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DEPARTMENT OF CONSTRUCTION MANAGEMENT

ASSESSMENT OF CONSTRUCTION EQUIPMENT REPLACEMENT DECISIONS (A CASE STUDY: ADDIS ABABA CITY ROAD AUTHORITY)

GEBEYEHU TEKA MITIKU

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ABABA UNIVERSITY ADDIS ABABA, ETHIOPIA

ASSESSMENT OF CONSTRUCTION EQUIPMENT REPLACEMENT DECISIONS (A CASE STUDY: ADDIS ABABA CITY ROAD AUTHORITY)

BY

GEBEYEHU TEKA MITIKU

ADVISOR

SOLMON SERTSE (Ph.D)

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DECLARATION

I, Gebeyehu Teka Mitiku, the under signed, declare that this thesis entitled: "Assessment of Construction Equipment Replacement Decisions (A Case Study: Addis Ababa City Road Authority)" is my original work. I have undertaken the research work independently with the guidance and support of the research supervisor. This study has not been submitted for any degree or diploma program in this or any other institutions and that all sources of materials used for the thesis has been duly acknowledged.

Gebeyehu Teka Mitiku	…….	……
Name of Student	Signature	Date

This is to certify that the thesis entitled: "Assessment of Construction Equipment Replacement Decisions (A Case Study: Addis Ababa City Road Authority)" submitted in partial fulfillment of the requirements for the degree of Masters of construction management and is a record of original research carried out by Gebeyehu Teka Mitiku, GSR/374/2012, under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend it to be accepted as fulfilling the thesis requirements.

Solomon Sertse (Ph.D)	----------	----------
Name of Advisor	Signature	Date

CERTIFICATE OF APPROVAL

This is to certify that the thesis prepared by Gebeyehu Teka Mitiku entitled "Assessment of Construction Equipment Replacement Decisions (A Case Study: Addis Ababa City Road Authority)" and submitted in partial fulfillment of the requirements for the Degree of Masters of Arts in Construction Management complies with the regulations of Addis Ababa University and meets the accepted standards with respect to originality and quality.

Signature of Board of Examiners:

Name of Advisor	Signature	Date
External examiner	Signature	Date
Internal examiner	Signature	Date
Chairperson	Signature	Date
Department head	Signature	Date

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ACRONYMS AND ABBREVIATIONS

AACRA	Addis Ababa City Road Authority
APWA	American Public Works Association
CEM	Construction Equipment Management
DCE	Domestic Construction Equipment
EAC	Equivalent Annual Cost
ERP	Equipment Replacement Problem
KII	Key Informant Interview
O&M	Operation and Maintenance
RCEFRI	Road construction equipment fleet record inventory
SOP	Standard Operating Procedures
SPSS	Software program for social science
TX DOT	Texas Department of Transportation

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ABSTRACT

Assets typically deteriorate with age, which raises operating and maintenance (O&M) expenses and lowers salvage values. Additionally, there may be more recent assets available for replacement that are more effective and better performance.Public and commercial organizations that own fleets and/or specialized equipment must therefore make decisions about when to replace them on a regular basis. Unfortunately, prior studies have highlighted the issue of agencies failing to replace their equipment on time. This problem is made worse in public contracts since, due to their service-oriented nature, there is no way to determine whether the equipment is profitable (economical).Therefore, the main purpose of this study is to investigate equipment replacement policies, procedures, and techniques of Addis Ababa City Road Authority. It also examines the obstacles of on time replacing of outdated equipment.To achieve this the study applied mainly the following information gathering tools i.e.; questionnaire, road construction equipment fleet record inventory (RCEFRI), document review and in-depth interview.Accordingly The results indicated that the work objectives, safety, and management goals were found to be the most influential qualitative factors affecting the decision of equipment replacement, while Maintenance cost, downtime cost, and capital/purchasing cost are among the top quantitative factors that are considered while making a decision to replace equipment.Researcher conducted replacement analysis using minimum cost method. Sample of nine (9), thirteen (13), and eleven (11) to heavy machinery, machinery and light weight machine and vehicles respectively were taken from population of Road equipment The result indicated that 21, 63% equipment are beyond their economic life .the previous replacement history of AACRA indicated that increasing maintenance and repair cost is the leading factor of replacement. on the other hand among 784 AACRA equipment 56% are 15 years and above.In this sense it is necessary for the authority to take action to utilize approaches to optimize equipment replacement decision. The research also suggest that AACRA must evaluate equipment's cost(Maintenance ,downtime cost…), performance (workout put….) and risk (accident,CO2 Emission…) factors and must replace equipment's based on economical replacement analysis .

Key word: *Equipment replacement decision, replacement factors, economic life, replacement analysis and on time replacement.*

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

The construction industry plays an important role in both industrialized and developing countries' development processes. Construction products provide the essential public infrastructure and private physical structures for numerous productive activities such as services, commerce, utilities, and other businesses. The industry is essential not only for the finished product, but it also employs a huge number of people (directly and indirectly) and has an impact on the economy of a country or region during the construction process. (Wibowo, 2019)

Especially in developing countries like Ethiopia, the construction industry plays a vital role. This is mainly because developing countries are considerably dependent on the growth and development of their physical infrastructure. (Lopes, 2011)

However, as the construction industry is full of challenges such as the absence of clear objectives, budget limitations, poor communication, inflated aspirations, time management, limited skills, lack of structure, inadequate risk management, obstructed cash flow, and safety issues or security concerns, without proper construction management, the above-stated socio-economic benefit can’t be achieved. (OpticVyu, 2023)

Thus, construction stock holders (property owners, lenders, suppliers, consultants, contractors, subcontractors, etc.), both in private as well as in public, must apply an efficient construction management system. Construction management involves the coordination of many elements, including project design and planning, procurement, budgeting and scheduling, labor tracking and coordination, site safety, material management, and quality control.

One of the tasks of construction management is to efficiently allocate, organize, and use construction resources (materials, manpower, machinery, etc.) to meet project objectives. Therefore, the construction industry requires effective resource management techniques in order to maintain profitability and continue contributing to the development of the nation.

One of the most crucial physical assets of a construction company is construction equipment. It is a significant component of construction projects and plays a significant role in construction operations. (Tatari, 2006)

Depending on the degree of mechanization, the cost of equipment in a project ranges from 10 to 30 percent of the total cost of the project. The cost of equipment can range up to 30% in fully mechanized modern projects like roads and dams. (Sharma, 2007).

Equipment management entails the administration, monitoring, and servicing of equipment assets. Effective equipment management can help businesses use their assets more efficiently and effectively by enabling for quick asset deployment when needed. Furthermore, equipment management gives businesses greater visibility into where, how, and when their assets are used. Equipment management involves planning, selection, utilization, personnel training, financial planning, preventive maintenance, and supervision.

Inadequate management practices of construction equipment and the subjective decisions on equipment leads to a major loss in the construction industry. On the contrary, effective construction equipment management can make the difference for construction companies. This is true because most of these companies are always looking forward, by the end of the day, to increase profits, reduce maintenance and operating expenses, and optimize utilization and minimize down time. (Journal of Engineering, June 2016).

Construction equipment management includes activities such as assessing the fleet of construction equipment and its costs while taking current projects into account through the practice of weighing the cost and use of construction equipment against project timeframes and revenue. The major goals of an equipment manager are to minimize downtime, maximize equipment use, and boost production while spending as little money as possible. (Sharma, 2007)

The fundamental elements for success are performance evaluation, cost analysis, and a desire to use the appropriate techniques for the circumstances. And in order to achieve maximum utilization, there is a need for logical planning, appropriate selection, operation, appropriate maintenance or repair, and deployment of equipment.

However in practical environment Equipment management is rife with challenges such as idleness, downtime, poor equipment maintenance procedures, incorrect estimates of the economic life and timing of replacement, inadequate training of equipment operators, equipment breakdown, excessive equipment maintenance, significant capital investment during acquisition, and a high unit cost of production. (Tennessee, 2021) Thus, it is important to have an equipment management system that integrates with human, technical, financial, and production systems to achieve efficiency and cost effectiveness.

The life cycle of the construction equipment employed in an enterprise begins with the identification of an opportunity in the planning stage and moves on to selection of equpment that best feet the ongoing project type and condition. The decision of whether to buy, lease, or rent for the chosen equipment comes next after choosing the proper machine for the project. It is more cost-effective and satisfying to lease it for a set amount of time or to rent it under some circumstances, while it is financially favorable to buy it under others.

The equipment will begin operating on the actual construction site once it is reached. Using construction equipment involves putting it to use at a given location to carry out the desired task.

Operating expenses, which are only incurred when the equipment is really used, are what keep the machinery running. The operational expenses of the equipment are also referred to as variable costs because they are dependent on a variety of circumstances.

Parallel to operation, the maintenance aspect that makes the equipment work continuously is also crucial. The fundamental goal of maintenance is to maintain the equipment in good, serviceable condition. Mechanical issues with equipment frequently arise during operation and must be resolved with appropriate maintenance and repair to prevent premature replacement.

Therefore, maintaining equipment is a crucial job in any contracting or equipment hire business.

This role covers all of the daily and recurring maintenance, lubrication, servicing, repairs, and services.

Finlay as equipment get aged at some point, the equipment starts to lose dependability as operating and maintenance expenses start to rise and surpass equipment profits. Older, less dependable equipment typically has a higher breakdown rate than newer equipment. As a result of these breakdowns, the construction projects for which the equipment is being used are disrupted, and these disruptions result in either direct or indirect financial losses for the construction firm/project and an equipment companies.

Thus, after a number of years of ownership, the outdated equipment requires replacement on a regular basis.However, in practical world a large portion of the fleet of equipment is older than the lifespan for which it was originally intended. In many circumstances, failing to replace the equipment results in high energy consumption, high maintenance costs, and an elevated risk of accidents and disasters. For equipment owners, choosing between replacing and fixing a piece of equipment can be quite difficult. (Tennessee, 2021)

Especially in pubic contractors with rare access to requisite funding when it is time to repair or replace a specific piece of equipment where the major source of funding for equipment fleet expenses comes from tax revenues that feed capital budgets, the use of replacement much neglected (Antioch, 2010).

Due to this controlling downtime and unforeseen expenses requires understanding which choice is best for the organization's operations and when assets should be replaced (Madusanka, 2016) During the typical equipment life cycle for firms competing in industries with extensive physical assets, making repair/replacement decisions for equipment is crucial. These choices impact

profitability and financial success in addition to requiring a substantial capital commitment. (Theron, 2016)

Equipment replacement can be triggered by either rising operating or maintenance costs or by the availability of technologically advanced equipment in the market. (Hartman., 2014)

Thus every company needs to have a clear policy for renewing its equipment, which must be replaced, not only when they are infallibly damaged, but also

when operating and/or maintenance costs over the asset exceeded the replacement cost;

- ✧ when there is an imminent risk of asset failure;
- ✧ when the impact of a likely failure exceeds the replacement cost
- ✧ when a presumed failure might compromise the reliability and security of the system and the people;
- ✧ When assets have become obsolete and inefficient to operate;
- ✧ If there is improvement in performance indicators, public and environmental safety (Zampolli, 2015).

As such, the purpose of this study is to investigate the Addis Ababa City Road Authority's practice of construction equipment management in terms of equipment performance evaluation and replacement analysis. To do this through a case study and interview, the research attempts to assess the AACRA equipment replacement policy,

replacement strategy, and replacement analysis process, followed by a sample replacement analysis. In addition, the study tries to study the equipment's data-keeping method and helpfulness during replacement analysis.

1.2. Problem Statement

Making decisions about whether to replace or not an asset involves weighing a few key factors, such as cost, performance, and the potential benefits of a new option (Fan, Machemeh and Gemar 2021). If the organization put off replacing the equipment, you might end up facing higher operating and maintenance costs, and organization could need extra resources. Plus, the salvage value might not be as favorable as organization hoped (Bugad 2019). On the flip side, if the equipment breaks down while the organization is waiting, it could suffer serious financial setbacks and delays, and the organization might have to scramble for funds to either fix the old equipment quickly or buy a new one.

So, over the past few decades how to optimize the timing and process of replacing equipment was a source of inspiration for the research. For instance, in worldwide context scholars researched about the limitations of the current construction equipment replacement decision (Alshiban, et al. 2024) . In nationwide context empirical studies analyzed the existing situation taking a selected company as a case study with regard to construction equipment management (Atnaw , et al. 2016).

Meanwhile, it is time to extend far beyond identifying factors that should be considered in the course of replacement decision making. For instance literatures reminds us the importance of the minimum cost method for minimizing costs for public agencies involved in road construction projects (Tadepalli, Divya ; 2023). In addition, minimum cost method is quite straightforward and provides a rational method to

conduct the objective comparison of alternatives rather than the intuitive method's professional judgment (Ryan, Gransberg and Popescu 2005).

This study was the response to this research inquiry. So, this study was to assess the equipment replacement decision making of AACRA in eyes of minimum cost method. In addition, the road projects are capital and equipment intensive construction sector. (Girma 2015) . This issue has also motivated the researcher to do this research.

1.3. Research questions

1. What are the current trends in equipment replacement in Addis Ababa City Road Authority?

2. What is the current condition of AACRA equipment's regarding their economic life and replacement

3. What are the challenges for timely equipment replacement?

1.4. Objective of the study

1.4.1. General objective

The main objective of the research was to assess the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method

1.4.2. Specific objective of the study

1. To investigate the current trends in equipment replacement in Addis Ababa City Road Authority

2. To evaluate the economic life of AACRA equipment's in eyes of minimum cost method

3. To assess challenges for timely equipment replacement

1.5. Significance of the study

For theoretical significance; it is believed that this study will contribute to the already existing body of knowledge and compensate for the paucity of a scholarly paper on the construction cost model.

The ever-changing theoretical intervention enjoyed paramount consideration with regard to optimal timing and process for equipment replacement in the construction industry. This study is important to bridge this gap by sharing theoretical knowledge to construction industry. In the contemporary study the researcher has shown a clear theoretical framework by theorizing road construction equipment replacement decision making via minimum cost theory and replacement theory. This study will also serve as an empirical source to the researcher in the future.

As part of practical significance; it is believed that this study will contribute to the practical implication of construction industry. The quest for research-based intervention was high on the priority list for the construction sector to have practical solution to how to optimize the timing and process of replacing construction road equipment. So, this study is important to bridge this gap for instance Addis Ababa City

Road Authority will be well informed about the current trends in equipment replacement. The authority will be at the position to know its decision making process about equipment replacement in terms of minimum cost method. In addition, the authority will be informed about the assess challenging on time equipment replacement.

1.6. Scope of the study

Although the notion of decision-making for the replacement of construction road equipment was broad and involved numerous underlying difficulties, the study's scope was limited to specific topical and spatial regions.

Conceptual scope of the study encompassed the current trends in equipment replacement, the equipment replacement decision making, and the issues challenging on time equipment replacement.

Geographical scope of the study was Addis Ababa. The time frame covering projects from 2015 to 2022. Concerning of methodological scope of the study; this research applied case study research type. The purpose of adopting this research design was to do thorough survey on the equipment replacement decision making of Addis Ababa City Road Authority. In this study context it was necessary to apply quantitative and qualitative research methods. For this study the population was the entire road construction equipment fleet and staffs of Addis Ababa City Road Authority.

On the other hand, the target population was road construction equipment (machinery, heavy machinery, and light-weight machinery and vehicles) with service year fifteen and above & staffs of Own Force Construction Plant Management Division of Addis Ababa City Road Authority. It's widely recognized that road equipment typically has a service life of about 15 years, and when it reaches that point, it's time to think about replacing or refurbishing it (Gransberg 2015).

In this study primary and secondary sources were used to gather information. As part of primary sources the researcher contacted the staffs of Own Force Construction Plant Management Division of Addis Ababa City Road Authority. As part of secondary sources the researcher used road construction equipment fleet record inventory (RCEFRI). The study also employed in-depth interview as part of primary sources. In addition, the researcher applied document review.

1.7. Limitations of the study

Although the study achieved its objectives, it should be noted that it was intertwined with so many bottlenecks. Primarily, the sample size used for replacement analysis using minimum cost method was small. In addition the study was backed by equipment replacement optimization theory real option theory. Other theories are beyond the scope of this study. This may limit the representation of the study while intending to use it for other study context.

Downtime costs includes lost output, construction delays, additional expenses for replacement equipment, and overtime labor brought on by equipment failures.

. The cost of capital would also be mentioned as one of the issues. If the funds were borrowed from a bank or another third party, it is the interest paid on the equipment purchase.(FasterCapital! 2021).

1.8. Operational definition of terms

Revenue: Revenue is a very important factor in deciding the replacement age of equipment, provided that there is direct income from the use of the equipment. This factor may be more relevant to plant hire companies and to subsidiary plant companies that operate as profit centers; however, it is of less importance to contracting companies with no direct income from their equipment.

Maintenance and Repair costs: Maintenance costs include expenditure on servicing, replacement of consumables, etc., whereas repair costs are due to labor, spare parts, and materials spent on necessary repairs of broken equipment.Although maintenance expenses and the cost associated with breakdown (downtime costs) are the main reason for replacement, other considerations also play a role. Literatures aired the following factors i.e.; income (revenue), expenses for upkeep and repairs, downtime, capital costs, depreciation, obsolescence, inflation, tax implications, and capital allowances (Tesfai and Temesgen 2021).

Downtime costs: As explained earlier, downtime costs are costs such as loss of production, delay in completion of the construction work, extra costs due to substitute equipment, and overtime work caused by equipment breakdowns.

Cost of Capital: The cost of capital is the interest paid on the money used for purchasing the equipment if the money has been borrowed from a bank or any other third party. If the company's own funds have been used for purchasing equipment, then the cost of capital would be the profit that could have been made if invested elsewhere in the company's business.

Depreciation: Depreciation is the loss of the resale value of equipment as a result of continued use. For example, if a piece of equipment is retained for one more year, the market value of the item would drop because of the deterioration caused by using it.Literature also cited depreciation as the factor influencing replacement decisions. Depreciation is the reduction in

an item's resale value brought on by continuous use. (Dachasa 2022). In addition, obsolescence is also so many times in literature as the factor. It is a reality that, as a result of technological advancement, newer equipment is typically more productive than older equipment.Some literature also recalled us inflation as the factor. Inflation is an increase in the price f new equipment (the price increase could also be due to advancement in technology).

Obsolescence: Obsolescence is the fact that newer equipment is superior, usually in productivity, to older equipment due to technological development. The obsolescence could be measured in terms of cost per unit output. It is believed that newer models of equipment cost less per unit output than earlier models. In the USA, contractors believe the annual obsolescence rate to be in the range of 1%–15%, with a weighted average of 5.6%. (Schexnayder, 1981)

Inflation: Inflation is simply the increased price of new machines (the price increase could also be due to technological development). For example, in the USA, the annual growth rate of inflation of all construction equipment in the period 1971–1981 was about 9.8%. (Schexnayder, 1981)

Tax considerations and Capital Allowances: Taxes and capital allowances also have some influence on the replacement decision. In the UK, some years ago, there was a tax relief of the taxable profits amounting to 100% of the purchase price (capital allowance) in the first year of ownership. This encouraged many contractors, particularly large companies with sizeable turnovers, to buy more and more equipment to replace their old equipment. However, the situation has now changed, and the maximum annual capital allowance is 25% of the book value, and the corporation tax relief on this is 35%, provided that a company has sufficient taxable profits to gain the benefit.

1.9. Organization of the study

There are five chapters in this work. The introduction is covered in Chapter 1. The study's history, problem description, goal, scope, and limitations are all covered in this chapter. Chapter two reviews literature. The literature part mainly review theoretical and empirical literatures. Under theoretical section the study reviewed literatures to define key terms such as construction industry, building construction project, reinforced concrete work, and construction cost estimate. The study also reviewed literatures about the underlying issues linked to the research topic such as the importance of accurate construction cost estimates, basic components of the cost of a construction project, construction cost estimation methods, model based construction cost estimation, construction cost modeling techniques, cost model evaluation factors, cost drivers in building construction, and modeling using cost drivers as alternative to construction industry. Finalize theoretical review by theorizing cost driver estimation. After meanwhile, the study also reviewed empirical literatures. At the end the study led in to the research gap and conceptual framework.

Chapter three deals with research methodology including research approach and design, sample size and sampling techniques, research subjects (respondents), data collection instruments and method of data analyses. Chapter four of the study is devoted to the presentation of data analysis and result. In addition, in chapter four the researcher discusses about the results. Chapter five is about conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

The first task of this chapter is to review theoretical and empirical literature's. In the theoretical part, this research reviewed literature to define key terms such as construction industry, building construction project, reinforced concrete work, and construction cost estimate. The study also reviewed literature's about the underlying issues linked to the research topic such as the importance of accurate construction cost estimates, basic components of the cost of a construction project, construction cost estimation methods, model based construction cost estimation, construction cost modeling techniques, cost model evaluation factors, cost drivers in building construction, and modeling using cost drivers as alternative to construction industry. Finalize theoretical review by theorizing cost driver estimation. After meanwhile, the study also reviewed empirical literature's. At the end the study led in to the research gap and conceptual framework

2.1. Definition and basic concepts

2.1.1. Road construction

Road construction, simply, is the building-up or enlarging of the roads -in fact precisely- for the sake of refining the good transportation system (Santos, Behrendt and Teytelboym 2010) . Road construction passed via the following steps. The first step is obtaining relevant legal documents as per the contract requirement. The next step is identifying and mobilizes earthwork resources as per the contract document. This step means the process of determining the resources required and getting the necessary finance to acquire these resources (Santos, Behrendt and Teytelboym 2010). The fourth step is characterized by determining the particular earthwork activity to be carried out

at the site. It is followed by acquiring the necessary permits and financial resource to mobilize these resources. The fifth step refers to mobilizing the earthwork resources from whichever location you identified as per the standard specifications of the contract documents. It is also followed by carry out site clearance and demolition activities based on contract document and construction procedure (JICA 20198) . The seventh step means interpreting drawings as per construction procedures, conduct setting out for earthworks based on design output. The next step is obtaining statutory requirements based on contract document and standard construction procedures. The ninth step is establishing road formation based on standard construction procedures (United States Department of Transportation 2024) . It is followed by taking and documenting ground levels according to Standard Operating Procedures (SOPs.). The tenth step is determining volumes of cut and fills materials in accordance with contract document. This is also followed by carrying out haulage and disposal of waste material as per the standard construction procedures. The twelfth step is operating and maintaining construction tools and equipment as per the SOPs.

2.1.2. Road construction equipment

The term "road construction equipment" describes the vehicles, machinery, and other tools used in the building and upkeep of roads, highways, and other transportation infrastructure (Mohamed and Gobran 2024) . Some literatures broadly classified road construction equipment in to construction equipment and construction plants. Construction equipment further classified in to earth works equipment, hauling and hoisting equipment, compaction and stabilization equipment, foundation equipment, pumping equipment, concreting equipment (Indian Roads Congress 2018).

Earth works equipment is also represented by bulldozers, shovels, clamshells and draglines, loaders, graders, scrappers, rollers, drills, grouting pumps, pile driving

and hammers (Mohamed and Gobran 2024). Hauling and hoisting equipment refers to tractors, normal and dump trucks, scrapers, hoists, conveyors and cranes. Compaction and stabilization equipment is also characterized by compactors. Foundation equipment refers to pile driving equipment. Pumping equipment is categorized in to pumps, hoses, pipes, and compressors. Mixers and vibrators are categorized under concreting equipment (Indian Roads Congress 2018). :

On the other hand, construction plants refer to aggregate production plants, asphalt mixing plant, and concrete batching plants. Crushers, screens, conveyors, and feeders are found in aggregate production plants. Asphalt mixing plant refers to aggregate batchers, bitumen emulsifier, and mixers. Feeders, mixers and silos are also found in concrete batching plants.

2.1.3. Road construction equipment management

Road construction equipment is one of the three primary inputs in the process of building a road. In order to complete construction tasks that are too difficult for human strength and to meet the high quailty demanded by contemporary construction engineering and designs, equipment has been developed and is used in the industry (Tadepalli, Divya ; 2023) . The second is to improve the economics of the road construction process. Equipment cost in a project might range from 10 to 30 percent of the project’s overall cost, depending upon the degree of mechanization. So, it is important to pay closer attention to the managerial aspects of such a large investment. Actually, proper management of equipment is crucial for the firm's success, as effective management of equipment would engender large savings for road construction.

The planning, use, upkeep, and eventual replacement of vehicles and equipment utilized in road construction projects are all included in road construction equipment

management. The management executed along road construction equipment life cycle. Road construction equipment life-cycle passes via the following stages i.e.; selection, acquisition, operation, maintenance, replacement. Selection governs the types, size, capacity, numbers and matching of equipment required to accomplish the road project. Acquisition is deploying the construction equipment based on financial analysis, project implementation schedule, and resource management capability. For acquisition there are three options. These are purchase or buy, rent, and lease, Operation-managing the way equipment operate determines how highest productivity is achieved. Maintenance is the stage of equipment management in terms of the frequency and nature of repairs and the associated expenses (Tadesse 2024) . Replacement as the stage of management refers to the undertakings carried out as the equipment reaches the end of its useful life.

2.2. Theoretical review

2.2.1. Road construction equipment replacement decision making process

Replacement means retire the machine and bring in a new unit that is equivalent to or nearly equivalent to the existing unit (Fan, Machemeh and Gemar 2021). At some point, the equipment starts to lose dependability as operating and maintenance expenses start to rise and surpass equipment profits. Older, less dependable equipment typically has a higher breakdown rate than newer equipment (Gage 2013) . These malfunctions cause the construction project for which the equipment is used to be interrupted, and this interruption costs equipment companies money either directly or indirectly. As a result, after a number of years of ownership, equipment owners are now required to replace their outdated equipment.

Determining when to replace outdated or ineffective equipment in order to maximize efficiency and cut expenses is part of the equipment replacement decision-making process. This process typically involves analyzing factors like equipment age, condition, maintenance costs, and potential benefits of new technology (Vorster 2017). By carefully evaluating these factors, organizations can make informed decisions that balance the costs of replacement with the potential gains in efficiency and productivity.

Over the course of road construction equipment replacement decision making process the following points are expected to be considered as mentioned in the following sub sections.

2.2.1.1. Issues linked to the replacement of equipment

Generally the following issues need to be considered. These are technical or performance issues, issues linked to financial or cost and tangible or risk factors.

Technical or performance issues

Equipment being obsolescence and its inadequacy for meeting the increased product demand would be seen as technical or performance issues. Maintenance costs, reduction in product quality, rate of output, and increase in labor cost and down time are also technical or performance issues (Tadepalli, Divya ; 2023) . Reduced safety as compared to new machine available/developed would also be considered as technical or performance issues. If the present equipment is polluting or spoiling working condition of the industry; it is also among technical or performance issues. Possibility of performing additional operations by new machine would be seen as the technical or performance issues (Vorster 2017). Being noisy equipment and causing diversion of the workers would also be seen as technical or performance issues. Among the

technical or performance issues are also how often the present equipment requires maintenance and repairs.

Issues linked to financial or cost

Being high repair and maintenance cost of the existing equipment/machinery would be seen as issues linked to financial or cost. Possibility of increasing in productivity by new machine is also among the issues linked to financial or cost (Tadesse 2024) . The initial cost of new equipment would also be considered as technical or performance issues. Salvage value of existing equipment and new equipment at the end of its useful life are also part of issues linked to financial or cost

Issues linked to tangible or risk factors

Among the issues linked to tangible or risk factors are deterioration, obsolescence, inadequacy, and working conditions. For instance, it becomes necessary to replace the machine when it wears out and does not function properly. Whenever new equipment comes on the market that is capable of producing more products of good quality with less labor and has more efficiency, the existing machine needs also to be replaced with this machine (Patel and Gohil 2019) . In addition, with the change in product design to meet customer demand or the quantity to be manufactured, old machinery becomes inadequate and, therefore, calls for different manufacturing equipment. Moreover, to make a replacement decision, working conditions are also important. Machinery that produces more smoke or noise (unpleasant conditions) and is hazardous to work may cause pollution and accidents (Atnaw , et al. 2016).

. 2.2.1.2. Equipment life

Regardless of an asset's remaining economic value, the period of time that the equipment can be operated before deteriorating beyond repair or usage is physical life

of equipment. Equipment life is categorized in to physical life, profit life and economic life (Tavakoli 1992)

Physical life

Over the physical life of the machine, it takes some time for the new machine to earn enough to cover the capital cost of its procurement. It then moves into a phase where it earns more than it costs to own, operate, and maintain. A machine finishes its life at a stage where the costs of keeping it going and the productive time lost to repair it are greater than what it earns during the period when it is operational (Vorster 2017)

Profit life

Profit life is the time period where 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 at a loss (Fan, Machemeh and Gemar 2021).

Economic life

Economic life is based on decreasing ownership costs with an increase in operating costs. The time period where these two opposite costs are equivalent is called the economic life (Indian Roads Congress 2018).

2.2.1.3. Factors influencing the replacement decisions

Although maintenance expenses and the cost associated with breakdown (downtime costs) are the main reason for replacement, other considerations also play a role. Literatures aired the following factors i.e.; income (revenue), expenses for

upkeep and repairs, downtime, capital costs, depreciation, obsolescence, inflation, tax implications, and capital allowances (Tesfai and Temesgen 2021).

Revenue determines the equipment's replacement age, provided that the equipment's operation generates a direct income. (Dachasa 2022) . As the factor maintenance costs are related to service and consumable replacement, whereas repair expenses are incurred because of labor, spare parts, and materials needed to fix damaged equipment. (Mathewos 2017).

Downtime costs includes lost output, construction delays, additional expenses for replacement equipment, and overtime labor brought on by equipment failures.

. The cost of capital would also be mentioned as one of the issues. If the funds were borrowed from a bank or another third party, it is the interest paid on the equipment purchase.(FasterCapital! 2021).

Literature also cited depreciation as the factor influencing replacement decisions. Depreciation is the reduction in an item's resale value brought on by continuous use. (Dachasa 2022) . In addition, obsolescence is also so many times in literature as the factor. It is a reality that, as a result of technological advancement, newer equipment is typically more productive than older equipment.

2.2.1.4. Life cycle cost analysis (LCCA)

Equipment LCCA is comprised of life cycle costs, equipment decision procedures, replacement analysis, and replacement models (Patel and Gohil 2019).

2.2.1.5. Equipment replacement policy and approaches

To make effective decisions when replacing equipment, it is necessary to build a policy with the criteria that must be considered. The replacement policy should be part of an organization's asset management policy. An equipment replacement decision can be based on the following approach i.e.; intuition and judgment, age-based approaches, cost-based approach, minimum cost method, multifactor approach, American Public Works Association (APWA) and practical methods (Dachasa 2022).

Intuition and judgment

The intuitive approach is arguably the most often used method for replacement decision-making because it is straightforward and depends on personal judgement to make replacement decision,this approach mostly relies on expert judgement or a perceived sense of accuracy.

Age-based approaches

In age-based approach there are two common ways for measuring the extent of replacement (Ryan, Gransberg and Popescu 2005) . The first is years approach. First, examine the number of years a machine has been in service. Then establish a trigger value where to start to really examine if a machine should be retired. The second is operating hours (engine hour) approach. The trigger value will have to vary by machine type, operating conditions, and perhaps additional factors

Cost-based approach

In cost based approach owning costs and operating costs are considered. They are primary types of costs (Gransberg 2015) . Ownership costs go down over time

because the residual value of a machine decreases as it gets older. Operating costs, on the other hand, increase over time as repair costs escalate.

Minimum cost method

Minimum cost method focuses on minimizing equipment costs based on not only the cost to operate and maintain a piece of equipment (O&M costs) but also the decline in its book value due to depreciation (Ryan, Gransberg and Popescu 2005). This is quite straightforward and provides a rational method to conduct the objective comparison of alternatives rather than the intuitive method's professional judgment.

Multifactor approach

Equipment replacement analysis can be based on more than just cost and age. There are several factors that can be scored individually and then combined into a composite score or ranking (Tadepalli, Divya ; 2023) . Each factor can be weighted in a way the equipment manager deems fit. With this analytical approach, we can take into consideration age, cost, utilization, and condition. Each of these factors can influence the decision to replace a piece of equipment, and each is based on real data. Other factors that we might take into consideration include availability, operating hours, and owning and operating costs. These factors speak to the reliability of a machine, another important consideration in the replacement decision-making process (Vorster 2017).

American public works association (APWA)

The American Public Works Association (APWA) proposes the use of a simple subjective points system to rank machines for replacement (APWA

2015) . The system asks users to award a certain number of points for factors such as age, miles traveled, reliability, cost, and condition based on their assessment of each factor. The points are totaled, and the unit with the highest score means it requires immediate consideration for replacement.

Practical methods

Public and private equipment owners have developed their own policies for making equipment management decisions. They are typically based on empirical data as well as past experience. Practical methods encompass public agency methods, Texas department of transportation, and Montana Department of Transportation.

Among practical method let us see public agency methods. The public agencies have evolved an equipment management strategy that is based largely on empirical terms that flow from the experiences of public equipment managers (Panegossi and Da Silva 2021). This is often translated to a specified fixed amount of usage in terms of mileage or engine hours that defines the equipment's economic life regardless of the actual O&M costs that are incurred on a given piece of equipment (Durdyev and Hosseini 2018) . Some agencies also select cost points for equipment operating and maintenance costs that are defined in terms of a percentage of the book value of the machine at which replacement is directed. Most agencies employ schedules or benchmarks for classes of equipment based on the criteria of age and usage and include life repair costs as well as the equipment's condition

Regarding to Texas Department of Transportation (TX DOT); it has equipment replacement criteria that are based on age, usage (miles or hours), and estimated repair costs. TX Dot's equipment fleet is quite large, comprising

approximately 17,000 units. This fleet is used to provide in-house road maintenance and small construction on the state's 301,081 total miles of roads and highways. With a fleet this large, the annual disposal program involves the replacement of approximately 10% of the total fleet (Texas Department of Transportation, TX DOT) (TRID 2022).

Among practical methods Montana Department of Transportation like TX DOT, it evaluates its equipment fleet annually to make a decision on which pieces of it should be replaced. It uses the expected annual costs of new equipment as the metric against which current equipment is measured. Regarding to Louisiana Department of Transportation and Development (La DOTD) it is critical repair method. It was very effective in verifying the optimum time for changing each unit. The method successfully calculated the optimum replacement point with 96% of certainty, and allowed the La DOTD to set up the priority ranking of replacement needs. As a result, available funds can be allocated and used effectively (Tran-SET 2021).

2.2.2. Challenges for timely equipment replacement

Literatures mentioned some points about issues challenging timely equipment replacement (Bantamlak 2013) . Some scholars raised the high cost of equipment replacement system and financial constraints and budgeting as challenges. Some scholars also cited the following issues i.e.; unavailability of data and lack of experience as of the challenging issues for timely equipment replacement. Others voiced complexity of decision making and lack of equipment implementation guideline as the issues (Tesfai and Temesgen 2021)

2.2.3. Theorize equipment replacement decision

This study has as a subject the decision making on equipment replacement and before that, it is essential to discuss the theories and models which explain such a decision. Particularly, the concept of equipment replacement optimization theory is to find out the most cost-effective point of time to replace the assets in order to lower lifecycle costs (Abensur, Santos and Bandeira 2023) . The equipment replacement problem (ERP) in particular analyzes how long an asset will work over a defined planning horizon (H) until it has to be replaced by another.

The equipment replacement problem (ERP) approaches in this study focus on only one optimization criterion (e.g., minimum cost). In addition, it pays attention to the real options emerged as an alternative to incorporate managerial flexibility (abandonment, postponement, anticipation) into traditional capital budgeting models (NPV, IRR, EAC), which assume that the initial conditions of the investment project remain unchanged throughout the planning horizon (;Hritonenko and Yatsenko 2007) . According to ERP, costs are divided into acquisition (purchase of the new asset), operational (human resources, maintenance, materials, depreciation) and residual values (sales value of the asset in use). Uncertainties with regard to the values can fall on any of these groups (e.g., the residual values) and, consequently, on the estimation of the economic life of the analyzed assets

This theory suits this study because the study variables (income, repair and maintenance costs, downtime costs, cost of capital, depreciation, obsolescence, inflation, & tax considerations and capital allowances) will have role on the equipment replacement decisions.

In addition, this study depends on real option theory. It is obvious the decisions managers often have to contend with are: when should an asset be replaced by another? Thus, a capital investment project can be regarded as an ensemble of real options on a real asset: the project. Throughout this paper, to produce empirical evidence on Geske's (1979) model, as adapted for real situations by Kemma (1993) and designated by Perlitz, Peske and Schrank (1999) as an alternative methodology to evaluate compounded options (Silva and Tadeu 2014).

2.3. Empirical review

2.3.1. Foreign research

Literatures identified major factors affecting for selecting heavy equipment in road work. To do this the study prepared questionnaire including 51 factors influencing the performance of individual equipment in road construction. Questionnaires were distributed among the engineers of different road projects in Chennai and data was collected and analyzed based on result conclusion was prepared (Patel and Gohil 2019).

Empirical researcher also reviewed literatures to provide perspective on current trends in equipment maintenance and replacement decision making processes (Gage 2013) . The scholar carried out a complete evaluation of the current processes and systems. A decision support system was also proposed to supplement the existing decision making.

Other scholars also researched about the limitations of the current construction equipment replacement decision (Alshiban, et al. 2024) . In this regard, empirical studies considered quantitative and qualitative criteria in the

decision-making process for equipment replacement (Alshiban, et al. 2024). A questionnaire survey using analytic hierarchy process and multi-attribute utility theory was used to rank these criteria and establish their utility scores. As the findings the identified criteria were classified into three categories: economic, technical and socio-environmental, encompassing a total of 15 criteria. The findings indicated that salvage value / meeting payback period / maximizing profitability held the highest importance in the replacement process, followed by considerations like high repair and maintenance cost; working condition and economic conditions. Safety and social benefits scored the least among all criteria and categories (Alshiban, et al. 2024).

2.3.2. Domestic research

Empirical research was conducted using a corporation as a case study to investigate the current status of construction equipment management. (Atnaw , et al. 2016) . The study made an effort to cover the following topics: the company's equipment management policy; the different maker kinds and capacities of the company's equipment; the evaluation and selection criteria used by manufacturers and suppliers; and the types of purchasing methods used. by attempting to address the company's equipment management policy, the evaluation and selection criteria used by suppliers and manufacturers, the types of purchasing processes used, and the various make types and capacities of the company's equipment.

Empirical studies also examined the practice of construction equipment management in defense construction enterprise (Bantamlak 2013) The study focused on examining the practice and challenges like lake of clear policy and guidelines, availability of the spear part, lack of training and development, lack

of skilled manpower and other factors that could influence construction equipment management practice in DCE .To answer research questions the study adopted the mixed research approach (Bantamlak 2013) . The study employed descriptive research approach and used secondary data and also primary sources like structured questionnaire and interview were carried out with enterprise management numbers, project managers, case team leaders and senior technicians. The survey and interview was conducted through purposive sampling technique. For the sake of achieving the objectives of this study, questionnaires were analyzed in descriptive form and findings were displayed in a table with assistance of a statistical package for the social science (spss) program and data from interview and document reviews were interpreted qualitatively (Bantamlak 2013) . The results show that construction equipment management practice from various perspectives of equipment management aspects in defense construction is assumed to be poor.

Researches were also conducted to study the general equipment management practice followed by high-grade level contractors (from grade one up to three) who are engaged in road construction and identified significant causes of problems related to the management of construction equipment. A structured questionnaire was prepared and distributed for 52 grade one up to three contractors who are in the Addis Ababa region of Ethiopia. Out of these, responses of 33 contractors were obtained (Girma 2015). The sample size was determined by using the Kish equation for 94% confidence of interval. The collected data were analyzed using SPSS 16 statistical software package producing frequencies, percentages, and cross-tabulation charts.RII ranking was used,To find the main reasons for equipment management problem.The finding obtained from this research indicates that only limited contractors (12.1%) have well-documented equipment management guideline (Girma 2015). The practice

of record-keeping of costs of operation and maintenance wasn't on the satisfactory level. Preventive maintenance wasn't also popular practice among contractors. Most of the time equipment maintenance was undertaken when it was breakdown. The equipment management practice of contractors was highly influenced by the limitation of the financial capacity of contractors. Most of the cause of the problem was due to inappropriate management practice they follow (Girma 2015).

2.4 Research gap

The foregoing empirical studied have made stride to identify factors affecting replacement decision making. Meanwhile, it is time to extend far beyond identifying factors that should be considered in the course of replacement decision making. For instance literatures reminds us the importance of the minimum cost method for minimizing costs for public agencies involved in road construction projects (Tadepalli, Divya ; 2023) . In addition, minimum cost method is quite straightforward and provides a rational method to conduct the objective comparison of alternatives rather than the intuitive method's professional judgment (Ryan, Gransberg and Popescu 2005).

This study was the response to this research inquiry. So, this study was to assess the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method. Additionally, the road sector accounts for the majority share of capital and equipment. (Girma 2015) . This issue has also motivated the researcher to do this study

CHAPTER THREE

RESEARCH METHODOLOGY

In Oliver's 2004 treatise, the methodology is outlined as the practical approach to organizing the entire research project. (Reimann, et al. 2018) . In essence, methodology is a strategy that describes how we will approach the issues at hand. It describes what data we will collect, how we will collect it, and how we will analyze that data in order to make inferences and suggestions. When conducting research, certain stages and procedures must be followed. Following the formulation of the problem statement, it ought to be clear what kind of data would be needed to investigate the issue and what kind of analysis would be most suitable for doing so. (Parveen 2015) Thus, this chapter outlined the approach used and listed the instruments and methods used to carry out this investigation.

3.1. Research design

Research design acts as a blueprint for tackling a research problem. Its main purpose is to streamline the process of gathering relevant data while keeping the use of effort, time, and money to a minimum, all in line with the research goals (Kothari 2004). This study applied case study research design. Case study research focuses on a specific event, person, place, thing, organization, or unit (or if more than one, typically a small number) (Schoc, 2020). Case study research involves a detailed and intensive analysis of a particular event, situation, organization, or social unit. The purpose of applying this research design was to do intensive analysis of the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method.

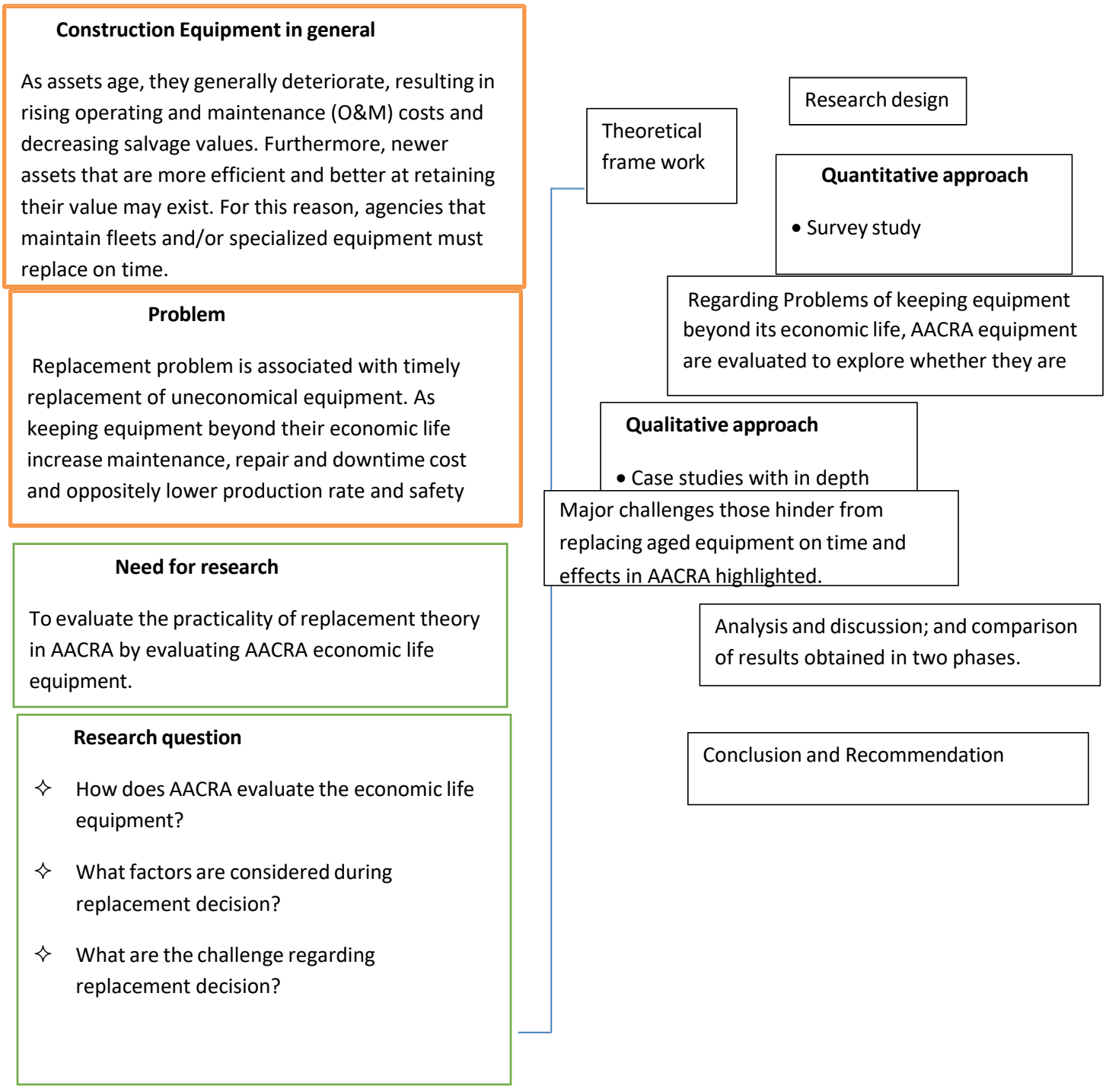

Figure 3.1 research design

3.2. Research approach

A research approach is a methodical strategy that directs a study and includes design, research techniques, and philosophical presumptions (Grover, 2015) Regarding to the research approach this thesis takes deductive approach. The reason behind using deductive approach was the study started with theory. For instance in this study the researcher pursued the following steps i.e.; theory, model construction, instrument construction, data collection, model testing, results, and interpretation to do analysis.

3.3. Research method

Research methods are vital tools and practices that enable you to address important questions and participate in meaningful discussions on those subjects.. Think of them as the various ways we explore and contribute to a shared understanding of our interests (Kothari 2004). This study employed mixed research method. The reason for applying quantitative research method was to do replacement analysis using minimum cost method. Quantitative method was employed to explore the current trends in equipment replacement and the challenges for timely equipment replacement via descriptive measures. The qualitative approach, on the other hand, was used to give the researcher the whole subjective perspective of the key informants, who had extensive knowledge of the research issue. So, among the lists of ways/tools/methods the researcher aware of; makes use of work with the subjects represented from the decision makers of Own Force Construction Plant Management Division of Addis Ababa City Road Authority

3.4. Types and sources of data

Method is a specific data collection process in accordance with the assumption of the selected methodology (Parveen 2015) . Primary data are those which are collected a fresh and for the first time and thus happen to be original in character. For this study primary data sources were the staffs of Own Force Construction Plant Management Division of Addis Ababa City Road Authority. As part of secondary sources the researcher used road construction equipment fleet records and documents (Own Force Construction Plant Management Division of Addis Ababa City Road Authority reports, research paper and review paper about the topic).

3.5. Population

Population refers to the entire group of individuals or elements that share a common characteristic or feature (Willie 2023) . In this study context the population was the entire road construction equipment fleet. During Interview for additional data collection staffs of Addis Ababa City Road Authority will be also part popullation. The target population, on the other hand, is a particular subset or section of the general population that is the main subject of a marketing campaign, intervention, or study. So, the target population was road construction equipment (machinery, heavy machinery, and light-weight machinery and vehicles) with service year fifteen and above & staffs of Own Force Construction Plant Management Division of Addis Ababa City Road Authority. It's widely recognized that road equipment typically has a service life of about 15 years, and when it reaches that point, it's time to think about replacing or refurbishing it (Gransberg 2015).

As member of the staffs of Addis Ababa City Road Authority the researcher counted thirty six (36) staffs working. Road equipment items (see Annex B, C, & D)

were identified. The population of items was nine (9), thirteen (13), and eleven (11) to heavy machinery, machinery and light weight machine and vehicles respectively. The target population (in case of staffs) was small in number, the data collection cost was very low, and made more reliable on the data; and hence the researcher chose census method for data collection than using sampling technique. In addition to evaluate the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method; the researcher conducted replacement analysis on nine road construction equipment (3 heavy machineries, 3 machineries, and 3 light weight machines and vehicles)

3.6. Methods of data collection

In this survey the researcher implemented primarily the following information collecting tools i.e.; questionnaire, road construction equipment fleet record inventory (RCEFRI), document review and in-depth interview

3.6.1. Questionnaire

The questionnaire is used as the primary data-collecting tool to obtain relevant information. The questionnaire was designed to do survey about the study participants' profile, the trend in equipment replacement decision and challenges for timely equipment replacement.

3.6.2. Road construction equipment fleet record inventory

Datasets about road construction equipment basic information and variables to do replacement analysis were acquired via road construction equipment fleet record inventory. Road construction equipment basic information were about machinery type, Manufactured year:, mark; mode and so on. Variables to do replacement analysis

were depreciation and replacement costs, investment costs, maintenance and repair costs, downtime costs and so on.

3.6.3. In-depth interview

KII guide line was prepared in order to gather information from the key informants. Four (4) key informants (senior decision makers) were represented from Own Force Construction Plant Management Division of AACRA. The purpose of the further interview was in order to triangulate the data gathered from the quantitative survey.

3.6.4. Document review

The researcher reviewed research materials i.e.; research article and article review to identify relevant factors to conduct replacement analysis

3.7. Data analysis

In this study the researcher followed statistical procedures for data management i.e.; data coding, monitoring, and verification particularly to the case of specific objective 1 & 3. The researcher has used SPSS V.25 as analytic tools or software package. The survey data was analyzed by descriptive statistics. For the case of specific objective 2; the researcher conducted replacement analysis by considering the following two scenarios and Douglas minimum cost method.

First scenario: Assuming maintenance cost and time value of money constant

According to the Douglas minimum cost method, If time is defined in discrete units, the replacement policy states that when the following period's maintenance cost

exceeds the current average cost, objects will be replaced to minimize the average annual cost.

Therefore, if the maintenance cost in the (n+1) year is higher than the average total cost in the (n) year and the maintenance cost in the (n) year is lower than the average total cost in the (n) year, replace the equipment at the end of n years. In the following section, practical equipment data from AACRA is used and analyzed in order to determine their replacement time. In this analysis the following assumptions are taken - (i) the equipment will depreciate constant amount of money per year & (ii) value money is constant.

First scenario: Assuming maintenance cost and time value of money changed

We shall suppose that a birr in n years will equal (1+0.1)-n when taking the time value of money into account. Thus, the amount (1+0.1)-n is known as the Present Value (PV) or Present Worth Factor (PWF) of one birr spent in n years.

PWF or PV of one birr spent in n years from now on is defined as = (1+r)-n if r is the rate of interest. The compound amount factor of one birr spent over n years is expressed as = (1+r)-n. Generally We shall make assumptions during replacement analysis.

(i) The equipment in question has no salvage value. (ii) The maintenance costs are incurred in the beginning of the different time period

Discount Rate Let r be the rate of interest. Therefore present worth factor of unit amount to be spent after one year is. $v = \frac{1}{1+r}$ Then v is known as the discount rate. The optimum replacement policy for replacement of item where maintenance costs

increase with time and money value changes with constant rate can be determined by following method: The equipment) is available for use over a series of time periods of equal intervals.

C = Purchase price of the item to be replaced ,R t = Running (or maintenance) cost in the n th year

R = Rate of interest $v = \frac{1}{1+r}$ Is the present worth of a birr to be spent in a year hence?

As a result of these two inequalities, rules for minimizing costs may be stated as follows:

1. Do not replace if the operating cost of next period is less than the weighted average of previous costs.

2. Replace if the operating cost of the next period is greater than the weighted average of the previous costs. Accordingly we will evaluate the following AACRA equipment based on the equipment data gained from the data base center whether they are in economical state or not.

3.8. Instrument reliability and validity

Validity refers to the level, to which a measuring instrument is truly measuring what it claims to be measuring, In this regard; for the case of Likert scale questionnaires to specific objective 3 was subjected to the content validity index. Therefore, in order to calculate this index, opinions on the content of the instrument/questionnaire was collected from fifteen (15) academicians and researchers

found in Addis Ababa University and private higher education institutions. Education backgrounds to academicians and researchers were Master of Science in civil engineering, Master of Science in mechanical engineering, Master of Science in information technology, Doctor of philosophy in business administration, and Doctor of philosophy in mechanical engineering. The instrument/questionnaire index was evaluated by fifteen (15) academicians and researchers. Using the formula CVR = (ne - N/2) / (N/2): 'ne' represents the number of experts who rated an item as "essential," and 'N' is the total number of experts; the result of content validity ratio formula was 60%. Actually, the minimum amount of content validity ratio (CVR) should be 49%. So, the instrument/questionnaire was valid.

3.9. Ethical considerations

Confidentiality was considered in all levels of the study during information gathering. This section of the research presents the ethical concern to be considered by the researcher while conducting this study and handling the respondents' information (confidentiality), honesty of the information, data collection and analysis. In respective of data collection, there are a number of ethical principles to which the researcher strictly sticks and considers. For instance, to collect pertinent data from bus, the researcher took support letter from Addis Ababa University Once the necessary data were collected, the researcher tried to handle and process the data obtained with great care by considering ethical principles. The data were handled property after receiving from the participants, and then were kept carefully. Regarding data analysis and reporting, the researcher tried to be honest, while analyzing and reporting the obtained results. A great deal of trust was placed in each researcher's integrity, and it would clearly be a major ethical issue. Therefore, the duty to represent data honestly was extended to the analysis and reporting stage of the research. This protected the distortion of the study's conclusion and recommendation.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter attempted to present the result analysis of the collected data. In addition, this chapter also incorporates the interpretation and discussion part. This study assessed the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method. The presentation and discussion of the result analysis in this chapter was organized in to five sections. Section one and section two present the response rate and the profile of study participants. Section three presents and discusses the result analysis of the collected data linking to the trends in equipment replacement. Section four presents and discusses about the result analysis of the collected data linking to evaluating authority's equipment replacement decision. Section five presents and discusses about the result analysis of the collected data linking to challenges for timely equipment replacement. .

4.1. Response rate

During the study, a total of thirty six (36) questionnaires were distributed with thirty six (36) of them returned adequately filled giving a response rate of 100%.

No	Questionnaire Status	Frequency	Percentage
1	Returned Questionnaires	36	100
2	UN-returned Questionnaires	0	0
Total		36	100

4.2. Respondents' profile

Information about the profile of the respondents was collected from the surveyed participants as presented (Table 4.1).

Table 4.1: Respondents' Profile

	Frequency	Percent
Educational Back ground:		
Degree	20	56
MA (MSC) Degree	8	22
Diploma	8	22
Year of Experience:		
2 years	6	16
3-5 years	10	28
6 -10 Years	10	28
11-14 Years	5	14
14-16 years	5	14
Area of competence		
Civil engineering	12	33
Management	5	14
Mechanical engineering	8	22
IT	11	31
Total	36	100

Reference : research survey SPSS V25 (2025)

As Table 4.1 shows, majority of school counselors are with the related areas of competency as the road construction industry require. In addition, almost all the study participants are Bachelor degree holders and above. Literature's also advised for the authority to be staffed with the related areas of competency for the staff does everything himself.

As far as work experience is concerned; majority (84%) of the staffs tenured in the office for more than three years. Their perspective on the research topic was based on their years of work experience over a large amount of time, as this percentage is significant for long-term teamwork. .

4.3. The trends in equipment replacement

4.3.1. Quantitative factors

This study sought to find out authority's consideration to quantitative factors in the course of road construction equipment replacement decision via degree of influence of quantitative factors as presented (Table 4.2).

Table 4.2: Quantitative factors

Quantitative factors	Frequency/percent	Degree of influence						
		Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)	Mean	SD
Maintenance and repair cost	36	-	-	-	3	33	4.91	0.28
	100	-	-		9	91		
Revenue	36	33	3	-	-	-	1.08	0.28
	100	9	91	-	-	-		
Downtime cost	36	-	-	4	32	-	3.88	0.318
	100	-	-	12	88	-		
Cost of capital	36			4	32	-	3.88	0.318

	100	-	-	12	88	-		
Depreciation	36	-	3	33	-	-	2.91	0.28
	100		9	91	-	-		
Obsolescence	36	33	3	-	-	-	1.08	0.28
	100	9	91	-	-	-		
Capital cost	36			4	32	-	3.88	0.318
	100	-	-	12	88	-		
Inflation	36	-	3	33	-	-	2.91	0.28
	100		9	91	-	-		
Overall mean	**3.07**							

Reference : research survey SPSS V25 (2025)

As the outcome demonstrated in tabular array 4.2 in AACRA maintenance and repair cost always influences the authority's equipment replacement decision. This is reported by 91% study participants. It is also indicated by the mean value (4.91) near to 5 qualitatively signifying very high influence (Table 4.2). In AACRA cost of capital and capital cost most often influence the authority's equipment replacement decision. This is echoed by 88% surveyed participants It is also shown by the mean value (3.88) near to 4 qualitatively signifying high influence (Table 4.2).

4.3.2. Qualitative factors :-This study assessed authority's consideration to qualitative factors in the course of road construction equipment replacement decision via degree of influence of qualitative factors as presented (Table 4.3).

Table 4.3: Qualitative factors

Qualitative factors	Frequency/percent	Degree of influence						
		Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)	Mean	SD
Management goals	36	-	-	-	4	32	4.87	0.29
	100	-	-		10	90		
Environmental Responsibility	36	13	23	-	-	-	2.18	0.21
	100	37	63	-	-	-		
Employee Morale	36	-	-	6	30	-	3.68	0.329
	100	-	-	15	85	-		
Employee Safety	36	-	-	6	30	-	3.68	0.329
	100	-	-	15	85	-		
Image in Industry & among others	36	-	3	33	-	-	2.91	0.28
	100		9	91	-	-		
Overall mean	**3.46**							

Reference:research survey SPSS V25 (2025)

As the outcome demonstrated in tabular array 4.3, authority's management goals always influence the equipment replacement decision. This is reported by 90% study participants. It is also indicated by the mean value (4.87) near to 5 qualitatively signifying very high influence (Table 4.3). Employee morale and safety most often influence the authority's equipment replacement decision. This is vocalized by 85% surveyed participants It is also shown by the mean value (3.68) near to 4 qualitatively signifying high influence (Table 4.3).

4.3.3. The practical reason for currently replaced equipment

In 2024 AACRA replaced about 26 equipments and the study assessed the actual reason based n the data gained from AACRA data center (Table 4.4).

Table 4.4: the practical reason for the equipment replaced in 2024.

No	Reason of actual disposal	Replaced by the reason	%
1	The maintenance cost Is increasing from time to time due to repeated break	12	46
2	the equipment is idle for long time due to shortage of maintenance budget they are left in the work shop and damaged their part and stop functioning	5	19
3	Due to age the equipment become non functional	3	12
4	Due to spare part unavailability in the market	3	12
5	Uneconomical to maintenance the equipment further	2	8
6	Due to sudden break and accident	1	3
7	Obsolescence	0	0

As the result demonstrated in Table 4.4 among the equipment currently replaced ; majority have a service life of about 15 years and above and being replaced by the decision of equipment management department . the majority of equipment are replaced due to the ever increasing of the equipment maintenance cost This is reported by 12 (46%) of the surveyed equipment. Less majority are left in queues at garages for an extended period. This is shown by 5 (19%) of the replaced equipment.

4.4. Evaluate authority's equipment replacement decision

In order to evaluate authority's equipment replacement decision; the researcher conducted replacement analysis.

4.4.1. Scenario 1 :-By assuming maintenance cost and time value of money constant; the researcher conducted replacement analysis as presented

Table 4.5: Replacement analysis on quarry truck

Replacement policy for items, efficiency of which declines gradually with time without change in money value.							
e-krishi shiksha (online - college) method ..... if money value is constant							
Equipment replacement analysis when the value of money remain constant							
	Machinery type : Quarry truck Mark; mode BZKD32						
	Manufactured year: 2013 Purchase price : 5,557,215.55						
	Purchase year 2014 service Year :8						
Year	2016	2017	2018	2019	2020	2021	2022
Maintenance cost **(M.C)**	13000	14350	15500	20688.16	41456.96	91544.6	140365.74
Operation cost **(OP.C)**	240,000	258,000	273,000	280,000	288,000	288,000	290,000
Year	**Running Cost** (M.C+ OP.C) -2	**Cumulative Running Cost** $\Sigma f(t)$ -3	**Depreciation Cost** -4	**Total Cost TC** (5) = (3) + (4)	**Average Cost** A(n) (6) = (5)/(N	REMARK	
2016	253,000	253,000	277860.8	530,861	530860.8		
2017	272,350	525,350	277860.8	803,211	401605.4		
2018	288,500	813,850	277860.8	1,091,711	363903.6		
2019	300,688	1,114,538	277860.8	1,392,399	348099.74		
2020	329,457	1,443,995	277860.8	1,721,856	344371.184	Triger pint	
2021	379,545	1,823,540	277860.8	2,101,401	350233.42		
2022	430,366	2,253,905	277860.8	2,531,766	361680.8943		

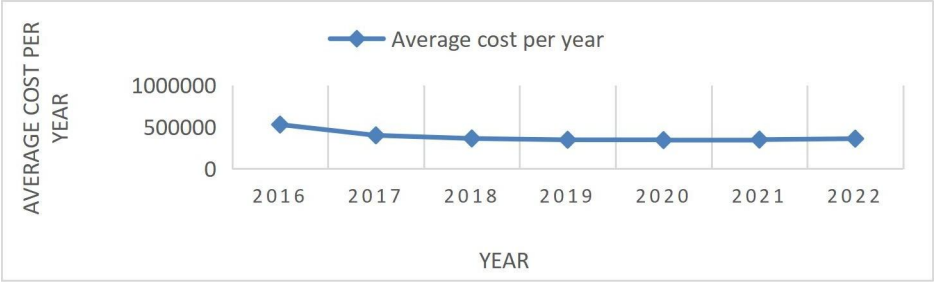

Figure 4.1: Replacement analysis on quarry truck

As illustrated in Table 4.5; the average total cost per year, A (n) is minimum in the 2020 (344371.2). Also the average cost in 2021 year (birr.350, 233.4) is more than the cost in 2020. Hence the Quarry truck would be replaced after 2020.

Replacement policy for items, efficiency of which declines gradually with time without change in money value.

e-krishi shiksha (online - college) method ..... if money value is constant

Equipment replacement analysis minbus

Machinery type : minibu Mark; modemode SY6482Q3

Manufactured year: 2009 Purchase price : 325000.00

Purchase year 2011 service Year :13

Year	2016	2017	2018	2019	2020	2021	2022	
Maintenance cost **(M.C)**	37223.18	24199.63	31884.12	32708.66	155185.83	32828.19	48344.8	
Operation cost **(OP.C)**	105,000	105,000	138,000	138,000	156,000	201,000	220,000	
Year	**Running Cost** (M.C + OP.C) -2	**Cumulative Running Cost** $\sum f(t)$ -3	**Depreciation Cost** -4	**Total Cost TC** (5) = (3) + (4)	**Average Cost** $A(n)$ (6) = (5)/(N)	REMARK		
2016	142,223	142,223	16248	389,190.10	158471.18			
2017	129,200	271,423	16248	732,190.60	143835.405			
2018	169,884	441,307	16248	1,057,531.20	152518.31			
2019	170,709	612,016	16248	1,401,752.10	157065.8975			
2020	311,186	923,201	16248	1,747,042.70	187889.884	Triger pint		
2021	233,828	1,157,030	16248	2,092,923.60	195546.2683			
2022	268,345	1,425,374	16248	2,463,380.20	205946.0586			

As demonstrated in table 4.6; the average total cost per year, A (n) is minimum in the 2017 (143,835.405). Also all average cost after 2017 (350, 233.4) are more than the cost in 2017. Hence according to the minimum cost method the minibus would be replaced after 2017.

Replacement policy for items, efficiency of which declines gradually with time without change in money value. loader

e-krishi shiksha (online - college) method ..... if money value is constant

Machinery type : Quarry truck Mark; mode BZKD32 Manufactured year: 2013 Purchase price : 1,505,692 Purchase year 1990 service Year :34							
Year	2016	2017	2018	2019	2020	2021	2022
Maintenance cost **(M.C)**	7223.18	8199.63	85884.12	8708.66	88185.83	89828.19	98344.8
Operation cost **(OP.C)**	104,060	108,000	148,000	138,000	156,000	201,000	220,000
Year	**Running Cost** (M.C + OP.C) -2	**Cumulative Running Cost** $\sum f(t)$ -3	**Depreciation Cost** -4	**Total Cost TC** (5) = (3) + (4)	**Average Cost** $A(n)$ (6) = (5)/(N)	REMARK	
2016	111,283	111,283	16248	127,531.18	127531.18		
2017	116,200	227,483	16248	243,730.81	121865.405		
2018	233,884	461,367	16248	477,614.93	159204.9767		
2019	146,709	608,076	16248	624,323.59	156080.8975		
2020	244,186	852,261	16248	868,509.42	173701.884		
2021	290,828	1,143,090	16248	1,159,337.61	193222.935		
2022	318,345	1,461,434	16248	1,477,682.41	211097.4871		

As illustrated in Table 4.7; the average total cost per year, A (n) is minimum in the 2017 (121,865.405). Also all average cost after 2017 (159204.9) are more than the cost in 2017. Hence according to the minimum cost method the excavator would be replaced after 2017.

4.4.2. Scenario 2

By assuming maintenance cost and time value of money changed; the researcher conducted replacement analysis as presented

Table 4.8: Replacement analysis on loader

Replacement policy for items, efficiency of which declines gradually with time but with change in money value.

e-krishi shiksha (online - college) method

Equipment replacement analysis Template

Machinery type :Loader Mark; CAT Model:,950F,4DS03117

Manufactured year: 1996

Purchase price : 1619040

Purchase year 1997 service Year :22

Year	2015	2016	2017	2018	2019	2020	2021	2022
Maintenance cost	34217.18	57812.62	77123.85	88356	115240	145490	165988	197370
Operation cost	1,000,000	1,340,000	1,580,000	1,580,000	1,800,000	1,880,000	2,001,000	2,200,000
Discounted factor	1	0.7	0.7	0.5	0.4	0.4	0.4	0.3

At the end of year (n)	**Operating & maintenance cost R_n**	**Discounted factor**	**Discounted operation & maintenance cost**	**Cumulative Discounted operation & maintenance cost**	**Discounted total cost**	**Cumulative discounted factor**	**Weighted average annual cost**	REMARK
-1	-2	-3	(4)=(2)x(3)	-5	(6)=(5)+PURCHASE COST	-7	(8)=(6)+(7)	
2015	1,034,217	1	1,034,217	1,034,217	2,653,257	1	2,653,257	
2016	1,397,813	0.9091	1,270,751	2,304,969	3,924,009	1.9091	2,055,423	
2017	1,657,124	0.8264	1,369,447	3,674,416	5,293,456	2.7355	1,935,096	
2018	1,668,356	0.7513	1,253,436	4,927,852	6,546,892	3.4868	1,877,622	minimum
2019	1,915,240	0.683	1,308,109	6,235,961	7,855,001	4.1698	1,883,784	
2020	2,025,490	0.6209	1,257,627	7,493,587	9,112,627	4.7907	1,902,149	
2021	2,166,988	0.5645	1,223,265	8,716,852	10,335,892	5.3552	1,930,066	
2022	2,397,370	0.5132	1,230,330	9,947,182	11,566,222	5.8684	1,970,933	

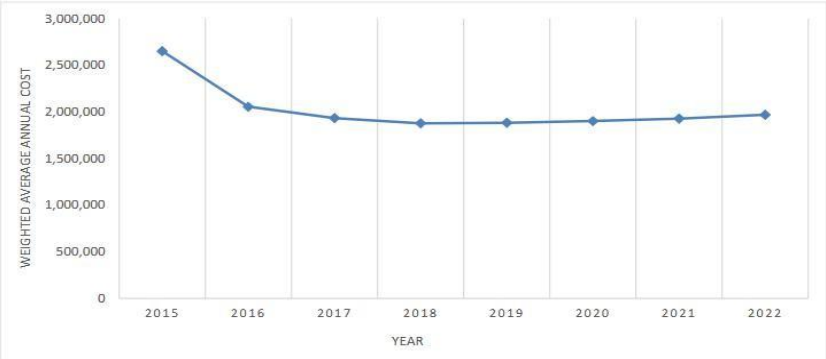

Figure 4.4: Replacement analysis on loader

As illustrated in table 4.8 and figure 4.4; 1,877,622<1,883,784<1,902,150 so it would be better to replace the loader after 2019 year.

Replacement policy for items, efficiency of which declines gradually with time but with change in money value.

e-krishi shiksha (online - college) method

Equipment replacement analysis Template

Machinery type :Asphalt paver Mark; CAT Model:,BB-650

Manufactured year: 1995 Purchase price :545,626.90

Purchase year 1997 service Year :22

Year	2015	2016	2017	2018	2019	2020	2021	2022
Maintenance cost	34217.18	5781.62	2277.85	18356.8	47484.45	34549.44	46598.21	49737.55
Operation cost	180,000	1,840,000	195,000	195,000	215,000	215,000	2,574,500	260,000
Discounted factor	1	0.9091	0.8264	0.7513	0.683	0.6209	0.5645	0.5132

At the end of year (n)	**Operating & maintenance cost** R_n	**Discounted factor**	**Discounted operation & maintenance cost**	**Cumulative Discounted operation & maintenance cost**	**Discounted total cost**	**Cumulative discounted factor**	**Weighted average annual cost**	REMARK
-1	-2	-3	(4)=(2)x(3)	-5	(6)=(5)+PURCHASE COST	-7	(8)=(6)+(7)	
2015	214,217	1	214,217	214,217	214,217	1	214,217	
2016	1,845,782	0.9091	1,678,000	1,892,217	1,892,217	1.9091	991,157	
2017	197,278	0.8264	163,030	2,055,248	2,055,248	2.7355	751,324	
2018	213,357	0.7513	160,295	2,215,543	2,215,543	3.4868	635,409	minimum
2019	262,484	0.683	179,277	2,394,820	2,394,820	4.1698	574,325	
2020	249,549	0.6209	154,945	2,549,765	2,549,765	4.7907	532,232	
2021	2,621,098	0.5645	1,479,610	4,029,375	4,029,375	5.3552	752,423	
2022	309,738	0.5132	158,957	4,188,332	4,188,332	5.8684	713,709	

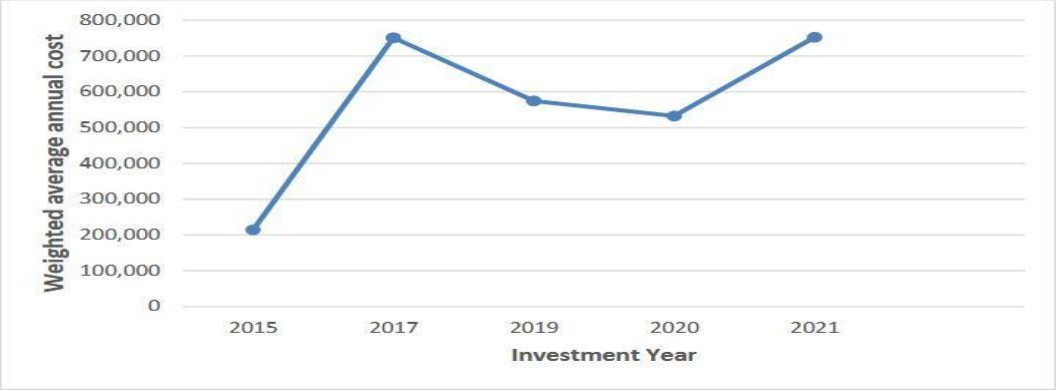

Figure 4.5: Replacement analysis on asphalt paver

As elaborated in Table 4.9 751324<63540<574325 so it is better to replace the asphalt pave after 2019 year.

4.4.3. Douglas minimum cost method

By assuming maintenance cost and time value of money constant; the researcher conducted replacement analysis as presented

Table 4.10: Replacement analysis on Minibus

Douglas minimum cost method					
TABLE .1 Depreciation and Replacement Costs					
End of Year	**Replacement Cost**	**Book Value**	**Loss on Replacement**	**Cumulative Use (h)**	**Cumulative Cost per Hour**
2015	1,157,440.00	1,157,440	0	0	
2016	1,215,312	868,080	347,232	2,000	173.6
2017	1,273,184	694,464	578,720	4,000	144.7
2018	3,509,001	582,578	2,926,423	6,000	487.7
2019	3,661,566	493,841	3,167,725	8,000	396
2020	3,814,132	408,962	3,405,169	10,000	340.5
2021	3,509,002	351,090	3,157,912	12,000	263.2
2022	3,643,964	304,793	3,339,171	14,000	238.5
2023	3,778,925	262,752	3,516,173	16,000	219.8

Table 4.11: Investment cost on Minibus

Year	Investment Start of Year	Depreciation	Investment End of Year	Additional Investment Cost (15% of initial investment)	Cumulative Investment Cost	Cumulative Use (h) per year	Cumulative Cost per Hour
2015	3,509,000	877,250	2,631,750	526,350	526,350	2,000	263.18
2016	3,684,450	736,890	2,947,560	552,668	552,668	4,000	138.17
2017	3,859,900	621,873	3,238,027	578,985	578,985	6,000	96.5
2018	3,509,001	534,484	2,974,517	526,350	526,350	8,000	65.79
2019	3,661,566	629,332	3,032,235	549,235	549,235	10,000	54.92
2020	3,814,132	539,736	3,274,396	572,120	572,120	12,000	47.68
2021	3,509,002	462,726	3,046,276	526,350	526,350	14,000	37.6
2022	3,643,964	507,387	3,136,576	546,595	546,595	16,000	34.16
2023	3,778,925	529,050	3,249,876	566,839	566,839	18000	31.49

Table 4.12: Maintenance and repair cost on Minibus

Year	Annual maintenance and repair cost	Cumulative Cost	Cumulative Use (h)	Cumulative Cost per Hour
2015	267,306	267306	2,000	133.65
2016	243,060	510,366	4,000	127.59
2017	294,020	804,386	6,000	134.06
2018	328,056	1,132,442	8,000	141.56
2019	404,090	1,536,532	10,000	153.65
2020	443,030	1,979,562	12,000	164.96
2021	570,045	2,549,607	14,000	182.11
2022	629,067	3,178,674	16,000	198.67
2023	629,067	3,807,741	16,000	237.98

Table 4.13: Down time cost on Minibus

Year	Downtime (%)	Operating Cost	Downtime Cost per Hour	Downtime Cost per Year	Cumulative Downtime Cost	Cumulative Use (h)
2015	21	70	14.7	29400	29400	2,000
2016	26	80	20.8	41600	71,000	4,000
2017	30	120	36	72000	143,000	6,000
2018	25	120	30	60000	203,000	8,000
2019	35	180	63	126000	329,000	10,000
2020	35	250	87.5	175000	504,000	12,000
2021	20	270	54	108000	612,000	14,000
2022	28	270	75.6	151200	763,200	16,000
2023	28	270	75.6	151200	914,400	16,000

Summary of Cumulative Costs per Hour									
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Depreciation and replacement ($/h)	173.62	144.68	487.7	396	340.5	263	238.5	219.76	
Investment ($/h)	263.18	138.17	96.5	65.79	54.9	47.68	37	34	
Maintenance and repairs ($/h)	133.65	127.59	134.1	141.6	153	164	182	198	23
Downtime (productivity adjusted) ($/h)	14.7	18.11	24.82	27.53	36.45	47.5	50	56	67
Total ($/h)	**585**	**428.5**	**743**	**631**	**585.5**	**523**	**508**	**508**	607

Table 4.14: Summary of cumulative costs per hour for Minibus

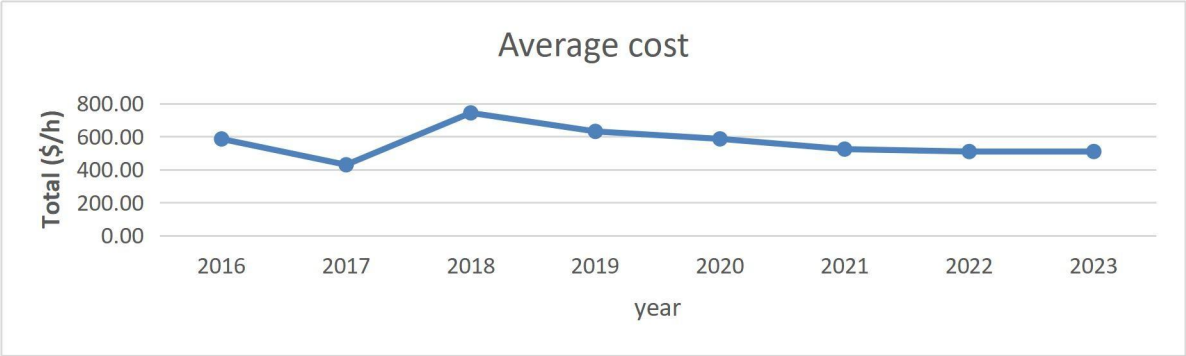

Figure 4.6: Average cost to minibus

As indicted by table 4.14 and figure 4.6 it is noted that the total cost per hour is minimum in the 2016 (428.5). Hence according to the minimum cost method, the minibus would be replaced after 2016. In eyes of minimum cost method the foregoing result shows that the authority wasn't at the position of timely replacement decisions.

The transcribed information obtained by the key informants also strengthened this finding. Key informant demonstrated the issues in part by saying that

AACRA uses none of the methods of evaluation techniques to replace inefficient equipment. Instead simply the authority uses availability of spare part as evaluation technique for replacement.

4.5. Challenges for timely equipment replacement

This study also assessed the challenges for timely equipment replacement as presented (Table 4.15).

Table 4.15: Challenges for timely equipment replacement

Statements	Frequency/percent	Degree of influence						
		fiercely disagree (1)	Disagree (2)	Medium (3)	Agree (4)	Strongly agree (5)	Mean	SD
Complexity of decision making	36	-	-	-	1	35	4.99	0.158
	100	-	-		4	96		
The high cost of equipment replacement	36	-	-	3	34	-	3.91	0.298
	100	-	-	5	95	-		
Unavailability of data on equipment performance, maintenance costs, and technological advancements	36	-	-	3	34	-	3.91	0.298
	100	-	-	5	95	-		
Difficulty to estimate the remaining value accurately	36	-	-	36	-	-	2.899	0.301
	100		-	97	-	-		
Uncertainty in future performance	36	30	10	-	-	-	1.76	0.446
	100	83	17	-	-	-		

As the result illustrated in Table 4.17 always AACRA face challenge by complexity related to decision making as it is reported by 96% study participants. It is also indicated by the mean value (4.99) near to 5 qualitatively signifying strongly agree (Table 4.17). Another issue facing the City Road Authority is the rising expense of replacing equipment. And unavailability of data on equipment performance,

Maintenance costs and technological advancements. This is echoed by 88% surveyed participants. It is also shown by the mean value (3.91) near to 4 qualitatively signifying agree (Table 4.2).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5. General

This chapter presents the conclusions of the study by combining the research results of both case studies and sample equipment replacement analysis based on the objectives stated in Section 1.3 under the introduction chapter. Accordingly, in this chapter, the main conclusions for this research are summarized. Recommendations are also forwarded to maximize the net benefit gained from construction equipment by replacing uneconomical equipment based on time-based equipment replacement analysis.

5.1. Conclusion

5.1.1 Replacement policy

Contractors are expected to follow certain procedures for replacing their equipment, as it is crucial for maintaining operational efficiency, managing costs, and ensuring that equipment remains reliable and functional. These procedures are either detailed as part of a comprehensive manual, or as a separate policy that contractors adopt to purchase new equipment and to replace the old ones. As there are Several factors influence equipment replacement decisions, and different organizations may adopt: Age-Based Replacement Policy, Economic Life-Based Replacement, Maintenance cost-Based Replacement Policy, Technology Obsolescence Policy ,Run-Time or Usage-Based Policy that suit their specific needs.

Accordingly, even though AACRA is using an age-based policy that is every equipment must serve less than 20 years the case study result indicated that from 786 equipment about 416 that is 53% of AACRA Equipment's are beyond this age limit.

Failing to replace the equipment results in high energy consumption, high maintenance costs, and an elevated risk of accidents and disasters. (Tennessee, 2021)

5.1.2. Replacement analysis system

Decisions about heavy equipment should be made based on sound economic principles, note motions, or intuition (Douglas, 1975). Economic replacement theory models attempt to answer the question, "What is the optimum economic life of this piece of equipment?" The goal is to find an optimum length of service for a given machine.

Financial Evaluation of Equipment Replacement Proposals Net present value, payback period, internal rate of return, annual cost minimization, total cost minimization, economic life, and profitability index are methods available for contractors to use in the financial evaluation of the alternatives.

Unfortunately, the result from interview and previous replacement indicated that AACRA uses none of the above methods of evaluation techniques to replace inefficient equipment instead the reason for replacement is high maintenance cost elongated down time and availability of spare part are evaluation techniques for replacement.

5.1.3 Factors to be considered

Among quantitative factors that influence replacement analysis The most important economic factors are maintenance & repair cost time, value of money, revenues, operating costs, depreciation, salvage value, taxes, inflation, obsolescence, and downtime.

in AACRA quantitative factors such as maintenance and repair costs, downtime costs, and capital costs are the prime and most influential factors in the replacement decision. The result from the interview and previous replacement history showed that maintenance cost given primary consideration during replacement and it holds 30% of replacement reason , as idleness of equipment affect the equipment by damaging its body and the company by the decreased working hour downtime is given second priority 15% being reason of replacement the 3rd reason of quantitative factor is cost of capital required to replace the old one on the other hand the factors like depreciation, obsolescence and salvage value are the most ignored quantitative factors replacement.

During replacement the contractors evaluate subjective or qualitative factors including employees' morale, employees' safety, environmental responsibility, their image in the industry and the management goals. Accordingly the research tried to explore the influence of those factors during replacement decision by assigning a different degree of importance to each of these factors through interview and by referring previous replacement history the result indicated that Since the primary aim of any public agency is to facilitate infrastructure through its investment, the goals of management are ranked highly and heavily considered when making a replacement decision as such about 78% respondent ranked management goal first. Next, AACRA gives substantial consideration to their human resources, in terms of safety and morale, when making replacement decisions It seems that the company recognizes the importance of safety to their goal achievement, as accidents have adverse effects on employees' productivity and expenditure and company image in the industry as such 4 respondent out 6 (67%) ranked Safety second considered factor during replacement , while morale is ranked third. The environmental responsibility is ranked fourth in the evaluation process. As the out aged equipment have high carbon emission but in AACRA where more than 62% equipment are beyond 15 years, the environmental responsibility factor assigned little consideration.

5.1.4 Equipment data

Analysis of Equipment Replacement Proposals requires data to follow systematic and sound procedures when deciding to replace equipment. Accordingly, all the necessary technical and financial data for each piece of equipment must be kept in a way suitable for a substantiated replacement analysis and decision.

Accordingly, in AACRA equipment data such as purchase year &cost, maintenance and repair cost tax operation cost and service cost such as grease, oil are kept both in soft and hard copy.

5.1.5 Sample replacement analysis study on AACRA equipment

This research attempts to find the optimum length of service by using a variety of techniques based on the science of economics. Accordingly Based on the equipment data stored in AACRA equipment data center the research has study there. As the research focuses on public contractors, specifically AACRA, the research used minimum cost methods to evaluate AACRA equipment that is expected on the verge of its economic life. The survey results indicate that only 23% are on economic life.

Table 5.1 summery of survey result

Ikrishka Mode one (Constant money value)			Ikrishka Mode one (Changing money value)			Duoglas minimuim cost method		
Sample sieze	Economic life	%	Sample sieze	Economic life	%	Sample sieze	Economical life	%
12	2	27	10	3	19	11	3	23
Average equipment on economical life					23%			

5.1.6 Use of Software Programs for Replacement Analysis

Computers are used nowadays in almost every field. Software programmers are always looking for ways to reduce time, resources, and the cost of doing routine and mathematical activities that can be taken care of by software programs. Software programs also help in ensuring accurate and correct calculations. Nowadays codes and programs can be written for replacement models, that facilitate and reduce the time and effort in performing the replacement analysis process. It is found that AACRA use computers only to store equipment data .This finding clearly indicates that AACRA is not taking full advantage of computers and computer programs in improving their performance, and optimizing the utilization of their resources.

5.2. Recommendation

The following suggestions are offered in light of the results and previous conclusions.

5.2.1 Replacement decision

As equipment replacement policies are crucial for maintaining operational efficiency, managing costs, and ensuring that equipment remains reliable and functional. Several factors influence equipment replacement decisions, and different organizations has to adopt various policies to suit their specific needs. And the research suggests having one from the following or there Here are some common considerations and policies associated with equipment

replacement: as AACRA is service oriented company the research suggests to use either age based or service hour and maintenance cost or operation expense detailed as follows.

Age-Based Replacement Policy:

- Under this policy, equipment is replaced after a specified number of years, regardless of its condition. For example, an organization might replace vehicles every 20 years

Condition-Based Replacement Policy:

- Equipment is replaced when it becomes costlier to maintain and repair than to replace. Organizations often use condition assessments and predictive maintenance techniques to determine when equipment is nearing the end of its useful life.

Economic Life-Based Replacement Policy:

- Equipment is replaced when it reaches the end of its economic life, which is the point at which the total cost of owning and operating the equipment is minimized.

Run-to-Failure Policy:

- Some organizations, especially for low-value or easily replaceable assets, may choose to run equipment until it fails completely. This policy minimizes upfront costs but can lead to higher long-term maintenance expenses.

Performance-Based Replacement Policy:

- Equipment is replaced when its performance no longer meets the required standards or when better alternatives become available. This policy focuses on maintaining optimal performance levels.

Technology Obsolescence Policy:

- Equipment is replaced when it becomes technologically outdated, making it less efficient or compatible with newer systems or processes.

Run-to-Obsolescence Policy:

- Some organizations may choose to run equipment until it becomes obsolete, even if it still functions adequately. This policy minimizes replacement costs but may result in efficiency and competitive challenges.

Regulatory Compliance Policy:

- Equipment may need to be replaced or upgraded to meet changing regulatory or environmental standards.

Risk-Based Replacement Policy:

- Equipment replacement decisions are based on risk assessments. High-risk equipment is replaced more frequently, while low-risk equipment may have longer replacement cycles.

Run-Time or Usage-Based Policy:

- Equipment is determined by the number of hours it has been in use or its usage levels. This is common in industries where equipment is heavily used, such as aviation.

Accordingly, by taking into consideration replacement factors the research suggests Multi-factor Replacement decisions policy detailed as follows, Equipment replacement analysis can be based on more than just cost and age. There are several factors that can be scored individually and then combined into a composite score or ranking. Each factor can be weighed up in a way the equipment manager deems fit. With this analytical approach, we can take into consideration age, cost, utilization, and condition. Each of these factors can influence the decision to replace a piece of equipment, and each is based on real data. Other factors that we might take into consideration include availability, operating hours, and owning and operating costs. These factors speak to the reliability of a machine, another important consideration in the replacement decision-making process.

Equipment				
Decision Criteria	Good 10 points	Bad Zero points	Weighting	
Year of Manufacture	2013	1994	15%	Age
Miles travelled	80,000	700,000	15%	
Miles travelled, last 12 months	30000	10000	30%	Utilization
Inspection score	8	3	10%	Condition
Labor cost per mile, last 12 months	$ 0.08	$ 0.30	15%	Cost
Parts cost per mile, and last 12 months	$ 0.25	$ 0.40	15%	

5.2.2 Replacement analysis method

Decisions about heavy equipment should be made based on sound economic principles, note motions, or intuition (Douglas, 1975). Economic replacement theory models attempt to answer the question, "What is the optimum economic life of this piece of equipment?" The goal is to find an optimum length of service for a given machine. As such the cost minimization method is an acceptable model for public contractors, while the profit maximization model is for private or profit-oriented companies.

Minimizing equipment costs is always an important goal for equipment owners. However, it is the dominant method for public agencies that own large and small fleets of construction equipment, as they have no mechanism to generate revenue to offset their costs. To achieve this goal, the minimum cost method focuses on minimizing equipment costs based on not only

the cost to operate and maintain a piece of equipment (O&M costs) but also the decline in its book value due to depreciation.

This is quite straightforward and provides a rational method to conduct the objective comparison of alternatives rather than the intuitive method's professional judgment. For the sake of simplicity, the example shown in this part of the minimum cost method does not include many of the costs discussed above, and you will need to determine which of the following will be included when implementing this equipment replacement decision-making methodology: penalty costs for downtime, obsolescence costs, labor costs, tax expenses (consideration of depreciation methods available), and inflation. In Douglas's minimum cost method, the decision to replace equipment is made when the estimated annual cost of the current machine for the next year exceeds the minimum average annual cumulative cost of the replacement.

5.2.3 Factors to be considered

During replacement analysis and decision quantitative factors such as capital cost, time value of money, revenues/working hour, operating costs, depreciation, salvage value, taxes, inflation, obsolescence, and downtime and the qualitative factors workers safety, image in the industry environmental safety Must be considered.

5.2.4 Equipment data

Analysis of Equipment Replacement Proposals requires data to follow systematic and sound procedures when deciding to replace equipment. Accordingly, all the necessary technical and financial data for each equipment must be kept in a way suitable for a substantiated replacement analysis and decision.

Data preservation ensures that data remains accessible and intact over time. In today's digital age, its importance has risen steeply. Data preservation involves maintaining and safeguarding data for long-term access. This practice ensures that the data remains usable and intact for future needs. The scope of data preservation extends beyond just storing data. It encompasses a series of managed activities designed to ensure continued stability and access to data. This includes implementing measures to avoid data dishonesty and unauthorized modification. It is important to consider various factors such as data format, storage medium, and access protocols.

On the other hand, Computers are used nowadays in almost every field. Software programmers are always looking for ways to reduce time, resources, and the cost of doing routine and mathematical activities that can be taken care of by software programs. Software programs also help in ensuring accurate and correct calculations.

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ANNEX A: QUESTIONNAIRES

ADDIS ABABA UNIVERSITY

Dear Respondent,

I invite you to participate in a research study titled " Assessment of Construction Equipment Replacement Decisions (A Case Study: Addis Ababa City Road Authority)." The purpose of this questionnaire is to assess the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method. Your insights and experiences are invaluable to this study. I kindly request you to provide reliable information for the quality of the research work. Your participation is completely voluntary, and all responses will be kept confidential. The questionnaire will take approximately thirty (30) minutes to complete.

Thank you in advance

Sincerely,

Gebeyehu Teka Mitiku
Contact Address:

Mobile Phone No: +251-940-270-852

E-mail:gebeyehuteka@yahoo.com

General Instructions

You don't need to write your name.

For Part 1, tick (√) in the box of your choice.

For Parts 2 and 3, tick (√) in the box of your choice in terms of level of occurrence (1= never; 2= occasionally; 3= sometimes; 4= fairly often; 5= always) and degree of agreement (1= strongly Disagree; 2=disagree; 3=Neutral; 4=Agree; 5=Strongly Agree) respectively

Part 1: Demographic Information

Age

☐ 21 – 30 Years ☐ 41-50 Years

☐ 31- 40 Years ☐ 51-60 Years

Sex

☐ Male ☐ Female

Educational Back ground

☐ Certificate ☐ Diploma ☐ Degree

☐ Master degree ☐ PHD (Doctorate Degree

Other ----------

Area of competency ----------

Marital Status

☐ Single ☐ Married ☐ Divorced ☐ Widow

Year Of Experience

☐ Less than 4 years ☐ 4-8 years ☐ 8-13 Years

☐ 14-18 Years ☐ 19-23 Years ☐ Greater than 23 Years

Part 2: Quantitative factors

S/N	Quantitative factors	Degree of influence				
		Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
1	Maintenance and repair cost					
2	Revenue					
3	Downtime cost					
4	Cost of capital					
5	Depreciation					
6	Obsolescence					
7	Capital cost					
8	Inflation					

Part 3: Qualitative factors

S/N	Qualitative factors	Degree of influence				
		Very low (1)	**Low (2)**	**Medium (3)**	**High (4)**	**Very high (5)**
1	Employee Morale					
2	Employee Safety					
3	Environmental Responsibility					
4	Image in Industry & among others					
5	Management Goals					

Part 4: The reason for the equipment currently not operating

Statements	**Responses**	
The reason for the equipment currently not operating	Left in queues at garages for an extended period	
	Left at workshop for an extended period	
	Being uneconomical for repairing	
	Having a service life of about 15 years and above and being nonfunctional	

Part 5: Challenges for on time replacement

S/N	Statements	Degree of Agreement				
		Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
1	The high cost of equipment replacement system					
2	Unavailability of data on equipment performance, maintenance costs, and technological advancements					
3	Difficulty to estimate the remaining value accurately.					
4	Complexity of decision making					
5	Uncertainty in future performance					

ANNEX B: CONSTRUCTION ROAD EQUIPMENT (HEAVY MACHINERY)

S/N	Equipment type	No	Age >15	Age<15	Remark
1	Dumbstruck	99	80	19	
2	Water truck	14	8	6	
3	Vacuum tank truck	3	3	0	
4	Mixer truck	7	3	4	
5	Jet truck	4	1	3	
6	Fuel truck	6	6	0	Equipment data not available
7	Asphalt distributor	3	1	2	
8	Mobile garage	1	1	0	Equipment data not available
9	Crane Mounted Truck	6	3	2	
10	Low bed	8	4	4	
11	Bus	22	5	17	
Total		**9 heavy machinery items**			

ANNEX C: CONSTRUCTION ROAD EQUIPMENT (MACHINERY)

	Table 4.6 Machinery				
	Equipment type	**No**	**Age >15**	**Age<15**	**Remark**
1	Dozer	8	8	0	
2	Grader	12	10	2	
3	Loader	35	28	7	
4	Excavator	21	18	2	
5	Asphalt paver	6	6	0	
6	Roller	39	38	1	
7	Backhoe loader	10	10	0	
8	Tractor	7	7	0	
9	Dumper	3	0	3	Equipment data not available
10	Asphalt Milling	2	1	1	
11	Fork lift	2	0	2	
12	Cordon curve	2	2	0	
13	Broom Machine	1	1	0	
14	Air compressor	12	10	2	

ANNEX D: CONSTRUCTION ROAD EQUIPMENT (LIGHT WEIGHT MACHINE AND MACHINERY)

S/N	Equipent Type	No	Age >15	Age <15	Remark
1	Nissan Pick up	4	4	0	
2	Double Cabin Pickup 4x4	198	88	110	
3	Land Cruser	17	10	7	
4	Mini Bus	18	12	6	
5	Automobile	16	13	3	
6	Light Dump truck (2 ton)	11	11	0	
7	Motor cycle	10	6	4	
8	Welding machine	8	8	0	
9	**Lighting Tower**	3	0	3	
10	Concrete batching plant	1	0	1	
11	Asphalt Cutter	8	3	5	
Total		**11 Light weight machine and vehicles item**			

ANNEX E: ARTICLE REVIEW

ASSESSMENT OF CONSTRUCTION EQUIPMENT REPLACEMENT DECISIONS (A CASE STUDY: ADDIS ABABA CITY ROAD AUTHORITY) Research By Gebeyehu Teka

Ethiopian Institute of Architecture, Building Construction, and City Development (EIABC),

Addis Ababa University

ABSTRACT

Assets typically deteriorate with age, which rises operating and maintenance (O&M) expenses and lowers salvage values. Additionally, there may be more recent assets available for replacement that is more effective and better performance. Public and commercial organizations that own fleets and/or specialized equipment must therefore make decisions about when to replace them on a regular basis. Unfortunately, prior studies have highlighted the issue of agencies failing to replace their equipment on time. This problem is made worse in public contracts since, due to their service-oriented nature, there is no way to determine whether the equipment is profitable (economical).Therefore, the main purpose of this study is to investigate equipment replacement policies, procedures, and techniques of Addis Ababa City Road Authority. It also examines the obstacles of on time replacing of outdated equipment. To achieve this the study applied mainly the following information gathering tools i.e.; questionnaire, road construction equipment fleet record inventory (RCEFRI), document review and in-depth interview. Accordingly The results indicated that the work objectives, safety, and management goals were found to be the most influential qualitative factors affecting the decision of equipment replacement, while Maintenance cost, downtime cost, and capital/purchasing cost are among the top quantitative factors that are considered while making a decision to replace equipment. Researcher conducted replacement analysis using minimum cost method. Sample of nine (9), thirteen (13), and eleven (11) to heavy machinery, machinery and light weight machine and vehicles respectively were taken from population of Road equipment The result indicated that 21, 63% equipment are beyond their economic life .the previous replacement history of AACRA indicated that increasing maintenance and repair cost is the leading factor of replacement. on the other hand among 784 AACRA equipment 56% are 15 years and above. In this sense it is necessary for the authority to take action to utilize approaches to optimize equipment replacement decision. The research also suggest that AACRA must evaluate equipment's cost(Maintenance ,downtime cost…), performance (workout put….) and risk (accident,CO2 Emission…) factors and must replace equipment's based on economical replacement analysis .

Key word: *Equipment replacement decision, replacement factors, economic life, replacement analysis and on time replacement.*

1 Introduction

The construction industry plays an important role in both industrialized and developing countries' development processes. Construction products provide the essential public infrastructure and private physical structures for numerous productive activities such as services, commerce, utilities, and other businesses. The industry is essential not only for the finished product, but it also employs a huge number of people (directly and indirectly) and has an impact on the economy of a country or region during the construction process. (Wibowo, 2019) Especially in developing countries like Ethiopia, the construction industry plays a vital role. This is mainly because developing countries are considerably dependent on the growth and development of their physical infrastructure. (Lopes, 2011) However, as the construction industry is full of challenges such as the absence of clear objectives, budget limitations, poor communication, inflated aspirations, time management, limited skills, lack of structure, inadequate risk management, obstructed cash flow, and safety issues or security concerns, without proper construction management, the above-stated socio-economic benefit can't be achieved. (OpticVyu, 2023)

Thus, construction stock holders (property owners, lenders, suppliers, consultants, contractors, subcontractors, etc.), both in private as well as in public, must apply an efficient construction management system. Construction management involves the coordination of many elements, including project design and planning, procurement, budgeting and scheduling, labor tracking and coordination, site safety, material management, and quality control.

One of the tasks of construction management is to efficiently allocate, organize, and use construction resources (materials, manpower, machinery, etc.) to meet project objectives. Therefore, the construction industry requires effective resource management techniques in order to maintain profitability and continue contributing to the development of the nation. One of the most crucial physical assets of a construction company is construction equipment. It is a significant component of construction projects and plays a significant role in construction operations. (Tatari, 2006) Depending on the degree of mechanization, the cost of equipment in a project ranges from 10 to 30 percent of the total cost of the project. The cost of equipment can range up to 30% in fully mechanized modern projects like roads and dams. (Sharma, 2007).

Equipment management entails the administration, monitoring, and servicing of equipment assets. Effective equipment management can help businesses use their assets more efficiently and effectively by enabling for quick asset deployment when needed.

Furthermore, equipment management gives businesses greater visibility into where, how, and when their assets are used. Equipment management involves planning, selection, utilization, personnel training, financial planning, preventive maintenance, and supervision. Inadequate management practices of construction equipment and the subjective decisions on equipment leads to a major loss in the construction industry. On the contrary, effective construction equipment management can make the difference for construction companies. This is true because most of these companies are always looking forward, by the end of the day, to increase profits, reduce maintenance and operating expenses, and optimize utilization and minimize down time. (Journal of Engineering, June 2016).

Assessment of Construction Equipment Replacement Decisions (A Case Study: Addis Ababa City Road Authority)

Construction equipment management includes activities such as assessing the fleet of construction equipment and its costs while taking current projects into account through the practice of weighing the cost and use of construction equipment against project time frames and revenue. The major goals of an equipment manager are to minimize downtime, maximize equipment use, and boost production while spending as little money as possible. (Sharma, 2007)

The fundamental elements for success are performance evaluation, cost analysis, and a desire to use the appropriate techniques for the circumstances. And in order to achieve maximum utilization, there is a need for logical planning, appropriate selection, operation, appropriate maintenance or repair, and deployment of equipment.

However in practical environment Equipment management is rife with challenges such as idleness, downtime, poor equipment maintenance procedures, incorrect estimates of the economic life and timing of replacement, inadequate training of equipment operators, equipment breakdown, excessive equipment maintenance, significant capital investment during acquisition, and a high unit cost of production. (Tennessee, 2021) Thus, it is important to have an equipment management system that integrates with human, technical, financial, and production systems to achieve efficiency and cost effectiveness. The life cycle of the construction equipment employed in an enterprise begins with the identification of an opportunity in the planning stage and moves on to selection of equipment that best feet the ongoing project type and condition. The decision of whether to buy, lease, or rent for the chosen equipment comes next. after choosing the proper machine for the project. It is more cost-effective and satisfying to lease it for a set amount of time or to rent it under some circumstances, while it is financially favorable to buy it under others.The equipment will begin operating on the actual construction site once it is reached. Using construction equipment involves putting it to use at a given location to carry out the desired task.

Operating expenses, which are only incurred when the equipment is really used, are what keep the machinery running. The operational expenses of the equipment are also referred to as variable costs because they are dependent on a variety of circumstances. Parallel to operation, the maintenance aspect that makes the equipment work continuously is also crucial. The fundamental goal of maintenance is to maintain the equipment in good, serviceable condition. Mechanical issues with equipment frequently arise during operation and must be resolved with appropriate maintenance and repair to prevent premature replacement.

Therefore, maintaining equipment is a crucial job in any contracting or equipment hire business. This role covers all of the daily and recurring maintenance, lubrication, servicing, repairs, and services.

Finlay as equipment get aged at some point, the equipment starts to lose dependability as operating and maintenance expenses start to rise and surpass equipment profits. Older, less dependable equipment typically has a higher breakdown rate than newer equipment. As a result of these breakdowns, the construction projects for which the equipment is being used are disrupted, and these disruptions result in either direct or indirect financial losses for the construction firm/project and an equipment companies.

Thus, after a number of years of ownership, the outdated equipment requires replacement on a regular basis. However, in practical world a large portion of the fleet of equipment is older than the lifespan for which it was originally intended. In many circumstances, failing to replace the equipment results in high energy consumption, high maintenance costs, and an elevated risk of accidents and disasters. For equipment owners, choosing between replacing and fixing a piece of equipment can be quite difficult. (Tennessee, 2021) Especially in pubic contractors with rare access to requisite funding when it is time to repair or replace a specific piece of equipment where the major source of funding for equipment fleet expenses comes from tax revenues that feed capital budgets, the use of replacement much neglected (Antioch, 2010)

downtime and unforeseen expenses requires understanding which choice is best for the organization's operations and when assets should be replaced (Madusanka, 2016) During the typical equipment life cycle for firms competing in industries with extensive physical assets, making repair/replacement decisions for equipment is crucial. These choices impact profitability and financial success in addition to requiring a substantial capital commitment. (Theron, 2016) Equipment replacement can be triggered by either rising operating or maintenance costs or by the availability of technologically advanced equipment in the market. (Hartman., 2014)

Thus every company needs to have a clear policy for renewing its equipment, which must be replaced, not only when they are infallibly damaged, but also when operating and/or maintenance costs over the asset exceeded the replacement cost;when there is an imminent risk of asset failure;when the impact of a likely failure exceeds the replacement cost when a presumed failure might compromise the reliability and security of the system and the people;When assets have become obsolete and inefficient to operate; If there is improvement in performance indicators, public and environmental safety (Zampolli, 2015).

As such, the purpose of this study is to investigate the Addis Ababa City Road

Authority's practice of construction equipment management in terms of equipment performance evaluation and replacement analysis. To do this through a case study and interview, the research attempts to assess the AACRA equipment replacement policy, replacement strategy, and replacement analysis process, followed by a sample replacement analysis. In addition, the study tries to study the equipment's data-keeping method and helpfulness during replacement analysis.

2 LITERATURE REVIEW

The first task of this chapter is to review theoretical and empirical literatures. In the theoretical part, this research reviewed literature to define key terms such as construction industry, building construction project, reinforced concrete work, and construction cost estimate. The study also reviewed literature's about the underlying issues linked to the research topic such as the importance of accurate construction cost estimates, basic components of the cost of a construction project, construction cost estimation methods, model based construction cost estimation, construction cost modeling techniques, cost model evaluation factors, cost drivers in building construction, and modeling using cost drivers as alternative to construction industry. Finalize theoretical review by

theorizing cost driver estimation. After meanwhile, the study also reviewed empirical literature's. At the end the study led in to the research gap and conceptual framework.

Table 1. Theoretical Frame works

Types of Approaches	**Description**
Intuition and judgment	it is straightforward and depends on personal judgement
Age-based approaches	are two common ways for measuring the extent of replacement
Cost-based approach	In cost based approach owning costs and operating costs are considered.
Minimum cost method	focuses on minimizing equipment costs based on not only the cost to operate and maintain a piece of equipment (O&M costs) but also the decline in its book value due to depreciation
Multi-factor approach	Equipment replacement analysis can be based on more than just cost and age. There are several factors that can be scored individually and then combined into a composite score or ranking

Tabe 2. Practical method refereces

Texas Department of Transportation (TX DOT);	They are typically based on empirical data as well as past experience.
Montana Departement of Transportation	Maintenance cost must not exceed 40% of its capital cost
American public works association (APWA)	Consider age,maintainance operation,capital cost and other factors

3. current practice

Empirical research was conducted using a corporation as a case study to investigate the current status of construction equipment management. (Atnaw , et al. 2016). The study made an effort to cover the following topics: the company's equipment management policy; the different maker kinds and capacities of the company's equipment; the evaluation and selection criteria used by manufacturers and suppliers;

and the types of purchasing methods used. by attempting to address the company's equipment management policy, the evaluation and selection criteria used by suppliers and manufacturers, the types of purchasing processes used, and the various make types and capacities of the company's equipment.

Empirical studies also examined the practice of construction equipment management in defense construction enterprise (Bantamlak 2013) The study focused on examining the practice and challenges like lake of clear policy and guidelines, availability of the spear part, lack of training and development, lack of skilled manpower and other factors that could influence construction equipment management practice in DCE.

To answer research questions the study adopted the mixed research approach (Bantamlak 2013) . The study employed descriptive research approach and used secondary data and also primary sources like structured questionnaire and interview were carried out with enterprise management numbers, project managers, case team leaders and senior technicians.

The survey and interview was conducted through purposive sampling technique. For the sake of achieving the objectives of this study, questionnaires were analyzed in descriptive form and findings were displayed in a table with assistance of a statistical package for the social science (spss) program and data from interview and document reviews were interpreted qualitatively (Bantamlak 2013) . The results show that construction equipment management practice from various perspectives of equipment management aspects in defense construction is assumed to be poor.

4. Study Methodology

The entire research work has been divided into four steps:

1. Conduct literature review to capture to scan global trend of equipment replacement ;

2. Collect objective data (replacement factors , on time replacement challenges and trends of equipment replacement trend of AACRA;

3. Conduct replacement analysis On AACRA Equipment's using minimum cost models.

4. Recommond model that suit fr the agency.

Construction Equipment in general

As assets age, they generally deteriorate, resulting in rising operating and maintenance (O&M) costs and decreasing salvage values. Furthermore, newer assets that are more efficient and better at retaining their value may exist. For this reason, agencies that maintain fleets and/or specialized equipment must replace on time.

Problem

Replacement problem is associated with timely replacement of uneconomical equipment. As keeping equipment beyond their economic life increase maintenance, repair and downtime cost and oppositely lower production rate and safety

Need for research

To evaluate the practicality of replacement theory in AACRA by evaluating AACRA economic life equipment.

Research question

- *How does AACRA evaluate the economic life equipment?*
- *What factors are considered during replacement decision?*
- *What are the challenge regarding replacement decision?*

Research design

Theoretical frame work

Quantitative approach

- *Survey study*

Regarding Problems of keeping equipment beyond its economic life, AACRA equipment are evaluated to explore whether they are

Qualitative approach

- *Case studies with in depth Major challenges those hinder from replacing aged equipment on time and effects in AACRA highlighted.*

Analysis and discussion; and comparison of results obtained in two phases.

Conclusion and Recommendation

Figure 3.1 research design

5 Population & Sampling

In this study context the population was the entire road construction equipment fleet. During Interview for additional data collection staffs of Addis Ababa City Road Authority will be also part population. The target population, on the other hand, is a particular subset or section of the general population that is the main subject ofa marketing campaign, intervention, or study. So, the target population was road construction equipment (machinery, heavy machinery, and light-weight machinery and vehicles) with service year fifteen and above & staffs of Own Force Construction Plant Management Division of

Addis Ababa City Road Authority. It's widely recognized that road equipment typically has a service life of about 15 years, and when it reaches that point, it's time to think about replacing or refurbishing it.

The population of items was nine (9), thirteen (13), and eleven (11) to heavy machinery, machinery and light weight machine and vehicles respectively. The target population (in case of staffs) was small in number, the data collection cost was very low, and made more reliable on the data; and hence the researcher chose census method for data collection than using sampling technique.

In addition to evaluate the equipment replacement decision making of Addis Ababa City Road Authority in eyes of minimum cost method; the researcher conducted replacement analysis on nine road construction equipment (3 heavy machineries, 3 machineries, and 3 light weight machines and vehicles) resulted in a coefficient of determination (R2) ranging from 0.84 to 97 which showed a good test of fit.

Methods of data collection Questionnaire: -

The questionnaire is used as the primary data-collecting tool to obtain relevant information. The questionnaire was designed to do survey about the study participants' profile, the trend in equipment replacement decision and challenges for timely equipment replacement.

Road construction equipment fleet record inventory :- *Datasets about road construction equipment basic information and variables to do replacement analysis were acquired via road construction equipment fleet record inventory. Road construction equipment basic information were about machinery type, Manufactured year:, mark; mode and so on. Variables to do replacement analysis were depreciation and replacement costs, investment costs, and maintenance and repair costs, downtime costs and so on.*

In-depth interview

KII guide line was prepared in order to gatherinformation from the key

Informants. Four (4) key informants Construction Plant Management Division of AACRA. The purpose of the further interview was in order to triangulate the data gathered from the quantitative survey.

Document review: - *The researcher reviewed research materials i.e.; research article and article review to identify relevant factors to conduct replacement analysis*

Data analysis:-*In this study the researcher followed statistical procedures for data management i.e.; data coding, monitoring, and verification particularly to the case of specific objective 1 & 3. The researcher has used SPSS V.25 as analytic tools or software package. The survey data was analyzed by descriptive statistics. For the case of specific objective 2; the researcher conducted replacement analysis by considering the following two scenarios and Douglas minimum cost method.*

6 Results & Findings

Quantitative factors

This study sought to find out authority's consideration to quantitative factors in the course of road construction equipment replacement decision via degree of influence of quantitative factors as presented (Table 4.2).

As the outcome demonstrated in tabular array 4.2 in AACRA maintenance and repair cost always influences the authority's equipment replacement decision. This is reported by 91% study participants. It is also indicated by the mean value (4.91) near to 5 qualitatively signifying very high influence (Table 4.2). In AACRA cost of capital and capital cost most often influence the authority's equipment replacement decision. This is echoed by 88% surveyed participants It is also shown by the mean value (3.88) near to 4 qualitatively signifying high influence (Table 4.2).

Table 4.2. ***Quantitative factors***

Quantitative factors	***Frequency/percent***	***Degree of influence***						
		Very low (1)	***Low (2)***	***Medium (3)***	***High (4)***	***Very high (5)***	***Mean***	***SD***
Maintenance and repair cost	*36*	-	-	-	*3*	*33*	*4.91*	*0.28*
	100	-	-		*9*	*91*		
Revenue	*36*	*33*	*3*	-	-	-	*1.08*	*0.28*
	100	*9*	*91*	-	-	-		
Downtime cost	*36*	-	-	*4*	*32*	-	*3.88*	*0.318*
	100	-	-	*12*	*88*	-		
Cost of capital	*36*			*4*	*32*	-	*3.88*	*0.318*
	100	-	-	*12*	*88*	-		
Depreciation	*36*	-	*3*	*33*	-	-	*2.91*	*0.28*
	100		*9*	*91*	-	-		
Obsolescence	*36*	*33*	*3*	-	-	-	*1.08*	*0.28*
	100	*9*	*91*	-	-	-		
Capital cost	*36*			*4*	*32*	-	*3.88*	*0.318*
	100	-	-	*12*	*88*	-		
Inflation	*36*	-	*3*	*33*	-	-	*2.91*	*0.28*
	100		*9*	*91*	-	-		
Overall mean	***3.07***							

Table 4.3: Qualitative factors

Qualitative factors	***Frequency/percent***	***Degree of influence***						
		Very low (1)	***Low (2)***	***Medium (3)***	***High (4)***	***Very high (5)***	***Mean***	***SD***
Management goals	*36*	-	-	-	*4*	*32*	*4.87*	*0.29*
	100	-	-		*10*	*90*		
Environmental Responsibility	*36*	*13*	*23*	-	-	-	*2.18*	*0.21*
	100	*37*	*63*	-	-	-		
Employee Morale	*36*	-	-	*6*	*30*	-	*3.68*	*0.329*
	100	-	-	*15*	*85*	-		
Employee Safety	*36*	-	-	*6*	*30*	-	*3.68*	*0.329*
	100	-	-	*15*	*85*	-		
Image in Industry & among others	*36*	-	*3*	*33*	-	-	*2.91*	*0.28*
	100		*9*	*91*	-	-		
Overall mean	***3.46***							

The practical reason for currently replaced equipment In 2024 AACRA replaced about 26 equipments and the study assessed the actual reason based on the data gained from AACRA data center (Table 4.4).

Table 4.4 Reason of actual disposal

No	***Reason of actual disposal***	***Replaced by the reason***	***%***
1	*The maintenance cost Is increasing from time to time due to repeated break*	*12*	*46*
2	*the equipment is idle for long time due to shortage of maintenance budget they are left in the work shop and damaged their part and stop functioning*	*5*	*19*
3	*Due to age the equipment become non functional*	*3*	*12*
4	*Due to spare part unavailability in the market*	*3*	*12*
5	*Uneconomical to maintenance the equipment further*	*2*	*8*
6	*Due to sudden break and accident*	*1*	*3*
7	*Obsolescence*	*0*	*0*

This study also assessed the challenges for timely equipment replacement as presented (Table 4.5).

Table 4.5 Challenges for timely equipment replacement

Statements	***Freq uenc y/pe rcen t***	***Degree of influence***						
		fierce ly disag ree (1)	***Dis agr ee (2)***	***Mediu m (3)***	***Agre e (4)***	***Strong ly agree (5)***	***Mea n***	***SD***
Complexity of decision making	*36*	-	-	-	*1*	*35*	*4.99*	*0.158*
	100	-	-		*4*	*96*		
The high cost of equipment replacement	*36*	-	-	*3*	*34*	-	*3.91*	*0.298*
	100	-	-	*5*	*95*	-		
Unavailability of data on equipment performance, maintenance costs, and technological advancements	*36*	-	-	*3*	*34*	-	*3.91*	*0.298*
	100	-	-	*5*	*95*	-		
Difficulty to estimate the remaining value accurately	*36*	-	-	*36*	-	-	*2.89 9*	*0.301*
	100		-	*97*	-	-		
Uncertainty in future performance	*36*	*30*	*10*	-	-	-	*1.76*	*0.446*
	100	*83*	*17*	-	-	-		

As the result illustrated in Table 4.5 always AACRA face challenge by complexity related to decision making as it is reported by 96% study participants. It is also indicated by the mean value (4.99) near to 5 qualitatively signifying strongly agree (Table 4.5). Another issue facing the City Road Authority is the rising expense of replacing equipment. and unavailability of data on equipment performance, maintenance costs, and technological advancements. This is echoed by 88% surveyed participants. It is also shown by the mean value (3.91) near to 4 qualitatively signifying agree (Table 4.2).

Evaluate authority's equipment economic life

In order to evaluate authority's equipment replacement decision; the researcher conducted replacement analysis.

Scenario 1 :-*By assuming maintenance cost and time value of money constant; the researcher conducted replacement analysis*

Scenario 2 :- *By assuming maintenance cost and time value of money changed; the researcher conducted replacement analysis as presented*

Scenario 3 :- *Douglas minimum cost method*

Ikrishka Mode one (Constant money value)			*Ikrishka Mode one (Changing money value)*			*Duoglas minimuim cost method*		
Sample sieze	*Economic life*	*%*	*Sample sieze*	*Economic life*	*%*	*Sample sieze*	*Economical life*	*%*
12	*2*	*27*	*10*	*3*	*19*	*11*	*3*	*23*
Average equipment on economical life					*23%*			

Table 4.6 table sample replacement

This research attempts to find the optimum length of service by using a variety of techniques based on the science of economics. Accordingly Based on the equipment data stored in AACRA equipment data center the research has study there. As the research focuses on public contractors, specifically AACRA, the research used minimum cost methods to evaluate AACRA equipment that is expected on the verge of its economic life. The survey results indicate that only 23% are on economic life.

Conclusion

Various scholars and academicians have conducted many studies across the globe about equipment replacement. This research work was to assess the equipment replacement decision making of AACRA in eyes of minimum cost method. In AACRA equipment data such as purchase year &cost, maintenance and repair cost tax operation cost and service cost such as grease, oil are kept both in soft and hard copy as the equipment data from the data center indicates from 784 AACRA equipment about 65% are beyond a service life of about 15 years, and it's time to think about replacing. On the other hand AACRA maintenance and repair cost always influences the authority's equipment replacement decision. Authority's management goal always also influences the equipment replacement decision. AACRA uses none of financial evaluation of equipment replacement proposals. In addition in eyes of minimum cost method the foregoing result shows that the authority wasn't at the position of timely replacement decisions. Regarding to challenges; Always AACRA is challenged by complexity of decision making. The authority also challenged by the high cost of equipment replacement and unavailability of data on equipment performance, maintenance costs, and technological advancements.

Recommendation

The following suggestions are offered in light of the results and previous conclusions.

Among the equipment currently operating; majority have a service life of about 15 years and above and being no effective. This implies that the
Authority needs to have a strategic way of disposing equipment.

Addis Ababa City Road Authority maintenance and repair cost always influences the authority's equipment replacement decision. In addition, in eyes of minimum cost method the foregoing result shows that the authority wasn't at the position of timely replacement decisions. In this sense it is necessary for the authority to take action to utilize approaches to optimize equipment replacement decision.

Always AACRA is challenged by complexity of decision making. The authority also challenged by the high cost of equipment replacement and unavailability of data on equipment performance, maintenance costs, and technological advancements. In this sense it is necessary for the authority to take action to improve its bureaucracy and develop its database system.

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