment management paves way for the successful completion of construction projects (Pindoria et al., 2017).

Good equipment management begins at the time the equipment is purchased/hired. Purchasing/hiring the proper equipment that matches the need of assigned tasks, while achieving the lowest costs, is necessary to attain suitable equipment management. Proper record keeping provides information for planning maintenance/ replacement, ensuring that they occur at the proper time. Managing equipment includes preventative maintenance, planning maintenance, and replacement activities (Abdelaal et al., 2016).

Construction equipment is one of the important resources of modern-day construction in building sites. Equipment selection is an important factor in the implementation of many construction projects. Equipment managers are habitually called upon to make economic decisions involving the machines in their charge. Their duties include repairs, rebuilds, and maintenance (Ranjithapriya & Arulselvan, 2020).

2.2.2. Construction Equipment Management

Construction Equipment is an important factor to run the project successfully. It is important for both private constructions and public organizational Construction projects' success. A large number of quantities of equipment are required in construction even in small construction companies also there is a need to invest high initial costs in equipment.

Equipment management is the portion of project management. Authentic management of assets in projects can create noteworthy investment funds in time and cost. However, nowadays, construction businesses are still confronting many issues concerning low efficiency, destitute security, and inadequate quality. For successful equipment management,

it is essential to consider the productivity of the equipment. For finding out the productivity of equipment, considering factors influencing them is necessary. Appropriate equipment management can increment equipment productivity which leads to minimizing the cost and time of the current project (Methe et al., 2018).

According to Kanchana et al. (2018) equipment management includes proper planning, selection of the right equipment, procurement at right time, installation at the right place, operation and maintenance, and equipment replacement when needed. Equipment management helps in increasing productivity at a minimum cost. Operational and strategic planning are the two main factors in effective equipment management. Operational responsibilities include day-to-day management of construction equipment as strategic operations include procurement of new equipment. Under procured equipment may lead to losses in the invested capital. The various type of equipment maintenance includes corrective maintenance, preventive maintenance, productive maintenance, zero-hour maintenance, and periodic maintenance.

Construction equipment management is associated with procurement, retirement, replacement, operation, logistics, and maintenance of the equipment. The business objective of a heavy equipment company is to minimize operation, maintenance, and repair costs whilst keep maximizing the utilization of the equipment. These responsibilities can be classified into two groups, i.e. operational and strategic. These responsibilities are held by the project manager to determine the equipment requirement within a specific period (Nugraha & Putranto, 2019).

Construction equipment management is an important factor to run the project successfully. The effectiveness of construction machinery is a major factor that differentiates construction companies in terms of heavy construction and also light construction. Time and cost are important factors in a construction project. Selection and planning of equipment are required for its proper utilization. To complete the project within a stipulated time utilization of equipment becomes a priority. Data about the equipment and work are required from construction companies (Lincy, 2019).

The selection of construction equipment for a work site is; a key factor to be measured for the timely completion of the project within the predetermined budget. Cost efficiency is the main

criterion of construction equipment management. Another major characteristic of effective construction equipment management is defensive maintenance which can help to save a lot of time, and cost and reduce project delays. Equipment is an item that is portable from small hand tools to the truck, and crane. The complexity of today's construction projects makes it harder to appraise equipment alternatives and make the right selection of equipment. Based on their experience, equipment managers decide on the day-to-day management of equipment operations, and also on tactical operations such as new equipment procurement. Thus responsibilities of the equipment managers, ensuring that the equipment is properly used, maintained, utilized, and managed, are rather challenging. Effective operation of construction equipment should be maintained to avoid exploitation of such a huge investment. Also, repair and maintenance should be carefully intended and high productivity rates should be realized during operations (Ranjithapriya & Arulselvan, 2020).

2.3. Equipment Productivity

Good site management in construction must continually pursue the efficient utilization and allocation of labor, material, and equipment. Improvement of equipment productivity should be a considerable concern for the control of infrastructure projects. In GCC countries, whilst the direct unit cost of equipment per hour in terms of cost rates paid may not be significantly high, findings indicate indirect costs are significant including hiring, transporting, storage, technical support, supervision, and insurance.

Productivity in construction in analytical methods is defined as unit output per hour. It is important to note that equipment productivity is a measure of the overall effectiveness of organizational systems in utilizing labor, equipment, and capital to convert labor efforts into useful output, and is not a measure of the capabilities of labor alone. The efficiency and effectiveness of organization systems in utilizing resources will lead to minimizing construction waste. The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus productivity (Abdelaal et al., 2016).

The use of heavy equipment that is not right with the conditions and employment situation will affect the low productivity of the equipment and not achieving the predetermined schedule or target. Many found a significant increase in the use of heavy equipment at construction sites as a form of business to meet the demand in the past few decades. By

paying attention to the problems that occur, it is concluded that the heavy equipment used in a project is influenced by the productivity of the equipment to the volume of work to be carried out, while the amount of equipment needed depends on the time available, site conditions, weather conditions, equipment efficiency, equipment capacity, number equipment, and equipment operator capabilities (Syafrudin et al., 2020).

According to Irriene & Maulvi (2021) Productivity is the capacity for production, the state of being a productive force, the effectiveness of the production effort, especially in industry, and the production effort per unit. In theory, productivity is output divided by input. For the productivity of a tool, the output is measured from the work that can be completed by the tool concerned per unit time, for example, m^3 per hour, while the input is the tool itself. Therefore, there are two types of productivity, namely the productivity of individual tools, when the work is completed by the tool alone, and the second is group productivity/group of tools when the work is completed by a group of tools.

2.4. Selection of Construction Equipment

For proper selection of equipment, a considerable experience in the operation and maintenance in the field is essential. Records kept for operation, maintenance and actual output obtained under comparable conditions of previous projects will greatly help in deciding equipment selection. the Following are the main points that should be considered in the process of equipment selection; these are Suitability for job conditions, Size of the equipment, Standardization, Availability of equipment, Availability of spare parts, the economy, reliability of the equipment, Service support, and Past performance (Bantamlak, 2013).

The choice of construction equipment is crucial because, while a good choice might increase profits for contractors, a poor choice can increase overhead costs. The various equipment selection criteria include extensive experience in operation and maintenance, information from prior projects on O &M and actual output obtained, knowledge of technology and the capacity of current brands of equipment, the time needed to complete the projects, and the cost that will be incurred. The availability of additional options in today's technology environment has made equipment choosing more difficult (Kanchana et al., 2018)

For proper selection of equipment, a considerable experience in the operation and maintenance in the field is essential. Following are the main points which should be considered in the process of equipment selection (Beharu, 2021).

I. Suitability for Job Conditions: The equipment must meet the requirement of the work, climate and working conditions.
II. Size of the Equipment: Size of equipment should be such that it must be able to be used with other matching units.
III. Standardization: It is better to have same type and size of equipment's in the project.
IV. Availability of Equipment in the market: The equipment which is easily available in the market should be purchased.
V. Availability of Spare Parts: While selecting a particular type or make of equipment, it should be ensured that the spare parts will be available at reasonable price throughout the working life of the equipment.
VI. Multipurpose Equipment's (Versatility): There are certain types of equipment are which are not utilized fully.
VII. Availability of Know-how: The equipment selected should be satisfactorily handled by available operators and mechanics.
VIII. Use in Future projects: When equipment completes only a part of their useful life in a project, it should be kept in view that the equipment can be used in future projects and may not become obsolete.
IX. The Economical Aspects: While selecting the equipment, it should be considered that the cost of unit production should be Minimum.
X. Reliability of the Equipment: Equipment selected for the project must be reliable one.
XI. Service Support: Service support should be available in the area of project where the equipment shall be used. Service after sales is a major criterion for selection of equipment.
XII. Operating Requirements: The equipment selected should be easy to operate and maintain, acceptable to the operator and should have lesser fuel consumption.
XIII. Past performance: If the equipment being purchased is of new make and model, it is desirable to enquire about its performance from other users, who are using this make and mode.

2.5. Construction Equipment Fleet Management Tools

To manage equipment fleets, many researchers have tried to develop accurate and reliable techniques. Most of the fleet management tools available on the market are specialized for maintenance issues, that is, for equipment pieces to be available when they are needed. The real-time tracking of equipment is also very important to better allocate existing equipment pieces. The location of equipment can be tracked with existing tools available in the market. One of the fleet management software applications in the market is "Fleet Focus", capable of managing diverse fleets of all sizes. This software application is capable of tracking all functions associated with the maintenance of equipment and vehicles, such as preventive maintenance, work orders, processing repairs, analyzing operational expenses, computing billing, and recording the usage of vehicle equipment. Besides including the standard features, Fleet Focus works in real-time using a single dataset (Hakob & Skibniewski, 2017).

As quoted by Pindoria et al. (2017), the new system for estimating onsite productivity and forecasting project cost and time of earthmoving operations. The new system uses limited GPS (Global Positioning System) data, collected from a construction site using GPS (Global Positioning System) receivers mounted on hauling units. The new system utilizes only samples of GPS data which is received from satellites as a substitute approach to current systems that require collecting a large volume of data. The system is can be used during the construction or execution of a project by reconfiguring the fleet dynamically while operations are in progress to support needed corrective actions.

Through correct equipment selection and optimization, production monitoring, tracking of equipment, keeping a maintenance schedule, etc., the use of equipment fleet management boosts the productivity of the entire site and increases profitability. For this, a variety of advanced technologies and techniques, including telematics, GPS navigation, information transfer systems, and diverse software, can be used. The conceptual sub-components of fleet management include things like equipment assignment and selection, equipment optimization, maintenance, production monitoring, material, and position tracking, etc. (Kadam & Patil, 2015).

It is well known that asset management software automates manual operations. It keeps the data correct and does away with spreadsheets. Equipment that is regarded as the foundation of

the firm is frequently stolen or lost, which is a serious problem in the business sector. When they are not identified, daily activities are disrupted, production work is delayed, and efficiency suffers as a result. Equipment tracking is done to prevent theft and misplacement. Asset tracking strategies like barcoding, QR Codes, RFIDs, and others can be used to track down specific pieces of equipment (pcsinfinity privet limited, 2021).

One essential element for making dump truck firms work more efficiently is a GPS tracker for dump trucks. Traditional GPS trackers can improve operational efficiency in a few significant ways, including giving companies the resources they need to retrieve stolen property will help prevent theft at construction sites. Other initiatives include tracking fuel usage and increasing employee performance transparency. These existing assets will, however, be swamped by the additional data that platform- and app-based GPS monitoring can supply as the sector develops and business needs change (Elizabeth Sholes, 2020).

2.6. Construction Equipment Maintenance Strategy

The total productivity effort in modern industry is depending upon equipment and machinery. So those are a very important part of the industry. Therefore, downtime or idleness of equipment and machinery becomes very expensive. Hence, the plant machinery should be properly maintained which is very much important. The highest percentage of cost is commonly considered to be maintenance costs which are related to operating a piece of equipment (Manikandan et al., 2018).

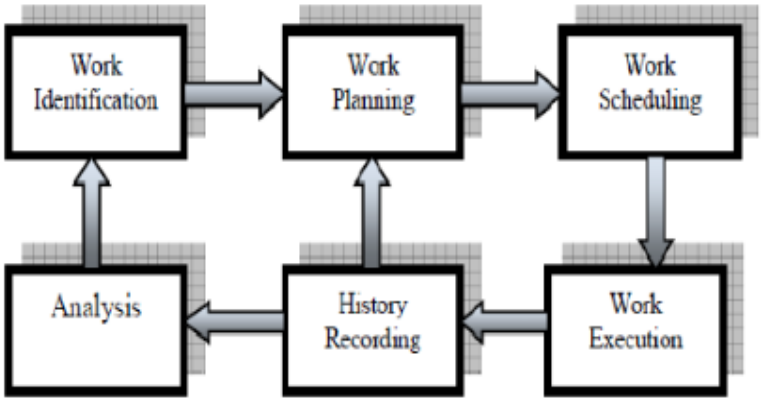

Figure 2.1 Maintenance Process Source: (Phadatare & Charhate, 2016)

A maintenance strategy is a planned way to upkeep devices, which contains actions such as "identification, researching, and execution of many repairs, replace and inspect decisions". Implementation of the strategy requires an executable, tactical plan.

Basic maintenance strategies are the following: preventive (PM), corrective (CM), and condition-based maintenance (CBM). General maintenance policy, integrate mentioned approaches to build tools for maintenance personnel. Considering assumptions of Total Productive Maintenance TPM, (Gackowiec, 2019) proposes two general maintenance strategy categories: reactive (also named corrective maintenance) and proactive. Reactive methods are directed toward repairs after breakdowns occurred, while proactive tasks are aimed to avoid these repairs and failures. Detailed classification of the strategies included in mentioned main groups is shown in Figure 2.2

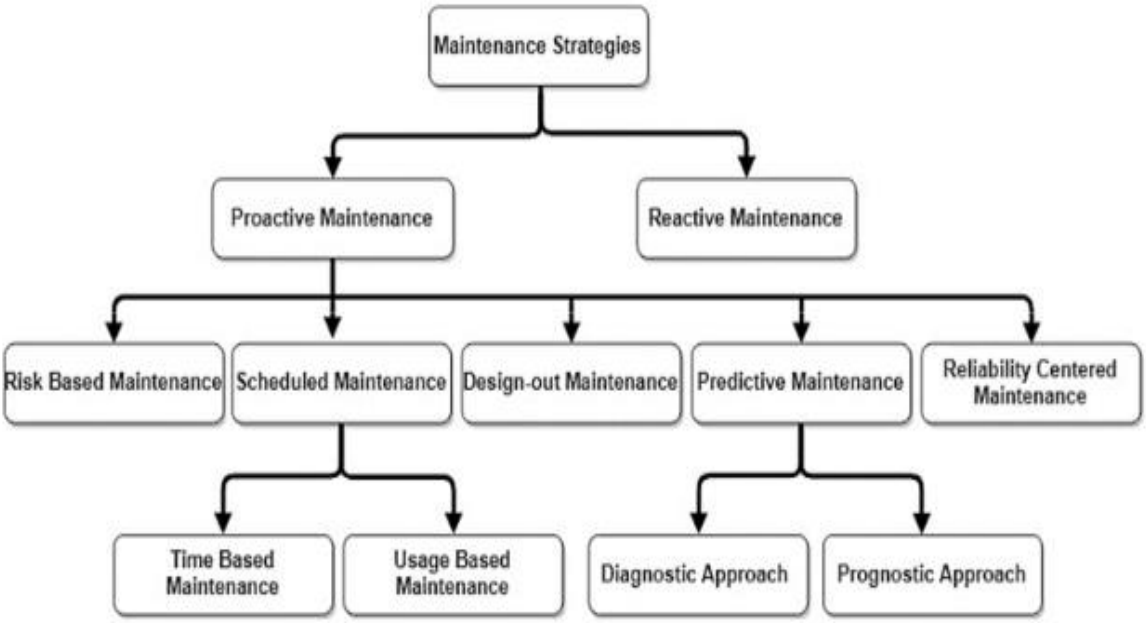

Figure 2.2 Classifications of maintenance strategies Source: based on (Gackowiec, 2019)

When properly performed, proactive maintenance is a highly effective but underutilized generic maintenance method. When properly applied, proactive maintenance, a highly effective but underutilized generic maintenance method, significantly increases equipment reliability. Without sacrificing dependability or safety, proactive maintenance strives to eliminate, decrease, automate, or simplify maintenance. In its most basic form, proactive maintenance comprises three key concepts: maintenance enhancement, maintenance prevention, and maintenance elimination. It is concerned with empowering people to address

problems. Proactive maintenance entails going beyond routine task lists and reactive fixes to examine the root causes of a component failure. Finding a method, item, or process that prolongs the life of a component and necessitates fewer inspections may be necessary. Standardizing screws, enhancing access to difficult-to-reach inspection areas, or demonstrating to internal customers how to properly complete a work order are all examples of relatively easy solutions (Azmi & Danish, 2017).

2.7. Major Problems of Managing Construction Equipment

According to Manikandan et al. (2018) idle time, downtime, poor equipment maintenance practices, improper determination of economic life and timing of replacement, poor training of equipment operators, equipment breakdown, over maintenance of equipment, huge capital investment during acquisition, the balance of interdependent equipment, misunderstanding the scope of work carried out, the unit cost of production and equipment suitability for job condition was found to be the major problems that affect construction equipment planning and management.

As cited by Yitayal (2020) equipment is one of the key factors for improving contractors' capability in performing their work more effectively and efficiently. By utilizing machinery, an extensive volume of work can be completed in a shorter period and within the project schedule. However, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investment in the acquisition phase, which usually constitutes a major financial burden.

2.7.1. Acquisition phase

The primary consideration in the buy, lease, or rent decision is the amount of risk the contractor wishes to assume. This risk is typically associated with financial considerations which are a huge capital investment. The evaluation of this risk makes equipment acquisition an important managerial concern. It is advisable to consult an accountant before the purchase of equipment to evaluate cash flow and tax implications. Along with these financial considerations, how much the equipment is to be utilized is the most important consideration for return on investment. Future work volume, production needs, project-specific or client requirements, long-term company goals, acquisition time, and equipment availability must be

considered when developing a utilization strategy for a piece or fleet of equipment. The capital investment in the purchase and/or rental/lease, and operation of the equipment is very high, it has to be managed to ensure maximum return on investment, productivity, and minimum operating, maintenance, and repair cost (Gransberg et al., 2018).

Heavy civil construction equipment expenditures represent an average of about 30% of the corporate assets (Awaad et al., 2022). Consequently, concerns about how businesses buy new equipment, whether they have equipment acquisition policies, and how important equipment policies are too large, medium, and small heavy construction firms should be of interest.

2.7.2. Operational phase

Contractors are often faced with problems relating to a high rate of equipment breakdown and accidents resulting from unskilled operator abuse. Poor training of equipment operators has often been claimed major cause of equipment-related accidents (Yitayal, 2020).

The equipment operator is the last shooting person that determines the productivity of the equipment. Misuse of equipment, induced by the negligence of the operator and lack of proper training and know-how on the part of the equipment supervisor, may result in increased frequency and cost of downtime. An operator's skill is one of the most important factors and it affects that operator's performance and the direct cost of DT through job efficiency (Mekdim, 2017).

2.7.3. Maintenance phase

Proper maintenance management of construction equipment is never over-emphasized since the cost and time that exceed the designated budget or schedule on projects are often resulted from poor equipment maintenance practice. When the machine breaks down, the production drops to zero and the equipment starts costing money to its owner rather than making money. Construction equipment maintenance programs generally consist of three major components: preventive maintenance, routine maintenance, and major repairs. If the first two programs are both aggressively applied and well managed, the major repair program is minimized, and even more importantly, the first two programs occur as scheduled under the owner‟ control whereas major repairs occur randomly and usually at times when they seem to create the most distress to the project. Poor equipment maintenance practices cause major breaks on equipment spare parts and increase the downtime of equipment, this reduces the productivity

of equipment and increases project cost. Thus, to understand effective construction equipment management, one must also understand effective construction equipment maintenance (Gransberg et al., 2018).

2.7.4. Disposal phase

Determining equipment's economic life and timing for replacement is often problematic because such decision is influenced by various factors such as machine obsolescence and efficiency. Construction equipment life can be defined in three ways: physical life, profit life, and economic life. The figure below shows graphically how these different definitions relate to the life cycle of a typical piece of equipment (Bharati, 2020).

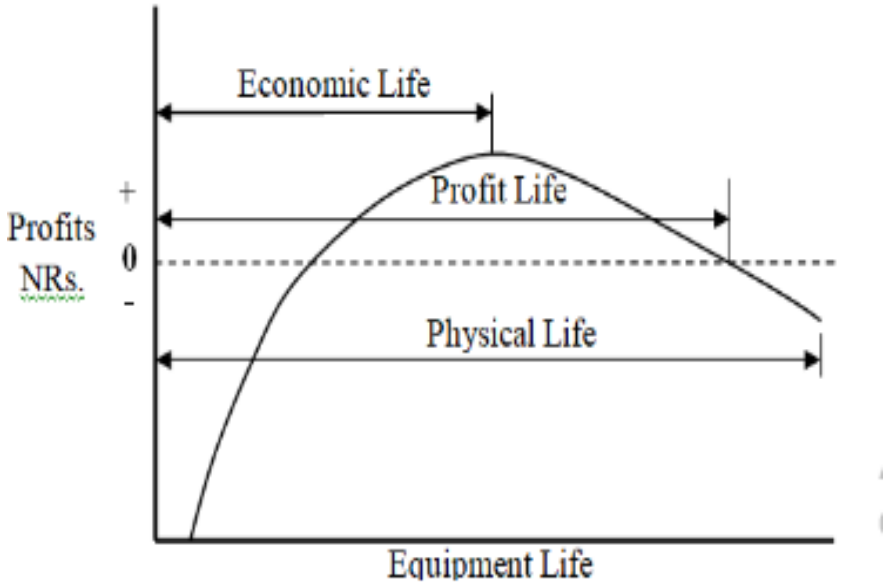

Figure 2.3 Equipment Life (Bharati, 2020)

The physical life of the equipment is identified as the service life. This period ends when equipment can no longer be operated. Profit life is the period when equipment is generating a profit. This is the most desired stage of the equipment's life because after this point in time the equipment will operate with a loss. Economic life is based on decreasing ownership costs with the increase in operating costs. The period that these costs are equivalent to is called economic life. When the operating costs exceed the ownership costs, a piece of equipment is costing more to operate rather than own.

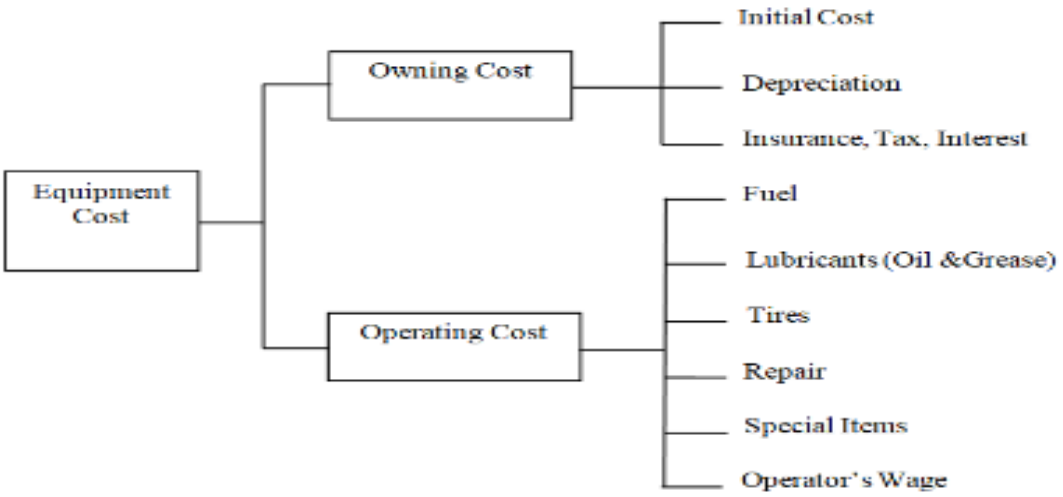

Figure 2.4 Equipment cost (Bharati, 2020)

Life Cycle Cost

The Life Cycle Cost (LCC) of equipment is the total cost throughout its life including purchase price, installation, operation, maintenance, and any other costs directly attributable to owning and using the asset. Life cycle cost involves identifying and quantifying all costs related to the entire life of a piece of equipment instead of a specified shorter period. The historical record of costs incurred and the historical record of services obtained from a piece of equipment permit the calculation of the equipment's life cycle cost.

LCC=Operating Cost + Ownership Cost……..……. equ.1

As quoted by Yitayal (2020) the following are some of the problems faced during construction equipment usage; Sudden and unexpected equipment failures, or breakdowns, Unnecessary costs due to poor technology and wrong mechanism, Additional costs due to maintenance, repair, and accidents, Lack of a systematic method for selection of suitable equipment and combinations, Constrains in placing or accommodating the equipment and Difficulty to manage, supply and schedule machinery.

2.8. Construction Equipment costs

For contractors in the heavy civil construction industry, the cost of owning and operating equipment is a key part of doing business in a profitable manner. Failing to properly estimate equipment cost has led many contractors into hardships. Without knowing the actual

equipment ownership costs, contractors might report higher than justified paper profits due to inaccurate accounting practices that do not factor the cost of idle equipment into the company's overall profit picture. Then at the end of the year, they find that they actual were losing money because of the incurred costs of idle equipment impacting the actual profit margin. This situation is particularly dangerous in a declining market where the contractor's annual volume is lower than normal due to fewer projects being let. It can also happen in growing companies who have not yet developed a mature estimating database of actual equipment costs.

2.8.1. Ownership Cost

Ownership costs are fixed costs. Almost all these costs are annual in nature; and include:

2.8.1.1. Initial Cost

On an average, initial cost makes up about twenty-five percent of the total cost that will be invested during the equipment's useful life. This cost is paid for getting equipment into the contractor's yard, or construction site, and ready for operation.

2.8.1.2. Depreciation

Depreciation represents the decline in market value of a piece of equipment due to age, wear, deterioration, and obsolescence.

2.8.1.3 Investment Cost

Investment (or interest) cost represents the annual cost (converted to an hourly cost) of capital invested in a machine. If borrowed funds are utilized for purchasing a piece of equipment, the equipment cost is simply the interest charged on these funds.

2.8.1.4. Insurance Tax and Storage Costs

Insurance cost represents the cost of fire, theft, accident, and liability insurance for the equipment. Tax cost represents the cost of property tax and licenses for the equipment. Storage cost includes the cost of rent and maintenance for equipment storage yards, the wages of guards and employees involved in moving equipment in and out of storage, and associated direct overhead.

2.8.2. Cost of Operating Construction Equipment

Operating costs of the construction equipment, which represents a significant cost category and should not be overlooked, are those costs associated with the operation of a piece of equipment. They are incurred only when the equipment is actually being used.

2.8.2.1 Maintenance and Repair Cost

The cost of maintenance and repairs usually constitutes the largest amount of operating expense for construction equipment. Construction operations can subject equipment to considerable wear and tear, but the amount of wear varies enormously between the different items of equipment used and between different job conditions. Generally, maintenance and repair costs get higher as the equipment gets older.

2.8.2.2. Tire Cost

The tire cost represents the cost of tire repair and replacement. Because the life expectancy of rubber tires is generally far less than the life of the equipment they are used on, the depreciation rate of tires will be quite different from the depreciation rate on the rest of the vehicle.

2.8.2.3 Consumable Costs

Consumables are those items that are required for the operation of a piece of equipment that literally get consumed in the course of its operation. These include but are not limited to fuel, lubricants, and other petroleum products. They also include such things as filters, hoses, strainers, and other small parts and items that are used as the equipment is run.

2.8.2.3 Mobilization and Demobilization Cost

This is the cost of moving the equipment from one job site to another. All too often it is overlooked in bidding because of the hope that the previous job will have already paid for 2-19 it. However, that may be, the costs of equipment mobilization and demobilization can be large and are always important items in any job where substantial amounts of equipment are used.

2.8.2.4 Equipment operator cost

Operator’s wages are usually added as a separate item after other operating costs have been calculated. They should include overtime or premium charges, workmen’s compensation insurance, social security taxes, bonus, and fringe benefits in the hourly wage figure.

2.8.2.5 Special Items Cost

The cost of replacing high wear items such a dozer, grader, and scraper blade cutting and end bits, as well as ripper tips, shanks, and shank protectors, should be calculated as a separate item of operating expense. As usual, unit cost is divided by expected life to yield cost per hour.

2.9. Effects of Poor Equipment Management on Construction Projects

Usually, it seems to be a big challenge for different stakeholders and main contractors to decrease the costs of the projects through the optimum use of construction equipment to increase the quality of the project and decrease time and cost (Aadal et al., 2014). He identified the most important issues in construction management regarding the use of equipment. These are the effect of spare parts availability to decrease downtime, the effect of employing expert mechanics to increase the repair quality, the impact of gasoline and petrol availability to decrease wasting the time, the impact of periodic control and serviceability of plants and equipment to increase productivity, the impact of training persons who are involved plants and equipment to increase productivity. These factors have a significant role in construction projects and different contractors should consider them in their projects.

To safeguard the construction industry from financial losses, the project managers have to play a great role to minimize losses and optimize productivity by improving the management problems, equipment utilization techniques, the effectiveness of the operators, and the working conditions on the site as cited by (Mekdim, 2017).

2.9.1. Delay (Time overrun)

Usually, contractors have different pressures such as budget problems, time constraints, quality of the project, and increasing safety. Consequently, several pieces of equipment uses seem to be a very essential factor to improve the ability of the contractors during the project time. Management of construction equipment directly affects project duration. Thus to minimize construction delays, it is very important to manage CE appropriately.

2.9.2. Cost Overrun

Several factors that cause cost overruns in road construction projects have been identified in various places and times. Different problems and challenges may happen for the contractors

during the working procedure with the equipment such as the life cycle of the machines and different financial risks, which may cost a lot for the company.

2.9.3. Loss in Productivity of Equipment

Productivity is the ratio of useful work output to the time spent to complete that work. Loss of equipment productivity is the decline in the output/ productivity of construction equipment due to various circumstances or events. (Abebaw, 2014) states that the main equipment-related losses are three: Availability losses/ Inactivity Losses, Performance loss/ Speed Losses, and Quality loss /Defective losses.

2.10. Factors Affecting Equipment Productivity

Earthmoving operations and highway construction commonly entail extensive utilization of heavy construction equipment. Various factors affect directly and indirectly the efficient utilization of equipment and subsequently can lead to productivity decline in earthmoving operations. Efficient utilization of equipment is considered a crucial element toward the success of the earthmoving project (Salem et al., 2017).

According to Manikandan et al.(2018) factors affecting productivity in construction can be divided into two categories: human-related factors and management-related factors. These factors affect the morale and motivation of individuals. Quality of supervision, material management, site planning, constructability, and change management are the most significant management-related factors that influence productivity directly. The cost of the project must include the cost of equipment needed to build the project. The constructor must be able to determine, as accurately as possible, the duration of each piece of equipment required for each activity of the project (Pindoria et al., 2017).

According to Methe et al.(2018) the study appeared that all the 3 groups-contractors, clients, and specialists of members for the most part established that out of 83 factors the best 10 impacting factors influencing equipment productivity organized in descending arrange of RII are: Lack of ability of operator, Rework, Lack of supervision, Improbable planning and expectation of labor execution, Delay in placing the equipment, Two or more groups sharing equipment, Communication between site administration and operator, Equipment breakdown, Lack of proper maintenance, and Non- payment of charges/Delay in payment. From the

different literature studies (Khot & Patil, 2020) was identified the following factors which impact equipment productivity are recorded below:

2.10.1. Operators Factors

Unskilled laborers and poor raw materials are elements that reason for low productiveness. If skilled labor is unavailable and a contractor is needed to complete precise obligations with less-skilled labor, it's far from all likelihood that productiveness could be negatively impacted. These are Lack of experience, Lack of ability of operator, Disloyalty, Personal problems, and Lack of training.

2.10.2. Equipment Factors

Improper scheduling of work, and scarcity of critical production systems or labor, may also bring about a loss of productiveness. Improper making plans of mission-initiation strategies may additionally result in misplaced labor productivity. Including, delay in placing the equipment; two or more groups sharing equipment, Equipment breakdown, Lack of proper maintenance, and Spares not available.

2.10.3. Environmental Factors

Various natural elements affecting gadget productivity collected from preceding studies are climate situations and geographical situations. Productivity is found to be fantastically affected if the climate is simply too intense. These are Temperature and humidity effects, Rain, snow, wind effects, sandstorm, and Type of soil.

2.10.4. Technological Factors

Productivity can be affected if required substances, tools, or creation systems are not available at the suitable vicinity and time. If unsuitable tools or systems are provided, productivity can be negatively affected. These are, Rework, Compatibility and steady among contract records, Condition of haul road, Excess travel/ lifting, and Obstacle on site.

2.10.5. Management Factors

Motivation is one of the critical elements affecting a construction lab our productivity. Motivation can first-class be executed when the laborer's non-public ambitions are aligned with the agency's strategic dreams. Factors that include fee delays, a lack of a monetary

motivation system, non-provision of proper transportation, and a lack of training sessions are grouped on this topic. Includes, Lack of supervision, improbable planning and expectation of labor execution, Communication between site administration and operator, Non-payment of charges/ Delay in payment, and Interfacing of activities.

2.11. Best Practices for Construction Equipment Management

From different literature review (Mekdim, 2017) quoted that the best practice for Construction equipment management is as follows:

2.11.1. Selection

Contractors consider a selection of equipment fleet to be vital for any construction project to be successful. The task of the project planner, estimator, or engineer on the job is to select and match the right machine or combination of machines to the job at hand. Equipment selection best practices include- Using models based on traditional mass haul diagrams, artificial intelligence, genetic algorithm, and geographic information system to crew optimization; Mathematics of rough sets and fuzzy sets, and Analytical hierarchy process to take account of qualitative factors.

2.11.2. Acquisition

Contractors have two options in acquiring equipment. They may either own their machinery and equipment or hire it. Many contractors prefer to hire only those items of equipment, which are required to meet peak demand or specialized activities. The alternative decision to purchase will have an important financial consequence for the contractor since considerable capital sums will be blocked up in the plant, which must be operated at an economic utilization level to produce a profitable rate of return on investment Best practices for construction equipment acquisition determined by different researchers includes:-

First, the best practice is to Purchase equipment outright by cash, financing which includes; Decide on acquiring or disposing of equipment by the president, board directors, equipment managers, or project managers; Purchase equipment based on brand popularity and spare parts availability, functions, and its usage; Purchase the same brand that is being used regularly Purchase equipment from familiar dealers; Buy used machines because of cheaper price but still in good condition or need in functions and advanced technology and Buy used machines only the ones that do not have complicated systems, ones that do not have high repair costs

once a failure, ones that are not frequently utilized or ones that are frequently utilized for a long time.

The second one is Acquiring rental or leased equipment; Use a rental or leasing strategy for infrequently utilized equipment, to avoid equipment obsolescence, to avoid the uncertainty of spare part cost, to avoid initial financial burden to the company, to test newly launched machines, to save spare parts cost; Use standardized policy for a better relationship with dealers or easier equipment administration.

2.11.3. Operation

The equipment operator is the person in the construction organization who has control over equipment costs. Quality output can be partly achieved through skillful operators working with machines that are in good operational condition, thus educating equipment operators is one of the most important policies and holds great cost-saving potential. Best practices for construction equipment operation determined by different researchers include: - Allow an equipment operator to work with more than one machine; Providing training by in-house equipment department, equipment dealers, or external agencies, and Considering poor operating procedure as the main cause of equipment accidents.

2.11.4. Maintenance

Construction equipment is exposed to huge abuse, dirt, and various other elements, which can cause damage to equipment if they do not care for it properly. Maintenance of construction equipment is crucial as this preserve them for future construction jobs, and accident and save contractors from unnecessary expenses and time. Best practices for construction equipment maintenance determined by different researchers includes- Providing maintenance by equipment operators; Providing maintenance by in-house equipment department; Providing maintenance by equipment dealers; Providing maintenance by other external mechanics; Providing preventive maintenance programs to equipment; Seeking substitute equipment once machine suddenly breakdowns; Wait until the failed machine is completely repaired and ready for use; Transfer crews to other works once machine suddenly breakdowns; Accelerate speed of works once machine suddenly breakdowns; Modify project activity and schedule once machine suddenly breakdowns; Consider poor operating procedures as the main cause of machine failure and Consider poor maintenance and use of non-original parts as the main cause of machine failure during use.

In general, Kanya (2022) states that the five Effective Strategies to Manage Construction Equipment are as follows: Know the Capacity of Your Construction Equipment, Conduct Inspections Immediately After Use, Give Your Operators the Right Training, Perform Routine Maintenance and Make the Most of Downtime.

Also, Ahmed (n.d.) Identified that the top eight best practices for construction equipment management those used to improve productivity; These are: Inventory and track your equipment (GPS), Understand (a record) the value of your equipment, Provide operators with the proper training, Inspect equipment after use, Schedule preventative maintenance, Be prepared for breakdowns, Stay up-to-date on project details (Understanding project specifications), Go paperless (upload data electronically) and Use the right software.

2.12. Research Gap

There is a growing utilization of construction equipment as critical for road construction to provide high-quality service for users within a short period. As a result, internationally more research interest has been generated in the area of equipment management, equipment productivity, and factors affecting productivity. However, locally there is insufficient research those focus on factors that affect equipment productivity and ways that indicate to improve the performance of equipment using new technology for fleet management. This paper help to fill the gap created by the absence of proper equipment management on the construction sites and helps to improve the overall performance of heavy-duty construction equipment.

CHAPTER THREE

RESEARCH METHODOLOGY

According to Shanti & Shashi (2011) Research methods include all the techniques and methods which have been taken for research whereas research methodology is the approach in which research troubles are solved thoroughly. It is a science of studying how research is conducted systematically. The scientific approach which is adopted for conducting research is called methodology. The focus of this research project is an assessment of equipment management problems and factors affecting equipment productivity. To perform a project the researcher used both qualitative and quantitative data. Therefore, the choice of the mixed research method is justified as an appropriate research strategy. The determination of the study sample and the techniques of data collection are also described.

3.1. Setting/Study Area

The study areas of this research were located in the Oromia region west shoa and Ilubabor zone. The details about the study areas are described as follows.

The first segment or Ambo Road Overlay Project is found in the Western part of the country, West Shoa Zone, Oromia Regional State of Ethiopia; making its starting point at TokeKutaye Woreda's Guder town, near [362958.99,992157.43] and terminating Ambo town [379007.232,991280.398]. The length of the project is about 19.132 Km and the entire road section is two lanes divided carriageway with a median in the town section and an undivided carriageway under the rural section including a walkway and varying width of surface dressing shoulder in the town and rural section respectively.

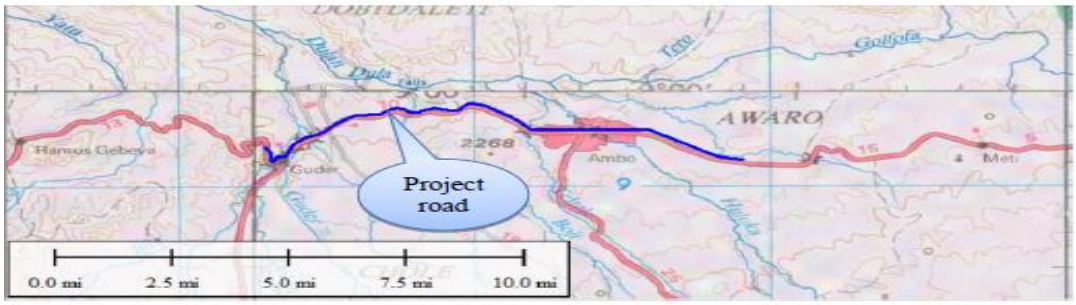

Figure 3.1 Guder -Ambo Road Overlay Project on Topo map (project document)

The Guder -Ambo Road Overlay Project lies in areas characterized by topography and altitude ranging from 1500 m to 1900m above mean sea level.

The second segment called mettu bypass road project is a bypass road that is needed to reduce the town traffic congestion. A bypass is a road or highway that relieves traffic congestion and improves travel time for the trough traffic, especially trucks. To achieve this goal the bypass shall avoid or 'bypasses a built-up area, town, or village to let through traffic flow without interference from local traffic. The total length of mettu bypass road project is about 8.7km.

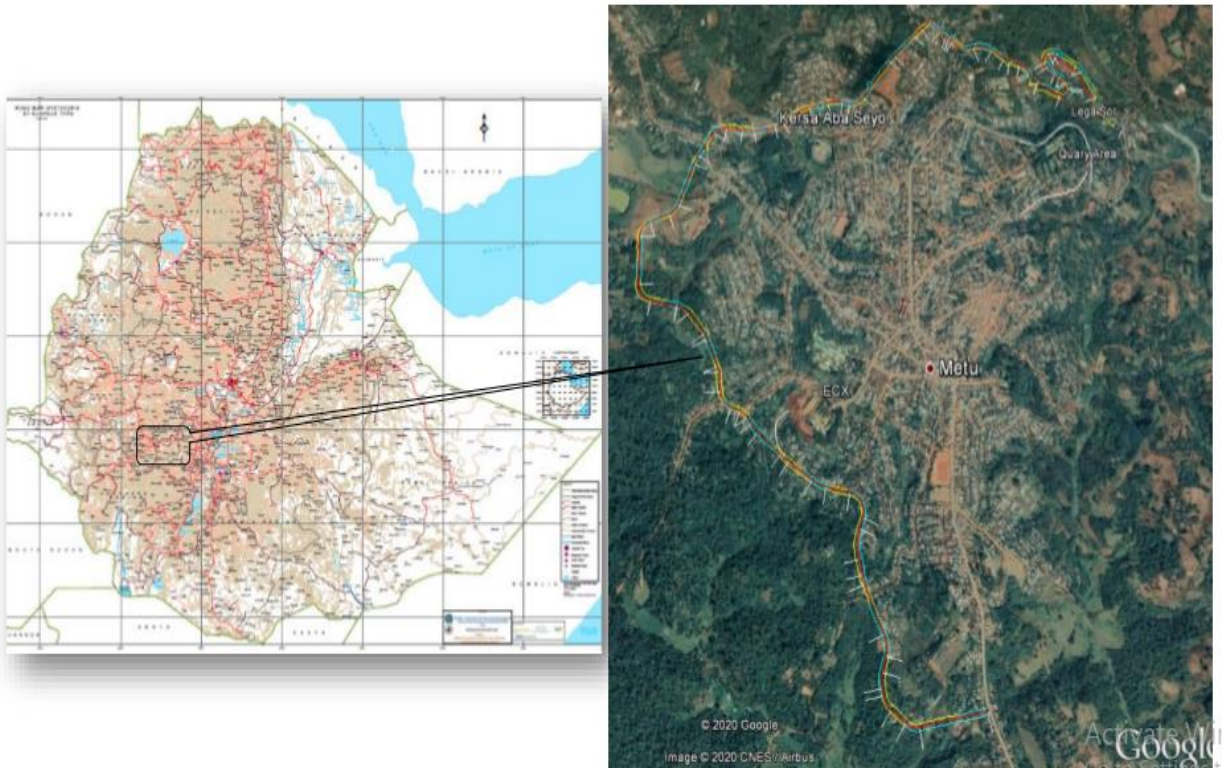

Figure 3.2 Mettu bypass road Project location map (project document)

The third project is the Homicho-Ammunition-Engineering industry Approach and Compound Road Project is Located in Oromia Region, West Shoa zone at (365254, 993191) connects the internal roads of the Homicho-Ammunition-Engineering industry. The project started at Guder town on the junction of the Homicho-Ammunition-Engineering industry which is 128 km from Addis Ababa and ends at the outskirt of the Homicho-Ammunition-Engineering industry. The length of a project constructed by Oromia Construction Corporation is about 6.885 km.

3.2. Research Design

Ranjit, (2005) described a research design as a procedural plan that is adopted by the researcher to answer questions validly, objectively, accurately, and economically. The following two objectives need to be fulfilled in a research design:

- To conceptualize an operational plan and undertake various procedures and tasks required to complete the study; and
- To ensure that these procedures are adequate to obtain answers to the research questions.

The main activities of the research design are summarized in the figure 3.1 shows as follows.

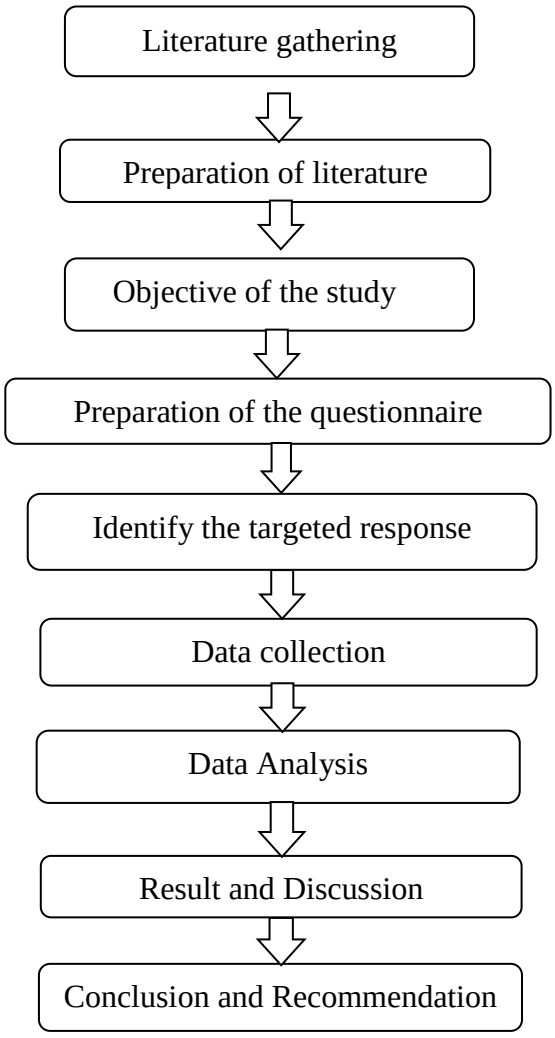

Figure 3.3 Research stages

3.3. Population and sample

3.3.1. Target Population

This study is intended to investigate the problems in heavy equipment management and factors affecting equipment productivity. To do this, the methods employed are survey design. Survey research according to (Fowler) is a means of gathering information, usually through self-report using questionnaires or interviews, or focus group discussions. The organization now had four ongoing asphalt road projects. The researcher was select three projects due to the left project located at wollega zone and difficult to obtain information. Therefore the target populations of this study are three public road construction projects all under construction by the Oromia construction corporation (OCC). The total populations of the study projects are about 148 employees; these are 43 employees are works on Mettu by-pass road project, 28 employees are works on Homicho road project and 77 employees are working on Ambo Guder road project.

3.3.2. Sampling Size

The sample size of the study is decided based on the sample size determination formula adopted (Kish, 1965) with the following equation for a 94% confidence level from the targeted population (Ajay & Micah, 2014).

$n=n'/ (1+ (n'/N))$

Where, n = total number of population and N = sample size from a finite population

n' = sample size from an infinite population= S2/V2

Where S2 = the variance of the population elements and, V = a standard error of the sampling population (usually, S= 0.5, and V = 0.06).

$n'= S2 / V2 = (0.5)2 + (0.06)2 = 69.44 \longrightarrow$ For N=148, $n = 69.44 / [1 + (69.44 / 148)] = 47$

Therefore, total sample size is 47. After identifying the sample size of the study population; the researcher distributed the sample population for three projects proportionately according to their size by using the below nonprobability sampling technique. To obtain equal proportion of respondents from each project, the following calculation was done.

No of respondent from Guder- Ambo asphalt road project: (47*77)/148 = 24

No of respondent from mettu bypass road project: (47*43)/148 = 14, and

No of respondent from homicho asphalt road project: (47*28)/148 = 9

The sample respondent frame incorporates a total of 77 professional employees, project managers, engineers, Forman's and operators.

3.3.3. Sampling Techniques

To select population of three projects the researcher was used purposive sampling from different non-probability sampling techniques. Because, Purposive sampling is a sampling technique that allows the researcher to pick informants based on the purpose of the study. While selection of respondents only the employee those directly participated on heavy equipment management was included; those are: project managers, team leaders, office/site engineers, Forman/surveyors and operator/ drivers.

3.4. Data Collection Method

3.4.1. Structured Questionnaire

The researcher used a Structured and semi-structured Questionnaire which is a tool for collecting and recording information about equipment management issues of interest with clear instructions and space for answers. The questionnaires are closed and open-ended and adopted in such a way as to have qualitative data related to the objectives of the research that are organized by the researcher from a literature review.

3.4.2. Document Review

Document review is a way of collecting data by reviewing existing documents. Documents may be hard copy or electronic and may include reports, program logs, performance ratings, funding proposals, meeting minutes, newsletters, and marketing materials (U.S. department of health and human service, 2018). To support the finding obtained from questioner; the researcher used an organizational annual performance report and reconnaissance data. The document reviews were used to triangulate the data collected by the questionnaires.

3.4.3. Observation

Observation is a way of gathering data mostly in qualitative research, by observing the behavior, and events, or noting physical characteristics in their natural setting. Observations can be overt (everyone knows that they are being observed) or covert (no one knows that they are being observed and the observer is concealed) (Ekka, 2021). While doing the research the researcher observed the current practice of equipment management on the projects and provides an appendix as evidence.

3.5. Data Analysis Method

To achieve the research objectives the data gathered were analyzed using SPSS and excel sheet to demonstrate descriptive statics, inferential statics, and relative importance index.

3.5.1. Descriptive methodology

The studies employ a descriptive methodological approach with a narrative data analysis technique. The information collected through questionnaires is analyzed using SPSS Version 23 within the framework of the study objectives. Qualitative data is used to enrich, illustrate, and elaborate the findings. The qualitative analysis focuses on answering the study questions. Information obtained from the primary source is used to make a descriptive analysis of the situation and based on the findings relevant conclusions are drawn.

3.5.2. Relative Importance Index (RII)

The Relative Importance Index (RII) was calculated using Excel 2010 which was important to rank different stated groups of questioners in this study since the value of the index specifies the ranked degree of importance as seen in Eq. 1.

Relative Importance Index $=\sum w/AN = 5n5+4n4+3n3+2n2+1n1/5N$ ……..Equation 1

Where w, is the respondent's weighting of each problem, effect, and factor, which can range from 1 to 5,

For instance, n1 represents the number of respondents for strongly disagree (very low)

n2, represents the number of respondents disagreeing (low),

n3, represents the number of respondents for neutral (medium),

n4, represents the number of respondents agreeing (high) and

n5, represents the number of respondents for strongly agree (very high). Thus, the highest weight (in this case, 5) is A and the total number of people is labeled as N.

The Relative Importance Index ranges from 0 to 1.

3.5.3. Inferential Statics

An inter-correlation analysis was used in this study to explain the intensity and direction of each variable's linear relationship. Thus, the study defines the relationship between variables and also the degree of that relationship. Since the data is standard, a parametric test was used to measure and interpret a Pearson product-moment correlation coefficient (r) for interval-level variables used in the questionnaire design. The value, which varies from –1.0 to +1.0, shows the direction (+ve and -ve) and the intensity of the relationships.

3.6. Validity and Reliability

3.6.1. Validity

Validity is the degree to which a test measures what it purports to measure and the validity of the questionnaire data depends crucially on the ability and willingness of the respondents to provide the information requested. The questionnaire employed was adapted from reviewed works of literature and similar study instruments and is made suit for the existing research environment. To test the content validity, the questionnaire was distributed by attaching it with the objective and research questions to ten experienced professionals who are currently working on the construction industry and academic areas. After that, the questionnaire was modified based on the received comments and distributed to the targeted populations.

3.6.2. Reliability

Cronbach's Alpha (α) was developed by Lee Cronbach in 1951 to provide a measure of the internal consistency of a test or scale; it is expected to always fall between 0 and 1. This system of measurement was originally developed in a context where a set of questions (also called items) are asked of a group of individuals to measure a specific concept.

The interpretation of Cronbach's Alpha (α) is the range of Cronbach's Alpha normally is between 0 and 1. Guideline provided by them to assess the reliability of any data as shown in the table below.

Table 3.1.Guideline for assessing reliability results

S.No	Range	Reliability
1	0.9 and above	Excellent
2	0.7 – 0.9	High
3	0.5 - 0.7	Moderate
4	0.5 and below	Low

Source: (Perry R. Hinton & Brownlow, 2014)

The result of reliability is discussed in next the chapter.

3.7. Ethical Consideration

All the research participants included in this study are appropriately informed about the purpose of the research and their willingness and consent are secured before the commencement of distributing the survey questionnaire and asking them to give their responses to the questionnaire. The other ethical consideration of this research is in keeping the findings not to be disadvantageous to participants. The author shall not intentionally misreport findings that would be disadvantageous to the participants.

CHAPTER FOUR

RESULT AND DISCUSSION

The general objective of this study was to assess the heavy construction equipment management practices on construction projects: A case study of Oromia Construction Corporation. The analysis and findings presented in this chapter are based on data collected from primary and secondary sources. 47 questioners were distributed to collect data on three projects but, 45 (95.7%) questionnaires were returned. Also, for data analysis SPSS and Microsoft excel were used.

4.1. Reliability

In this study, each statement of the questionnaires is rated on a 5-point Likert. To test the internal consistency of variables, Cronbach‘s alpha coefficient was calculated for each variable and the result is shown in the above table. As shown in Table 4.1, the result of Cronbach‘s Alpha of each variable is above 0.75 which tells us the reliability of the responses on the questionnaire is reliable and within acceptable ranges. Internal consistency is described as the extent to which all questions contribute positively towards measuring the same concept or construct and hence it is connected to the inter-relatedness of the items within the test (Cronibach, 1951).

Table 4.1. Cronbach’s Alpha

S. No	Variables	A	No of items
1	Major problems of construction equipment management.	0.771	9
2	Operators/ Human factors	0.828	7
3	Resource/ equipment factors	0.873	7
4	Work factors	0.797	5
5	Management factors	0.767	6
6	Others (nature)	0.807	3
7	Effect of poor equipment management on project performance	0.750	5
8	Best construction equipment management practice	0.835	14

4.2. Back Ground Information about Respondents

This section presents the background information of the respondents that includes the name of the project, educational Status, work experience, and Job position.

Table 4.2 Respondent profile versus working projects

Name of Project	Frequency	Percent	Valid Percent	Cumulative Percent
Guder- Ambo Asphalt road project	24	53.3	53.3	53.3
Mettu by pass road project	12	26.7	26.7	80
Homicho Asphalt road project	9	20	20	100
Total	45	100	100	

Source: SPSS Descriptive analysis result based on a questionnaire survey, 2022

Since the Number of employees who worked at the Guder_ Ambo Asphalt road project was a lot, therefore, the researcher distribute to more respondents and collect data from 24 (53.3%). While 12 (26.7%) and 9 (20%) of respondents were working at mettu bypass road project and the Homicho asphalt road project.

Table4.3. indicates the different educational levels of the respondents who participated in the survey. Most of the respondents 22 (48.9%) of them were holders of a first degree (BSc/ BA). 12 (26.7 %) of the respondents were holders of a Diploma. While 3 (6.7%) of the respondents were holders of master's and 8 (17.8%) did not indicate their education level.

Table 4.3Respondent Profile VS Educational Level

Educational Status	Frequency	Percent	Valid Percent	Cumulative Percent
MSc/Ma	3	6.7	6.7	6.7
BSc/ BA	22	48.9	48.9	55.6
Diploma	12	26.7	26.7	82.2
Other	8	17.8	17.8	100
Total	45	100	100	

Source: SPSS Descriptive analysis result based on a questionnaire survey, 2022

Table4.4 shows the Job position of respondents. Accordingly, most of the respondent's job positions were Forman/surveyors 18 (40%), and 10 (22.2%) of the respondents were operators and drivers. While 10 (22.2%) and 7 (15.6%) of respondent job positions were site engineer/ office engineer and project manager/ team leader respectively.

Table 4.4 Respondent Profile VS Job position

job position	Frequency	Percent	Valid Percent	Cumulative Percent
Project manager / Team leader	10	22.2	22.2	22.2
Site Engineer / Office Engineer	7	15.6	15.6	37.8
Forman / Surveyor	18	40	40	77.8
operator / Driver	10	22.2	22.2	100
Total	45	100	100	

Source: SPSS Descriptive analysis result based on a questionnaire survey, 2022

Table4.5 shows the Work Experience of each respondent; Close to 49 % of the respondents have work experience of 5 – 10 years and 13 (28.9%) of respondents' job experience was below 5 years. While 8 (17.8%) and 2 (4.4%) of the respondents have 10-15 and above 15 years of work experience respectively.

Table 4.5 Respondent Profile VS Work Experience

working experience	Frequency	Percent	Valid Percent	Cumulative Percent
>5	13	28.9	28.9	28.9
5 – 10	22	48.9	48.9	77.8
10 – 15	8	17.8	17.8	95.6
>15	2	4.4	4.4	100
Total	45	100	100	

Source: SPSS Descriptive analysis result based on a questionnaire survey, 2022

4.3. Current Equipment Management Practice on Projects.

Results of the review of the overall information regarding equipment management practice on projects are discussed in this section.

4.3.1. Criteria for Equipment selection

Table4.6. indicates the respondent's response to the question “Does your organization have any criteria for equipment selection? “; accordingly almost a total of respondents (95.6 %) answered “yes “whereas the least (4.4%) answers were” No”. Of 95.6 % of the respondent, most of them (60%) agreed as the company selects equipment based on least price and based on equipment capacity `, whereas (17.8%, 11.1%, 4.4%, and 2.2%) of respondents agreed the criteria for equipment selection depend on equipment capacity, the nature of the project, based on historical data and past experience in similar project and Availability of spare parts and manpower to operate respectively. Document review also indicates that the company equipment selection criteria are based on equipment capacity, horsepower, and year of manufacturing which assert the result of the questioner. For illustration, the corporation equipment selection method is shown in (table) Appendix B.

Table 4.6. Descriptive Statistics criteria for Equipment selection

criteria practiced for equipment selection as a corporation	Frequency	Percent	Cumulative Percent
No	2	4.4	4.4
least price and based on equipment capacity	27	60.0	64.4
Availability of spare parts and man power to operate	2	4.4	68.9
based on equipment capacity	8	17.8	86.7
based on historical data and past experience in similar project	1	2.2	88.9
depend on the nature of the project	5	11.1	100.0
Total	45	100.0	

Mithilesh & Nagavinothini (2016) and Azmi & Danish (2017) highlighted that equipment selection is considerably more crucial in large construction projects where the equipment fleet plays a crucial part in carrying out the task. The equipment fleet may account for the lion's share of the bid price for these projects. It is also important when attempting to finish a

project on time and within budget. Without the appropriate working equipment, productivity declines, delays rise, potential injuries may occur, and extra costs are incurred.

The cost, quality, and duration of a building project all depend on the use of the right construction equipment. The manufacturing and building industries have experienced significant growth, which has expanded the supply of possible construction equipment with the same function but distinct features. Any construction company should evaluate several factors when choosing the right construction equipment for a project, including ownership costs, operations costs, technical standards, etc. Because of this, choosing construction equipment can be referred to as an issue involving multi-criteria decision-making (MCDM) (Azmi & Danish, 2017).

4.3.2. Work standard for equipment performance evaluation

Table 4.7. Descriptive Statistics for having a work standard (Norm) for equipment

Response		Frequency	Percent	Cumulative Percent
	Yes	45	100	100

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Table4.2. Shows result of survey questionnaires that were designed to assess having equipment work standard for performance evaluation. The respondents agree that currently, the corporation has a work standard for equipment performance evaluation. But, when the machine is not executed as per standard; no one cannot ask the reason why under efficient. This indicates there is a lack of communication between employees and poor management problems which decrease the output (productivity) of equipment and leads to bankruptcy while using rental machinery.

4.3.3. Check list for equipment maintenance

Having a Checklist for maintenance is prevent equipment from disaster and makes an informed choice. As a result, reduce unscheduled downtime and increase productivity. Table4.8 indicates the reaction of respondents to having a checklist for equipment maintenance. Accordingly, 64.4 % of respondents disagreed with the question “do the projects have a checklist for equipment maintenance?” While the rest (35.6%) of respondents agreed. The researcher also observed that while performing maintenance for equipment there is no prepared checklist for the projects. But, by request of operators the maintenance is carried out.

Preventive maintenance (PM) is the basic policy in maintenance systems and is widely used in companies all over the world. However, because it is not carried out per the established planning and schedule, the company does not always completely benefit from its advantages. This is due to incorrect PM implementation, which causes the significant issue of an increase in machine downtime. Ineffective use of the PM checklist during implementation is one of the issues (Hasnida et al., 2013).

Azmi & Danish (2017) suggested that Preventive Maintenance (PM) is the most fundamental maintenance strategy that all businesses ought to use. The entire tasks essential to keeping facilities in good working order are included in PM. It is a process that involves following a schedule to check, service, repair, or replace the physical components of machinery, plant, and equipment. In a manufacturing system, PM on machinery and equipment is typically performed as part of its function to stop or delay its deterioration.

Mohane & Ambare (2019) revealed that the maintenance records for equipment are not kept by 70% of construction enterprises, which makes it impossible to monitor maintenance costs and causes a decline in profitability.

Table 4.8. Descriptive Statistics for having a check list for equipment maintenance

Response	Frequency	Percent	Cumulative Percent
Yes	16	35.6	35.6
No	29	64.4	100.0
Total	45	100.0	

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

4.3.4. Currently applied types of maintenance on projects

A survey result Table 4.9 indicate that primarily (53.3%) of respondents responded that a reactive maintenance is applied in those projects. Secondly, (28.9%) of respondent responded proactive maintenance and reactive maintenance is applied. Lastly, (17.8%) of respondents responded proactive maintenance is applied. The result indicates that the machinery of projects is maintained after the defect happened.

5 to 30 percent of all production costs are related to maintenance, and up to 33 percent of that sum is thought to be unnecessary waste, (Azmi & Danish, 2017). Overall Equipment Efficiency (OEE) attributes poor productivity and profitability to a lack of well-performed

maintenance, although only two of the six losses taken into account in OEE calculations are thought to be affected by maintenance.

Table 4.9. Descriptive Statistics for currently applied types of equipment maintenance

Maintenance Strategy	Frequency	Percent	Cumulative Percent
proactive maintenance (before stop working)	8	17.8	17.8
reactive maintenance (After stop working)	24	53.3	71.1
Both	13	28.9	100
Total	45	100	

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

4.3.5. Types of construction equipment acquisition method applied on projects

Table 4.10 shows the result of survey questionnaires that were designed to identify the most common Equipment acquisition method in the corporation. Eventually, most of the respondents (75.6%) agreed that corporations used owning & renting as a primary method for equipment acquisition.

However, owing as well as renting is the secondly utilized method for equipment acquisition according to the respondent. But as the researcher observed on site the corporation's primary equipment acquisition method is by purchasing. The second alternative used was renting from the owner of heavy equipment.

Table 4.10. Common types of construction equipment acquisition method applied on projects

Most common Equipment acquisition method in the corporation	Frequency	Percent	Cumulative Percent
Owning	10	22.2	22.2
Renting	1	2.2	24.4
Owning & Renting	34	75.6	100.0
Total	45	100.0	

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

The above result is related to Awaad et al. (2022), The proportion of businesses that own all of their equipment declines as company size rises. However, regardless of firm size, there are still a fair number of businesses that own 75% of their equipment. 35.6% of the organizations polled say they pay cash for capital equipment purchases. Lease-purchase arrangements, at 30.8 percent, are the second most prevalent form, while loans lasting longer than a year, at 25 percent, and are the third. The remaining portion is financed in many other ways.

4.3.6. Currently operator training policy in the corporation

Table4.11. shows the result of survey questionnaires that were designed to assess having a training policy for operators which is a factor to increase the productivity of the equipment. But, about 29 (64.4%) of respondents disagreed about the existence of operator training in the corporation. however, 35.6% of respondents agreed on the existence of operator training in the corporation. The agreed respondents replied that training is provided for operators only when the new equipment is purchased. Previously the corporation was provides training for a few operators on how they operate and awareness about preventive maintenance.

Table 4.11. Training policy for operators appeared in the corporation

Response for whether training policy appeared in the corporation	Frequency	Percent	Cumulative Percent
Yes	16	35.6	35.6
No	29	64.4	100
Total	45	100	

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Awaad et al.,(2022) revealed that Construction firms are often faced with problems related to a high rate of equipment failure or breakdown and accidents resulting from unskilled operator's abuse. Poor training of equipment operators has often been claimed as a major cause of equipment-related accidents.

4.3.7. Alternative software used for equipment management

A survey result Table 4.12 indicate that most (82.2 %) of respondents responded that there is no software unless Microsoft Excel is used to record performance and maintenance schedule

as well as for inventory administration applied in those projects. However, 17.8% of respondents agreed about software applied on projects for equipment administration. The response of the agreed respondent was primavera and Microsoft projects are used for equipment planning. But currently, many advanced technologies used to manage equipment are available on markets. For example, fleet focus, telematics, Barcode, QR code and information transfer systems...etc. are used to manage inventory, maintenance schedules, and equipment tracking. Using GPS it is easy to control the location and overall equipment activity whether out of work or not. Therefore, using new technology may decrease theft and maximize productivity by mobilizing equipment from crowded places to free areas.

Table 4.12. Alternative software used for equipment management

Alternative software used for equipment management	Frequency	Percent	Cumulative Percent
Yes	8	17.8	17.8
No	37	82.2	100.0
Total	45	100.0	

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

4.4. Major Problems of Managing Construction Equipment on the Projects

Questions that were developed to evaluate the Problems of managing construction equipment management in the projects were measured using the Likert Scale of measurement, from the range of very high‘ up to very low‘.

Table 4.13 shows that the respondent response “unexpected equipment breakdown and downtime, Idle time, poor maintenance practice and Non-availability of spare part,” are the major problems with an RII value of 0.74, 0.71, 0.70, and 0.70 respectively. Therefore to accomplish the project within the contract period the collaboration of the head office and projects is very essential to reduce those problems. But, Huge capital investment in the acquisition and high uncertainty delivery time of CE, improper determination of economic life and timing of replacement, Non-availability of Adequate maintenance facilities, workshops, and tools with adequate staff/mechanic at a project, Absence of trained manpower about CEM (like skilled operator, maintenance personnel, etc.) and Over maintenance are minor problems

with an RII value of 0.68, 0.66, 0.66, 0.64 and 0.63 respectively. Since the company uses rental as an option to perform activities the maintenance is made by the owner of the machine; this alternative may decrease the cost of maintenance.

Table 4.13. Problems of managing construction equipment management on the projects

S No	Problems of managing construction equipment management on the projects	RII	Rank
1	unexpected equipment breakdown & down time	0.74	1
2	Idle hour	0.71	2
3	Non availability of spare part	0.7	3
4	poor maintenance practice	0.7	3
5	Huge capital investment in acquisition and high uncertainty delivery time of CE	0.68	5
6	improper determination of economic life and timing of replacement	0.66	6
7	Lack of trained man power about CEM (like skilled operator, maintenance personnel	0.66	6
8	Non-availability of Adequate maintenance facilities, workshops and tools with adequate staff/mechanic at project	0.64	8
9	Over maintenance	0.63	9

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

The document review also indicates that from the annual plan of equipment around 203 million birr the corporation losses due to idle hours (6.9 %) and downtime (25.12%) in that year. The two results (questionnaire and document review) show that the corporation should have to focus on preventive maintenance and supervision of equipment on projects to decrease downtime and idle hours.

The outcome of Bantamlak (2013) also demonstrates that the firm faces significant difficulties in managing equipment due to the lack of spare parts, which increases equipment downtime. Additionally, it was discovered that recruiting experienced operators, continuously building their capacity, and establishing strong relationships with strategic and important spare part suppliers helped reduce the chance of equipment downtime.

Awaad et al. (2022) The main issues were identified as idle time, downtime, poor equipment maintenance practices, incorrect economic life and timing of replacement, inadequate training of equipment operators, equipment breakdown, excessive maintenance of equipment, significant capital investment during acquisition, the balance of interdependent equipment, misunderstanding the scope of work performed, unit cost of production, and equipment suitability for job condition.

4.5. The Factors Affecting Construction Equipment Productivity on the Road Projects

Table 4.14 – 4.18 shows that descriptive analysis of different five groups for various factors that affect the equipment productivity on projects.

Table 4.14. Operator/ Human factors

S No	Operator/Human factors	RII	Rank
1	Lack of training	0.752	1
2	Lack of ability of operator	0.683	2
3	Age of operators	0.679	3
4	Lack of experience	0.66	4
5	Lack of reward for highly performed operators	0.654	5
6	Absentees	0.629	6
7	Personal problems	0.619	7

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Table4.14. shows the measurement from the survey questionnaire on the factors affecting equipment productivity that is related to Human factors. Based on respondent's responses lack of training ranked first with an RII value of 0.764, Lack of reward for highly performed operators ranked second with an RII value of 0.742, Age of operators ranked third with an RII value of 0.72, and Lack of ability of operator ranked fourth with an RII value of 0.716, Lack of experience ranked fifth with an RII value of 0.681, Personal problems and Absentees are ranked sixth and seventh with an RII value of 0.631 and 0.627 respectively.

Unskilled labor and a lack of raw materials are factors that contribute to low productivity. If a contractor is required to carry out specific tasks with less-skilled personnel because skilled labor is not available, productivity is likely to suffer (Khot & Patil, 2020). Contractors

frequently deal with issues related to a high rate of equipment malfunction and accidents brought on by inexperienced operators. Accidents involving equipment are frequently attributed to inadequate training of the equipment users (Yitayal, 2020).

Table 4.15.Resource/ equipment factors

S No	Resource/ equipment factors	RII	Rank
1	Equipment breakdown	0.758	1
2	Equipment efficiency	0.74	2
3	Spares not available	0.74	2
4	Lack of proper maintenance	0.738	3
5	Two or more groups sharing an equipment	0.731	4
6	Delay in allocating the equipment	0.725	5
7	Unavailability of gasoline	0.721	5

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Table 4.15 shows the measurement from the survey questionnaire on the factors affecting equipment productivity that is related to Resource/ equipment factors. Based on respondent responses Equipment breakdown ranked first with an RII Value of 0.758, Spares not available and equipment efficiency (speed, age, and capacity) are ranked second with an RII Value of 0.74, Lack of proper maintenance ranked third with an RII Value of 0.738, Two or more groups sharing equipment, Delay in allocating the equipment and unavailability of gasoline are ranked fourth and fifth with an RII Value of 0.725 and 0.721 respectively.

Phadatare & Charhate (2016) suggested that many factors influence the overall productivity of the construction industry. Production is significantly impacted by equipment break down and idle run times. These idle and downtime factors have an impact on the project's overall cost. Less idling, fewer machine breakdowns, and fewer accidents in the plants increased the total equipment efficiency and adjusted process parameters. For the construction business, increasing the equipment manufacturing rate is crucial.

Table 4.16 shows the measurement from the survey questionnaire on the factors affecting equipment productivity that is related to work factors. Based on respondent responses Rework

ranked first with an RII value of 0.738, Condition of haul road ranked second with an RII value of 0.706, Excess travel/ distance ranked third with an RII value of 0.7, obstacle on site are ranked fourth with an RII value of 0.694 and overcrowding is ranked fifth with an RII value of 0.688.

Table 4.16.Work factors

S No	Work factors	RII	Rank
1	Rework	0.738	1
2	Condition of haul road	0.706	2
3	Excess travel/ distance	0.7	3
4	obstacle on site	0.694	4
5	overcrowding	0.688	5

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

This result was confirmed by the findings of Abdelaal et al. (2016) which showed that rework is the first rank out of a total of 29 factors affecting equipment productivity from questioner of three groups-clients, consultants, and contractors of participants which are calculated using Relative Importance Indices (RII).

Table 4.17.Management factors

S No	Management factors	RII	Rank
1	Delay in payment for obstruction	0.754	1
2	Routine checking overall productivity of equipment	0.735	2
3	unavailability of shift	0.7	3
4	Matching available machine vs. trucks-routine	0.667	4
5	miss Communication between employees	0.65	4
6	Improbable planning and expectation of labor	0.606	5

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Table 4.17 shows the measurement from the survey questionnaire on the factors affecting equipment productivity that is related to Management factors. Based on respondent responses Delay in payment for obstruction (compensation) ranked first with an RII value of 0.754, Routine checking overall productivity of equipment ranked second with an RII value of 0.735, unavailability of shift ranked third with an RII value of 0.7, Matching available machine vs.

trucks-routine and miss Communication between employees ranked fourth and fifth with an RII value of 0.667 and 0.65, Improbable planning and expectation of labor are ranked sixth with an RII value of 0.606.

Table 4.18 shows the measurement from the survey questionnaire on the factors affecting equipment productivity that is related to nature. Based on respondent responses Type of soils ranked first with an RII value of 0.704, Temperature and humidity effects second with an RII value of 0.64, and Rain and wind effects ranked third with an RII value of 0.625.

Table 4.18. Others (nature related) factor

S No	Others (nature)	RII	Rank
1	Type of soils	0.704	1
2	Temperature and humidity effects	0.64	2
3	Rain and wind effects	0.625	3

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

The above finding contrasts with that of Methe et al. (2018), whose findings show that the Temperature and humidity effects factor is ranked 1st in environmental factors. Rain and wind effects and the Type of soil are the 2nd and 3rd ranks factors that affect equipment productivity. This may be due to the research done on building construction since; the amount of excavated earthwork is too small.

Tables 4.19 indicate the overall rank of factors affecting equipment productivity on projects. According to the respondent response, the top ten factors are Equipment breakdown, Delay in payment for obstruction, Lack of training, Spares not available, Equipment efficiency, Lack of proper maintenance, Rework, Routine checking overall productivity of equipment, Two or more groups sharing an equipment, and Delay in allocating the equipment those needs highly emphasis to improve equipment efficiency.

Table 4.19. Factors affecting equipment productivity

S No	Factors affecting equipment productivity	RII	Overall rank
1	Equipment breakdown	0.758	1
2	Delay in payment for obstruction	0.754	2

3	Lack of training	0.752	3
4	Spares not available	0.74	4
5	Equipment efficiency	0.74	4
6	Lack of proper maintenance	0.738	6
7	Rework	0.738	6
8	Routine checking overall productivity of equipment	0.735	8
9	Two or more groups sharing an equipment	0.731	9
10	Delay in allocating the equipment	0.725	10
11	Unavailability of gasoline	0.721	11
12	Condition of haul road	0.706	12
13	Type of soils	0.704	13
14	Excess travel/ distance	0.7	14
15	Unavailability of shift	0.7	14
16	Obstacle on site	0.694	16
17	Overcrowding	0.688	17
18	Lack of ability of operator	0.683	18
19	Age of operators	0.679	19
20	Matching available machine vs. trucks	0.667	20
21	Lack of experience	0.66	21
22	Lack of reward for operators	0.654	22
23	Miss Communication between employees	0.65	23
24	Temperature and humidity effects	0.64	24
25	Absentees	0.629	25
26	Rain and wind effects	0.625	26
27	Personal problems	0.619	27
28	Improbable planning and expectation of labor	0.606	28

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

4.6. Effect of Poor Equipment Management on Project Performance

Table 4.20 shows the measurement from the survey questionnaire on the Effect of poor equipment management on project performance. Based on respondent's responses Delay (Time overrun) ranked first with an RII value of 0.72, Cost Overrun ranked second with an RII value of 0.698, Availability losses/ Inactivity Losses ranked third with an RII value of 0.676, Performance loss/ Speed Losses and Quality loss /Defective losses are ranked fourth with an RII value of 0.63 and 0.622.

Table 4.20. Effect of poor equipment management on project performance

S No	Effect of poor equipment management on project performance	RII	Rank
1	Delay (Time overrun)	0.72	1
2	Cost Overrun	0.698	2
3	Availability losses/ Inactivity Losses	0.676	3
4	Performance loss/ Speed Losses	0.662	4
5	Quality loss /Defective losses	0.622	5

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

Balaji & Venugopal (2017), also confirmed that the construction industry is currently facing several difficulties, particularly with time-consuming and unprofitable projects. This time overrun is the result of poor resource management; in recent decades, effective resource utilization was less than 60%; poor resource utilization has an impact on a variety of expenses, profit margins, project quality, on-time completion, etc. Contractors, owners, consultants, and the project managing, execution, and design teams all have varying degrees of influence on the progress of the projects in any construction project.

Awaad et al. (2022) one of the key elements affecting the general performance of the construction sector is productivity in road construction projects. One of the reasons for time and cost overruns in road construction projects is low productivity among the construction workforce.

4.7. Best Practice for Construction Equipment Management on Road Projects

table4.21. shows that the respondents response “Understand (record) the value of your equipment, Schedule and perform preventative maintenance, Provide operators with the proper training, Inspect equipment after use, Use the right software, Inventory and track your equipment, go paperless (upload data electronically) “are highly recommended best practice to improve equipment management with a mean score of 0.76, 0.752, 0.716, 0.694, 0.68, 0.672 and 0.648 respectively.

Table 4.21. Best practice for construction equipment management on road projects

S No	Best construction equipment management practice	RII	Rank
1	Understand (record) the value of your equipment	0.76	1
2	Schedule and perform preventative maintenance	0.752	2
3	Inspect equipment after use	0.716	3
4	Provide operators with the proper training	0.694	4
5	Use the right software	0.68	5
6	Inventory and track your equipment	0.672	6
7	Go paperless (upload data electronically)	0.648	7
8	Purchase the same brand that is being used regularly	0.622	8
9	Purchase equipment from familiar dealers	0.622	8
10	Use rental or leasing strategy for infrequent utilized equipment	0.622	8
11	Be prepared for breakdowns	0.6	11
12	Modify project activity and schedule once machine suddenly breakdowns	0.578	12
13	Transfer crews to other works once machine suddenly breakdowns	0.574	13
14	Accelerate speed of works once machine suddenly breakdowns	0.528	14

Source: SPSS Descriptive analysis result based on questionnaire survey, 2022

However, “Purchase the same brand that is being used regularly and Purchase equipment from familiar dealers , Use rental or leasing strategy for infrequent utilized equipment, Be prepared for breakdowns, Modify project activity and schedule once machine suddenly breakdowns, Transfer crews to other works once machine suddenly breakdowns and Accelerate speed of works once machine suddenly breakdowns” moderately recommended practice for equipment management with a mean value of 0.622, 0.622, 0.622, 0.60, 0.578, 0.574 and 0.528 orderly.

4.8. Correlation Analysis

With the help of the response from the questionnaire, the relationship between the group independent variables is formulated using correlation analysis. Correlation measures the strength of the linear association between two variables. In this paper, Pearson‘s and spearman correlation were used to identify the presence as well as the strength of relationship between the variables.

Table 4.22. Correlations between equipment productivity factor group variables

		Human Factor	Resource factor	Work Factor	Management Factor	Nature
Human Factor	Pearson Correlation	1	.487**	.530**	.604**	0.288
	Sig. (2-tailed)		0.001	0	0	0.055
Resource factor	Pearson Correlation	.487**	1	0.213	.456**	0.125
	Sig. (2-tailed)	0.001		0.0161	0.002	0.041
Work Factor	Pearson Correlation	.530**	0.213	1	.708**	.552**
	Sig. (2-tailed)	0	0.016		0	0
Management Factor	Pearson Correlation	.604**	.456**	.708**	1	.449**
	Sig. (2-tailed)	0	0.002	0		0.002
Nature	Pearson Correlation	0.288	0.125	.552**	.449**	1
	Sig. (2-tailed)	0.055	0.041	0	0.002	

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

The level of relationship between two variables, when measured by Pearson ‘s co-efficient, falls between -1.0 and +1.0 which indicates the strength and direction of relationship between the two variables. A correlation result between 0 and 1 implies positive relationship, when it is between -1 and 0 it implies that there is a negative relationship and if the result is zero, it indicates that there is no relationship at all. With this in mind, Correlation analysis is done between each group variable (human, work, resource, management and nature factors) & the following result is found.

The correlation between the variables for the group is shown in Table 4.22 above. Even if there is a positive correlation between each independent variable, resource has a less significant correlation between nature and human factor, which is 0.125 and 0.213. However, the outcome, reveals that every other variable has a considerable correlation with the group variable, ranging from (0.449** to 0.708**), and at significant levels of 0.02.

Table 4.23. Correlations Effect of poor equipment management group variables

			Quality loss /Defective losses	Performance loss/ Speed Losses	Availability losses/ Inactivity Losses	Cost Overrun	delay (Time overrun)
Spearman's rho	Quality loss /Defective losses	Correlation Coefficient	1.000	.667**	.627**	.480**	.361*
		Sig. (2-tailed)		.000	.000	.001	.015
		N	45	45	45	45	45
	Performance loss/ Speed Losses	Correlation Coefficient	.667**	1.000	.453**	.135	.282
		Sig. (2-tailed)	.000		.002	.047	.043
		N	45	45	45	45	45
	Availability losses/ Inactivity Losses	Correlation Coefficient	.627**	.453**	1.000	.183	.137
		Sig. (2-tailed)	.000	.002		.059	.057
		N	45	45	45	45	45
	Cost Overrun	Correlation Coefficient	.480**	.135	.183	1.000	.481**
		Sig. (2-tailed)	.001	.044	.048		.010
		N	45	45	45	45	45
	delay (Time overrun)	Correlation Coefficient	.361*	.282	.137	.481**	1.000
		Sig. (2-tailed)	.015	.043	.050	.010	
		N	45	45	45	45	45

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

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

The correlation between the variables for the group is shown in Table 4.23 above. Quality loss has up to 0.015 significant correlations between groups when we examine the relationships between each independent variable, which is (0.667**, 0.627**, 0.480**, and 0.361*). Additionally, the outcome demonstrates a moderate correlation between cost overrun and time overrun, which is (0.481**) at 0.01 significant levels.

4.9. Discussion of Main Findings and Implications

In this chapter, the results of the findings have been explained and discussed based on the analysis done on the data collected. The results of the study were discussed by triangulating the different source's results, questionnaire results, observation, and document review. The Data collected using questionnaires were analyzed using descriptive statistics (frequency distribution), inferential statics (correlation), and relative importance index (rank). The discussion attempted to accomplish the objectives of the study that answer the research questions. In this section the construction equipment management practice and the related problems; the factors that could influence construction equipment management practice have been analyzed finally, best equipment management practices are forwarded. As a result of not having a checklist for preventive maintenance; the corporation should provide a checklist, scheduling preventive maintenance and make supervision to suffer from unexpected breakdowns and idle time. Additionally, the result indicates that to manage equipment from wastage and theft using software and a GPS tracker is advisable. Also, the result highlighted that delay in payment for obstruction and lacks of providing training for operators are the main factors that affect equipment productivity next to equipment breakdown. Therefore to alleviate those problems collaboration between local administrator, client and contractor are mandatory. Generally, the researcher forwarded different best equipment management practices by grasping from the different literature reviews; Corporation is advisable to use those practices to improve productivity.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter presents a summary of the conclusions and recommendations that were drawn from the previous chapter of this study.

5.1. Conclusion

The main objective of this study was to assess the heavy construction equipment management practices on construction projects: case study of Oromia Construction Corporation by focusing on three projects constructed at Illubabor and West Shoa zone.

With the help of a self-administered questionnaire, observation, document review, and literature review data were analyzed using descriptive static, relative importance index and correlation.

100% of the respondents agreed that the corporation on having a work standard for equipment performance evaluation. Also, 60.4 % of respondents believe that the criteria used to select equipment by the corporation are based on equipment capacity. However, as indicated in appendix B equipment capacity, manufacturing year and horsepower are the criteria for equipment selection. Furthermore, 75.6 % of respondents believe that Owning & Renting is the most common Equipment acquisition method in the corporation.

80% of the respondents disagreed that the corporation uses Alternative software for equipment management. Additionally, over 57 % of respondents disagreed with having a checklist for equipment maintenance and training policy for operators appeared in the corporation. But, a reactive maintenance type of maintenance strategy is used on projects.

From the descriptive statistics unexpected equipment breakdown & downtime, idle time, non-availability of spare parts and poor maintenance practice are the major problems. While the rest Huge capital investment in the acquisition and high uncertainty delivery time of CE, improper determination of economic life and timing of replacement, Lack of trained manpower about CEM, Non-availability of Adequate maintenance facilities, workshops, and

tools with adequate staff/mechanics at a project, and Over maintenance minor problems regarding managing construction equipment management in the projects.

Equipment breakdown, Delay in payment for obstruction, Lack of training, Spares not available, Equipment efficiency, Lack of proper maintenance, Rework, Routine checking overall productivity of equipment, Two or more groups sharing an equipment, and Delay in allocating the equipment are the top factor from different groups those needs highly emphasis to improve equipment efficiency affect the productivity of equipment on those projects.

From the result and discussion, Delay (Time overrun), Cost Overrun, Availability losses/ Inactivity Losses, Performance loss/ Speed Losses, and Quality loss /Defective losses are Effects of poor equipment management on those project performances in descending order.

The result of the finding indicates that; understand (a record) the value of your equipment, Schedule and perform preventative maintenance, Provide operators with the proper training, Inspect equipment after use, Use the right software, Inventory and track your equipment, and Go paperless (upload data electronically), Purchase the same brand that is being used regularly, Purchase equipment from familiar dealers highly recommended practice, whereas the left moderately recommended practice for equipment management.

Finally, the correlation analysis of the study shows that all the variables (human, work, resource, management, and natural factors) have a positive relationship with each other. Except for the correlation between resources with nature and the human factor; all the other variables have a strong relationship.

5.2. Recommendation

Based on the conclusions made, the researcher came up with the following recommendations to strengthen the equipment management practice of the projects that will bring about optimizing the performance of equipment and increase the productivity of equipment which maximize the profit of the organization.

- Since most respondents agreed that there is a lack of prepared checklist for equipment maintenance and lack of alternative software used to manage equipment on projects, therefore it is advisable to use currently available advanced technologies used to

manage inventory, maintenance schedule, and equipment tracking; such as Fleet focus, telematics, barcode, QR code and information transfer systems.

- Providing GPS trackers on dump trucks to prevent theft at construction sites and monitoring fuel consumption is advisable.
- To decrease Delay (Time overrun), and Cost Overrun of the project happened due to delay of payment for obstruction (right of way) it is recommended that the client should have to pay high attention before starting construction of the project.
- Providing awareness training for site engineers about equipment planning and management policy and how to manage equipment at the project level.
- To accomplish the project within the specified budget and period it is advisable providing two working shifts, provide training for operators, and reward (motivation) for highly performed operators which increases the productivity of the equipment.
- Cost and expense of equipment should be daily electronically recorded and transferred from the property administration department to the engineering cost administration office using a computerized system for cost-benefit analysis.
- Scheduling and performing preventative maintenance for all equipment to reduce unexpected downtime.
- The projects should have to keep sufficient spare parts in advance in the stock. This can be achieved through the provision of high attention by top management and equipment personnel before finished from the warehouse.
- Moreover, the integration between top-level managers of projects with that of local administration needs to be strengthened to alleviate social problems by respecting road boundaries for demolishing obstructions within the specified time to decrease rework and accelerate the speed of works.

5.3. Further research

- Comparative Study on factors affecting equipment productivity and their effect on project performance.
- Evaluating the overall productivity of heavy equipment and challenge on projects.

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Appendix A: Questioner

Adama Science and Technology University

School of Civil Engineering and Architecture

MSc in Civil Engineering (Specialization in Construction Engineering and Management)

This is a questionnaire designed to collect data to Assessment of heavy construction equipment management practice on road projects: the case of Oromia Construction Corporation that will be used as an input for a thesis in partial fulfillment of MSc in Civil Engineering (Specialization in Construction Engineering and Management). Your genuine response is highly required as it is only used for academic purpose and will be strictly confidential. Therefore, your kind cooperation is appreciated in advance.

Part I: General information

1.1. Name of project …….

1.2. Educational status

A, MSc/MA ☐ B, BSc/BA ☐

C, Diploma ☐ D, Other ☐

1.3. Job Position

1, project manager /team leader ☐ 2, site (office engineer) ☐

3, Forman ☐ 4, operator ☐

1.4. Relevant working experience (Years)

1, less than 5 ☐ 2, between 5 and 10 ☐

3, between 10 and 15 ☐ 4, above 15 ☐

Part II –Questioner about current organization equipment management practice

1. Does your organization have any criteria for equipment selection?

   Yes ☐ No ☐

2. If yes, which equipment selection criterion is applicable in your organization? Please circle implement on your project.

   A, least price

   B, based on equipment capacity

C, Availability of spare parts and man power to operate

D, depend on the nature of the project

E. based on historical data and past experience in similar project.

F. least price and based on equipment capacity

3. What type of construction equipment acquisition method is the most common in your organization?

   Owning ☐ Renting ☐ Leasing ☐

   Owning & Renting ☐ Owning, renting & leasing ☐

4. Having equipment work standard for performance evaluation is vital to finish the project on specified budget and time. Does your organization have a work standard (norm)? Eg. Executed amount in (m^3/hr., trip/km …).

   Yes ☐ No ☐

5. Does the project have checklist for equipment maintenance?

   Yes ☐ No ☐

6. Which type of maintenance strategy is your organization commonly used? Please circle implement on your project.

   A, proactive maintenance (before stop working or failed)

   B, reactive maintenance (After stop working or failed)

   C, both

   If any please specify ……

7. Is there a training system or policy for operators in the corporation?

   Yes ☐ No ☐

If your answer is yes please specify the type of training ----------
---------- .

8. Does your organization use software except Microsoft excel for equipment management?

   Yes ☐ No ☐

   If your answer is yes please specify the type of software……...

   …….

Part III - close ended questionnaires

1. **Please identify the existing major problems of managing construction equipment in your project. Please tick (√) appropriate level of problem.**

S No	problems construction equipment management in the company	very low(1)	low (2)	Medium(3)	High(4)	very high(5)
1	Huge capital investment in acquisition and high uncertainty delivery time of CE					
2	poor maintenance practice					
3	over maintenance					
4	idle time					
5	unexpected equipment breakdown & down time					
6	improper determination of economic life and timing of replacement					
7	non availability of spare part					
8	Lack of trained man power about CEM (like skilled operator, maintenance personnel etc.)					
9	Non-availability of Adequate maintenance facilities, workshops and tools with adequate staff/mechanic at project					

2. **Please identify the effect of poor equipment management in your project performance. Please tick (√) appropriate level of effect.**

No	Effect of poor equipment management project performance	Very Low	Low	Medium	High	Very High
1	Delay (Time overrun)					
2	Cost Overrun					
3	Loss in Productivity of Equipment					
3.1	Availability losses/ Inactivity Losses					
3.2	Performance loss/ Speed Losses					
3.3	Quality loss /Defective losses					

3. **Please carefully read each of the following statements and respond by tick (√) on the appropriate box which best suits your opinion or level of agreement about the factors affecting construction equipment productivity in your project.**

S No	factors affecting construction equipment productivity	strongly dis agree (1)	Dis agree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
1	**Operators/ Human factors**					
1.1	Lack of ability of operator					
1.2	Lack of experience					
1.3	Absentees					
1.4	Personal problems (safety and health)					
1.5	Lack of training					
1.6	Lack of reward (financial motivation) for highly performed operators					
1.7	Age of operators					
2	**Resource/ equipment factors**					
2.1	Delay in allocating the equipment					
2.2	Two or more groups sharing an equipment					
2.3	Equipment breakdown					
2.4	Lack of proper maintenance					
2.5	Spares not available					
2.6	gasoline unavailability					
2.7	equipment efficiency(speed, age and capacity)					
3	**Work factors**					
3.1	Rework					
3.2	Condition of haul road					
3.3	Excess travel/ distance					
3.4	Obstacle on site					
3.5	overcrowding					
4	**Management factors**					
4.1	routine checking overall productivity of equipment (supervision)					
4.2	Improbable planning and expectation of labor					

4.3	miss Communication between employees					
4.4	Delay in payment for obstruction (compensation)					
4.5	unavailability of shift					
4.6	Matching available machine vs. trucks					
5	**Others (nature)**					
5.1	Temperature and humidity effects					
5.2	Rain and wind effects					
5.3	Type of soils					

4. What is your level of recommendation to improve construction equipment management practice regarding road construction projects?

No	Best construction equipment management practice	Very Low	Low	Medium	High	Very High
1	Inspect equipment after use					
2	Understand (record) the value of your equipment					
3	Provide operators with the proper training					
4	Inventory and track your equipment					
5	Schedule and perform preventative maintenance					
6	Be prepared for breakdowns					
7	Modify project activity and schedule once machine suddenly breakdowns					
8	Go paperless (upload data electronically)					
9	Use the right software					
10	Purchase the same brand that is being used regularly					
11	Purchase equipment from familiar dealers					
12	Use rental or leasing strategy for infrequent utilized equipment, to avoid equipment obsolescence					
13	Transfer crews to other works once machine suddenly breakdowns					
14	Accelerate speed of works once machine suddenly breakdowns					

Appendix B: Sheets for Equipment Management and Selection Practice

Table a. Dump truck work standard for performance evaluation

2014 OCC Dump Truck Rental Rate Specific projects, In Birr per m3 per km Including Fuel and VAT-									
S. No	Distance (trip Distance)	Loading capacity in m^3	Manufacturing Year (GC)	Option - I		Option - II		Option - III	
				Normal Soil, Gravel & Sand (biyyee fi C irrachaa)	Stone (dhagaa)	Normal Soil, Gravel & Sand (biyyee fi C irrachaa)	Stone (dhagaa)	Normal Soil, Gravel & Sand (biyyee fi C irrachaa)	Stone (dhagaa)
1	0 - 2.5 km	12~20	≥ 2008 or By Inspection	8.62	9.29	8.98	10.28	8.8	9.29
2	2.6 - 5 km			7.97	8.79	8.33	9.78	8.15	8.79
3	5.1– 10 km			7.47	8.49	7.83	9.48	7.65	8.49
4	10.1 – 30 km			6.97	7.89	7.33	8.88	7.15	7.89
5	30.1 – 50 km			6.45	7.09	6.81	8.08	6.63	7.09
6	50.10 KM -			5.95	6.59	6.31	7.58	6.13	6.59
7	75.1 -150			5.53	6.09	5.89	7.08	5.71	6.09
8	150.1 &			5.33	5.69	5.69	6.28	5.51	5.69

Table b. Criteria for equipment selection practice while renting shower truck

Shower Truck Rental Rate per Hour in 2014 Budget year for all projects (including fuel and vat.)					
No	**Type**	**Capacity in Liters**	**Manufacturing (GC)**	**Manual Spraying/ Sprinkling**	**Automatic Spraying/ Sprinkling**
				In birr per Hour	**In birr per Hour**
1	Shower Truck	8,000-12,000	≥ 2008 G.C	1,300	1,350
			2000-2007 G.C	1,200	1,350
			By Inspection	1,000	1,050
2	Shower Truck	12,001-16,000	≥ 2008 G.C	1,350	1,500
			2000-2007 G.C	1,250	1,400
			By Inspection	1,050	1,200
3	Shower Truck	16,001-17,999	≥ 2008 G.C	1,400	1,550
			2000-2007 G.C	1,300	1,450
			By Inspection	1,100	1,150
4	Shower Truck	18,000-20,000	≥ 2008 G.C	1,500	1,650
			2000-2007 G.C	1,400	1,550
			By Inspection	1,200	1,250
5	Shower Truck	≥ 20,001	≥ 2008 G.C	1,650	1,800
			2000-2007 G.C	1,550	1,700
			By Inspection	1,350	1,400

Table c. Criteria for equipment selection practice while renting heavy equipment

2014 OCC Machinery Rental Rate (Price Rate in Birr per Hour including VAT and Fuel)												
No	Type of Equipme	Manufacturing Year	Horse Power	Capacity in lit,m3,ton,	Projects (ETB)							
					1	2	3	4	5	6	7	
1	Dozer	≥2016	≥ 300	≥ 8.5m3 & With Ripper	3,750	3,750	3,800	3,850	3,850	4,000	4,100	
		2010 - 2015			3,700	3,700	3,750	3,800	3,800	3,850	3,950	
		By Inspection			3,500	3,500	3,550	3,600	3,600	3,650	3,750	
2	Chain excavator with Jack hammer	≥2016	≥ 245	≥ 32ton	2,900	2,950	2,950	3,000	3,100	3,200	3,300	
		2010 - 2015			2,800	2,850	2,850	2,900	3,000	3,100	3,200	
		By Inspection			2,600	2,650	2,650	2,700	2,800	2,900	3,000	
3		≥2016	200-244	≥ 29ton	2,800	2,850	2,850	2,900	3,000	3,100	3,200	
		2010 - 2015			2,700	2,750	2,750	2,800	2,900	3,000	3,100	
		By Inspection			2,500	2,550	2,550	2,600	2,700	2,800	2,900	
4		≥2016	185-199	≥ 27ton	2,700	2,750	2,750	2,800	2,900	3,000	3,100	
		2010 - 2015			2,600	2,650	2,650	2,700	2,800	2,900	3,000	
		By Inspection			2,400	2,450	2,450	2,500	2,600	2,700	2,800	
5	Chain Excavator w/Bucket	≥2016	≥ 245	≥ 32ton & Bucket cap. ≥1.71 m³	2,700	2,750	2,750	2,800	2,900	3,000	3,100	
		2010 - 2015			2,600	2,650	2,650	2,700	2,800	2,900	3,000	
		By Inspection			2,400	2,450	2,450	2,500	2,600	2,700	2,800	
6		≥2016	200-244	≥ 29ton & Bucket cap. 1.62-1.70 m³	2,600	2,650	2,650	2,700	2,800	2,900	3,000	
		2010 - 2015			2,500	2,550	2,550	2,600	2,700	2,800	2,900	
		By Inspection			2,300	2,350	2,350	2,400	2,500	2,600	2,700	
7		≥2016	185-199	≥ 27 ton & Bucket cap. 1.5 – 1.61m³	2,500	2,550	2,550	2,600	2,700	2,800	2,900	
		2010 - 2015			2,400	2,450	2,450	2,500	2,600	2,700	2,800	
		By Inspection			2,200	2,250	2,250	2,300	2,400	2,500	2,600	
8		≥2016	160-184	≥ 20 ton & Bucket cap. 1.– 1.49m³	2,000	2,050	2,050	2,100	2,200	2,300	2,400	
		2010 - 2015			1,900	1,950	1,950	2,000	2,100	2,200	2,300	
		By Inspection			1,700	1,750	1,750	1,800	1,900	2,000	2,100	
9		≥2016	140-159	≥ 15 ton & Bucket cap.0.6 –	1,900	1,950	1,950	2,000	2,100	2,200	2,300	
		2010 - 2015			1,850	1,900	1,900	1,950	2,050	2,150	2,250	
		By Inspection			1,650	1,700	1,700	1,750	1,850	1,950	2,050	

Appendix c: Field Observation of Equipment Management Practice

Figure i. Grader and loader waiting for spare parts

Figure ii. Dump trucks waiting for spare parts

Figure iii. Rollers waiting for maintenance

Figure iv. Dump trucks waiting for maintenance Figure v. Dump trucks waiting for loading