JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

DEVELOPMENT OF AN INTEGRATED COMPUTERIZED CONSTRUCTION EQUIPMENT MANAGEMENT SYSTEM (CEMS) MODEL FOR ADDIS ABABA CITY ROADS AUTHORITY

A Thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Construction Engineering and Management

By

Zerihun Tariku Hunegnaw

February, 2022

Addis Ababa, Ethiopia

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ZERIHUN TARIKU HUNEGNAW

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Advisor: Dr. Eng Bahiru Beweket ____________________

Co-Advisor: Eng. Abebe Eshetu ____________________

February, 2022

Addis Ababa, Ethiopia

DECLARATION

I declare that this research entitled "Development of an Integrated Computerized Construction Equipment Management System (CEMS) Model for Addis Ababa City Roads Authority" is my original work is my original work and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Zerihun Tariku Hunegnaw ______________ May 28/2022

Signature Date

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Zerihun Tariku Hunegnaw entitled "DEVELOPMENT OF AN INTEGRATED COMPUTERIZED CONSTRUCTION EQUIPMENT MANAGEMENT SYSTEM (CEMS) MODEL FOR ADDIS ABABA CITY ROADS AUTHORITY" and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Construction Engineering and Management.

Advisor: Dr. Eng. Bahiru Beweket ______________ June 11/2022

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ABSTRACT

The future of the Ethiopian construction industries lies in shifting organizational structures of organizations like AACRA towards high-growth competitive enterprises that are linked to the domestic economy that satisfies the development of heavy infrastructure like roads in the country. Reviving investment in such organizations for this purpose will require equipment management policies, strategies and substantial efforts to mobilize advanced information technology and software tools.

This study analyzed the value of major critical success factors for the selection, development and implementation of an Integrated computerized equipment management system (CEMS) functionalities based on the proposed and developed Integrated Equipment Management Conceptual Framework Model for Addis Ababa Roads Authority(AACRA). For quantitative survey design of this research, Proportionate Stratified Random Sampling was used for the population of 205 , a sample size of 134 was obtained, which is just over half the total population, is needed to obtain a confidence level of 95%. Non-Probabilistic Purposive/ Judgmental Sampling method was chosen based on pre-determined criteria, as a result 8 (eight) respondents were selected to participate in a one-on-one interview method.

The reliability of the survey was checked by Cronbach alpha which showed that the questionnaire is reliable to use. The validity of the survey was examined by factor analysis. Factor analysis proposed 9 factors and the study had 8 factors which almost confirms the relationship between the study factors and dimensions of factor analysis which is 9 From the study, it was observed that there most of the respondents belong to Equipment supply, administration, and maintenance work. Significant factors were analyzed using the ANOVA technique. Significant factors of our study included tools supply and management, asset maintenance, spare parts control, asset maintenance fleet management, and asset inventory.

Given the resulting outcomes, analysis took a deductive confirmatory approach driven by specific questions and ideas in which the interview participants responses were then considered within the context of existing self-management theory based on content analysis as a specific type of research tool rather than an inductive, exploratory approach. They respondents also largely agreed on common terms that are coded in all tables as per the analysis result shown in the tables. The average percentage distribution for each coded tables indicate that they would need to rely on the research results to identify the critical success factors for the implementation of CEMS.

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ACRONYMS

AACRA: Addis Ababa City Roads Authority

ASME: American Society of Mechanical Engineers

ANSI: American National Standard Institute

BPM: Business Process Modelling

BPR: Business Process Reengineering

CEMS: Computerized Equipment Management System

EMS: Equipment Management System

ESAM: Equipment Supply, Administration and Maintenance Subprocess

KPI: Key Performance Indicators

PSP: Public Service Provider

SWOT: Strengths, Weaknesses, Opportunities, and Threats

UML: Unified Modelling Language

CHAPTER 1 - INTRODUCTION

1.1. Background

The rapid changes in Ethiopian business environment due to government investment policies and other factors, the rise in international competition among companies, shrinkage of markets, and diffusion of the IT through organizations have put pressure on businesses to continually review and upscale their traditional construction equipment management strategy. In fact, there is a constant search for new ways to achieve a competitive advantage through new equipment management techniques. Therefore, increasing know how and coordination of the company's processes that crosses its equipment management functions becomes a main requirement of many companies and organizations like AACRA(Addis Ababa City Roads Authority), seeking a competitive advantage.

The problem of equipment management is continuing to bring a serious challenge to Ethiopian construction industries due to lack of equipment management policies and procedures, proper maintenance programs and underinvestment in the equipment management systems. The construction industries as a business operation, with highly capitalized assets, needs continued maintenance and administration of those equipment to prolong the life of assets in order to sustain or prolong the productive capacity of those assets for effective operations. The recurring nature of these problems indicates that equipment management control has weakened (Barrett, 2001). Undoubtedly, a combination of external and internal factors including population growth, weak infrastructure, and foreign debt, increasing inequalities between individuals, groups and regions have prevented many developing countries from achieving significant socio-economic improvements. Some developing countries such as Ethiopia have, therefore, made construction industry and its management their prime agenda.

A computerized construction equipment management system (CEMS) is of essential importance if the equipment supply, administration and maintenance sub process in AACRA is indeed to review its maintenance and fleet strategy and improve overall effectiveness. The current paper-based system does not reveal sufficient meaningful information for rational decision-making on the basis of clear performance indicators.

The planning function of a CEMS will give management a powerful control mechanism that is needed to pro-actively move part of the sub process's workload from being driven by breakdowns to being planned ahead by schedule. A third important benefit of a CEMS is that it allows for up-to-date reporting towards the fleet operations, which needs accurate information about vehicle acquiring utilization, tracking (fuel and operation), cost control and analysis and availability on a regular basis. This value is increased when the CEMS is interfaced with operational software for line management and equipment and vehicle scheduling with equipment planning team under construction sub process and project site manager.

Fleet Operations can only be expected to comply with maintenance schedules if the schedules are true and correct, communicated in advance and evidently effective. The equipment supply, administration and maintenance sub process need strong tools to make sure that they are. Only when the maintenance function is properly empowered to its task, it can fully assume its responsibility as a core business process.

The study shows that the resourcing of equipment-intensive horizontal construction projects is a complicated process, and that the reality in AACRA is no exception. The Authority's limited funding and resource base as a Public Service Provider (PSP) in a developing country further increases the problem and hence the need for efficiency in equipment management. The overall fleet composition is rather unbalanced by international standards with a share of 48% rental/lease (un published yearly report, 2019), which involves no capital investment but clearly drives up expense and operating costs.

The study on constructions equipment management confirms that the first and most essential step in making improvements in constructions equipment management is the implementation of an integrated CEMS. Integrated in this case means that the system should cover the full circle of justification, specification, acquisition, assignment, scheduling, utilization, maintenance and disposal of equipment.

Many companies have a culture use and follow heavy paper-based procedures. In spite of using this culture, these companies' equipment administration does not produce any relevant management information on the basis of which fleet decisions can be justified, as is nowadays the 'golden rule' of almost every rational equipment management effort all over the world.

The need for a proper equipment management system in any construction company is illustrated by the fact that their existing practices of equipment management (acquisition, allocation, utilization, maintenance and disposal) are not based on systematic data collection and analysis with regard to utilization and costs of equipment. Not only these companies do not have any set targets for equipment age, utilization and downtime; these measures are also not monitored systematically and in fact turned out to be impossible to determine within the current system.

The absence of performance metrics as such is a relevant finding of different studies, but at the same time made it difficult to benchmark these companies with similar organizations like AACRA elsewhere to any acceptable standard. However, comparison with common (international) best practices should be the guiding principle for an organization like AACRA to properly define the EMS procedures that they can adopt to improve the effectiveness and efficiency of their equipment management.

Considering the aforementioned context, it is important to note that lack of awareness of numerous and various challenges surrounding the successful implementation process could cause problems for the whole process of CEMS development and deployment. Furthermore, the problem of a lack of key success measures seems to be a serious obstacle for the CEMS implementation process. It is essential to define the success factors and manage them in order to carry out a successful implementation program.

Therefore, the future of the Ethiopian construction industries lies in shifting organizational structures of organizations like AACRA towards high-growth competitive enterprises that are linked to the domestic economy that satisfies the development heavy infrastructure like roads in the country. Reviving investment in such organizations for this purpose will require equipment management policies, strategies and substantial efforts to mobilize advanced information technology and software tools.

1.2. Statement of the Problem

AACRA clearly takes a great interest in technical maintenance and fleet management and has achieved a lot in the matter so far. Nevertheless, its performance in terms of vehicle/equipment utilization, availability and reliability must be improved. Whereas technical skills, manpower, materials and equipment are appropriately available, the equipment supply, administration and maintenance sub process lack essential tools for equipment management to make optimal use of its resources. Given the span of control over different project sites locations and the evident relevance of maintenance and fleet management for the authority's core business, equipment management has thus far received remarkably little attention – both in terms of policy as well as resources.

It is clear that the current equipment management system in place does not sufficiently reduce the number of unplanned interventions that are needed to keep the equipment operational. This is partly the result of lack of compliance since the equipment management system is often deferred in favor of operational demands. At the same time the maintenance program itself consists of only a limited set of preventive actions.

The authority's many years of experience should be able to reveal a much bigger range of effective measures to be scheduled in fixed intervals of time and/or distance, hence reducing the number of times an equipment needs to be 'touched' in a garage. Although they seem to rationalize the use of maintenance resources, traditional inspection-correction sequences are often inefficient and may even obscure patterns of predictable asset behavior. They also do not necessarily result in a controllable workload and demand more scheduled downtime than pre-defined regular interventions. Reliability and ease of planning should definitely become more prominent elements of AACRA's equipment management strategy.

1.3. Research Questions

In general, the research questions were developed based on the above statements of the problem, and extensive literature review in order to address the research objectives in the following section.

1. How does CEMS impact equipment supply, administration and maintenance efficiency and performance process in AACRA?
2. What are the most common decision elements for CEMS integrations that enables the system workable in the context of AACRA?
3. What are the main functionalities and sub systems of a new CEMS to be developed in the context of AACRA?

1.4. Objective of the Research

1.4.1. General Objective

The main objective of this research work was to design and develop an integrated computerized construction equipment management system (CEMS) model for Addis Ababa City Roads Authority. This was based on the theoretical understanding of current research in the literature and the result of empirical data established in this research.

1.4.2. Specific Research Objectives

The following are the specific research objectives, which were addressed in this research in light of the research questions:

1. To assess the impact of CEMS in equipment supply, administration and maintenance efficiency and performance process in AACRA
2. To Identify the most common decision elements for CEMS integrations that enables the system workable in the context of AACRA.
3. To develop a detailed CEMS model with functional and technical requirements using Unified Modelling Language (UML).

1.5. Scope of the Research

The key assumption to define the scope of work was, after the completion of this research work, the authority's higher-level management will review the outcome and result of this research work and implement the new computer aided equipment management system (CEMS) for AACRA. The researcher assumes, the proposed system will allow the Equipment Supply, Administration and Maintenance sub process to act autonomously as its duties and responsibilities already defined in the new BPR structures, rather than having to fit into the existing maintenance center management structure.

1.6. Significance of the Research

The purpose of a CEMS is not only to increase the efficiency of the equipment supply, administration and maintenance of the Authority, but also the Authority's effectiveness in terms of equipment supply, utilization and availability as well as quality of service and city people satisfaction. Optimizing the procedures and strategies for technical maintenance will also result in better equipment reliability and reduce the number of breakdowns and unplanned interventions. Efficient allocation and administration of equipment will increase the overall utilization rates.

The primary core of any such equipment management system should be a versatile module for maintenance control (workflow management and PM) and equipment administration (reservation/ allocation and utilization) that actively supports the ESAM department with both the equipment supply administration as well as the planning, routing and monitoring of maintenance and repair works. It should therefore contain a detailed database of the vehicles and construction machineries (specs/age/mileage) and their functional parts, a well-organized fuel supply distribution and control system, an expandable set of maintenance models with checklists for inspections and routine interventions, clear and mutually exclusive categories for job types and failure causes as well as a true projection of the authority's organizational structure and processes. Therefore, the purpose of this thesis work is threefold to study the existing management system; find out the limitations of the existing management system; and develop and propose an integrated new CEMS (Computerized Equipment Management System) suitable to the context of Addis Ababa Roads Authority.

1.7. Limitation of the Research

Based on the research questions and objectives, the scope of this thesis work was limited to study AACRA’s Equipment Management System only which did not address all other systems implemented and in use in the Authority. The population of the study was also limited to all employees at specific departments within AACRA who have direct relations with equipment supply, administration and maintenances processed.

CHAPTER 2 - LITERATURE REVIEW

With the advancement in technology, industries in almost every realm are moving towards the usage of computers. It would not be astonishing to mention that we are heavily reliant on technology as it makes an integral part of not only our businesses but also life. We are currently living in a digital era with mobile devices in our possession to create, collaborate, compute and sync our daily tasks (Hecht, 2018).

Companies and industries now look for low cost labor and efficiency resulting in relying heavily on technology (Alcácer & Cruz-Machado, 2019). German Government, in 2011, brought a new term on the face of Earth – namely Industry 4.0. This is assumed to be the fourth industrial revolution by many (Grieco et al., 2017; Motyl et al., 2017; Wagner et al., 2017; Weyer et al., 2015). The aim of Industry 4.0 is to make industries move towards the automation which would help achieve a higher level of operational productivity and efficiency (Grieco et al., 2017; Weyer et al., 2015).

Construction industry is no different. It wouldn't be wrong to mention that the future of construction industry depends on current technology usage which is expected to grow further in future (Gaith & R, 2009). Usage of computers in Construction industry however can be divided into two different realms of Automation and Information and Communications Technology (ICT).

Construction automation includes the usage of computers and other systems like Global Positioning System (GPS) to replace the daily onsite tasks like surveying, controlling the equipment and also to introduce advanced robotic systems in the construction industry. Construction ICT on the other hand includes capturing/ collecting, organizing, storing, analyzing/ processing, transmitting and sharing information. Previously, such technologies were utilized to gain the competitive advantage. However, over the course of years, the usage of computing technologies has become a basic part of the construction industry. So much so that absence of such technologies can result in disruption of tasks (Perkinson & Ahmad, 2006).

The combined usage of Automation and ICT in the construction industry has made it to resort to computerized management systems. Major contractors are increasingly using computerized equipment management systems (CEMS) to maintain, repair, manage, and even operate their construction equipment (Fan et al., 2006). Different literatures on this topic propose different approaches for the design and technical specifications of such a system along with their study results. However, most results of these studies include the introduction or strengthening of the following best practices in construction equipment management:

- to apply fleet level performance metrics and stay in line with goals/objectives
- to pool equipment and to make cost charge backs
- to distribute consumables and spare parts on the basis of assigned tasks
- to organize and monitor operator-performed preventive maintenance

These practices surely cannot be implemented all at once or from one day to another. It will require time, patience and persistence to make the best out of their intended benefits. It is, however, very important that any equipment management system to be implemented is capable of facilitating the application of these principles.

The introduction of CEMS in AACRA will create opportunities for better planning, needs analysis and condition monitoring, administration and proper operations. All of these new techniques have one thing in common: they steer away from the old run-to-failure approach in maintenance and equipment administration. It is therefore very important that other successful contemporary practices in equipment management also take root in Ethiopia, or else the country will inevitably face further descend on the global economic ladder. Of course, as a developing country the resources of the country are limited. But while the country may possess less assets and capital goods than others, there is no sensible reason why these assets should give the country lower returns than they do elsewhere.

2.1. Computerized Equipment Management

10 to 30% of the total construction project is devoted to construction equipment and therefore construction equipment is one of the most important resources. In order to reduce the cost and time of construction equipment that is planned to be utilized and also to increase the profit on any project, Equipment Management is imperative. Equipment Management includes planning, selection, procurement, instalment, operation and maintenance. Every small decision made for

the construction equipment has the tendency to disturb the scheduled time and costs of any construction projects (Akhil et al., 2020).

As predicted by, Schexnayder & David, 2003, the construction equipment management would see a huge change in how it is done in future. He predicts there would be information processing via advanced technical methods such as GPS. They would have sensors that would inform the management systems of problems like over-heating and low oil pressure. He also adds that it would improve the safety such as Crane operation would be controlled based on past data collected. This can include but would not be limited to the weight of load, boom angle and spool speed etc. Computerized Equipment Management System (CEMS) might sound new for a number of construction professionals but it is pretty common in other industries like Health Care Facilities (Baete, 1994; Basiony, 2013).

However, CEMS in construction is not that uncommon actually. Every now and then we see contractors, especially big ones, using different CEMS in order to manage their fleet. In fact, a number of big companies have also come up with their CEMS that they usually provide or sell along their construction equipment which are already installed with data collection instruments like GPS. Similarly, a number of researchers have come up with their own CEMS using different data collection, data mining and processing techniques (Caterpillar, 2021; Fan et al., 2008, 2006; Fan & Simman AbouRizk, 2007; Luo et al., 2020; Qualcomm, 2008; Sacks et al., 2003). Some of the CEMS currently used in the construction field and for research purposes are discussed in this literature review.

Project managers and department heads should demand more room to lift their efforts beyond repair and traditional ways of equipment administration as the only conceivable option in equipment management. In return, they must be willing to be held accountable and justify their operations by accurate reporting on technical and financial indicators – which become relevant as soon as people make decisions rather than wait for coincidence to determine their work schedule. This requires a professionalization of project management, adequate administrative tools and accounting methods that are capable of displaying the full picture of an asset's total life cycle cost.

Implementing computer aided equipment management systems is an effective approach towards solving the problems of decreased productivity and performance relative to labor costs and consequent rise in unit costs, which are continually plaguing present day project managers (Lin, 1976). Implementation of CEMS provides opportunities to achieve the competitive advantage in an intermediate to long-term time frame (Sohal, 1997). None of these ideas are new or revolutionary. Over the past few decades equipment management specifically, equipment maintenance has become a serious profession all over the world – boosting corporate profits as well as service levels in the public sector. Effective tools and methods have been developed to maximize the economic use of fixed assets, which as a particular skill has moved into the front line of business competition by evidently reducing operating costs.

2.2. Computerized Equipment Management System in Developed Countries – Case Studies

One of the greatest benefits of CEMS is the elimination of paperwork and manual tracking activities, thus enabling the equipment maintenance and administration staff to become more productive. It should be noted that the functionality of a CEMS lies in its ability to collect and store information in an easily retrievable format. A CEMS does not make decisions; rather it provides the management with the best information to improve the operational efficiency of a facility.

As mentioned earlier a number of construction equipment producers have come up with their versions of Construction Equipment Management System (CEMS). These systems are usually limited to be used for specific equipment. However, researchers, especially, in the developed have come up with their own generic CEMS using computing automation and ICT techniques. Two case studies of such CMMS are discussed below:

2.2.1. Case study of a Road Building and Maintenance Contractor in Canada

Fan et al., 2006, believe that most of what Schexnayder & David, 2003, predicted is coming to life. Most of the tasks like collection of electronic data can be collected by on-board controls and handheld devices. Even electronic data fuel transfer data collection is possible. However, most output is still delivered through old-style reports that represent facts as-it-is. They argue that construction industry still lacks a mechanism for automatic knowledge discovery and utilization of collected data. This causes the equipment manager to spend a huge chunk of his/ her time on advanced statistical tools for data analysis, which is technically demanding in addition to time consuming. Consequently, only a small part of data is utilized for analysis which makes a base for decision making. In order to overcome this problem, they recommend a model – a system which utilizes Data Mining. Data Mining is a hybrid science of disciplines like Statistics, Machine Learning and database technology. They made a three-layer system which collects and analyses data.

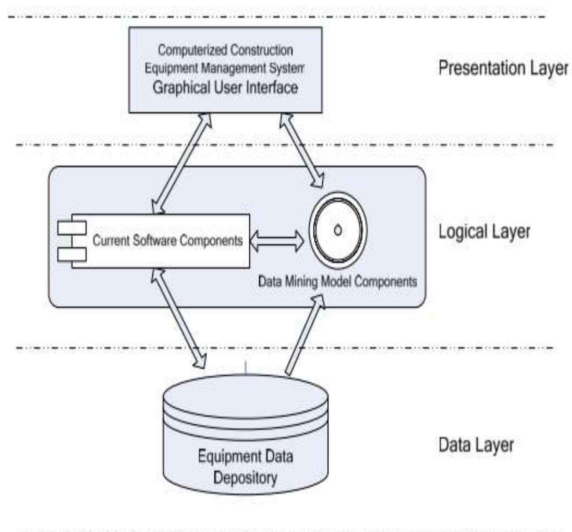


Figure 2.5. Three layer Data Mining System (Fan et al., 2006).

They used a case study of a road building and maintenance contractor in Alberta, Canada who owns a number of construction equipment. They collected the data from them and processed it through Autoregressive Tree Data Mining Model, Decision Tree and Multivariate Linear Regression and from that they created and validated a model. The model was deployed and checked. They concluded that such models do not only discover and represent the hidden knowledge from the equipment operational data but also real-time prediction is possible using the induced model.

2.3. Construction Equipment Monitoring for Project Performance Control

Management decisions usually impact the work carried out on the construction site by a huge extent. Unfortunately, most of these decisions are limited by time delay in required reports of performance of the project in terms of schedule, budget and quality. Much like Fan et al., 2006, Sacks et al., 2003, also believe that the traditional information and control system of construction equipment usually result in very long time lags because of how the reports are delivered. This results in undesirable trends being identified too late for the corrective measures to be taken.

Monitoring indirect performance parameters automatically have been proposed by Navon, 2005. A simple term for this kind of system can be Automated Project Performance Control (AAPC). The main idea of such system is to shorten the reporting cycle to merely a day. A number of projects have been considered in this area which includes but is not limited to automated labor monitoring system and a system for monitoring and reporting work done by heavy earth work equipment (Sacks et al., 2003).

Sacks et al., 2003, suggest monitoring equipment as a part of automated project performance control. Almost all the work on the construction site is dependent on construction equipment. Tower and Mobile cranes, Concrete Pumps and Hoists being some of the examples. Researchers argue that tracking and recording the activity of these equipment is pretty simple especially with the advanced technology we have today. They propose a system solution which is a typical monitoring and controlling loop, see Figure 2.

A decision rules processor shall receive data daily from the monitoring black box installed on equipment. The data would, for example in case of a loading crane, consist of load weights and crane hook coordinates, which would later be converted to local site coordinates so they can be related to particular building elements on the construction site. The rules processor would draw on knowledge base gathered from data collected in past such as unloading durations, profiles, typical weights and heights of equipment etc. The data itself would be drawn from a Building Project Model interface which would also include details of pending activities, their durations, material components and their weights etc.

Based on these three sources, the system would create a correlation between the equipment movement and specific activities and would draw some conclusions with calculated level of certainty. Finally, the collected information would be made available to the management and would be used to update the project database.

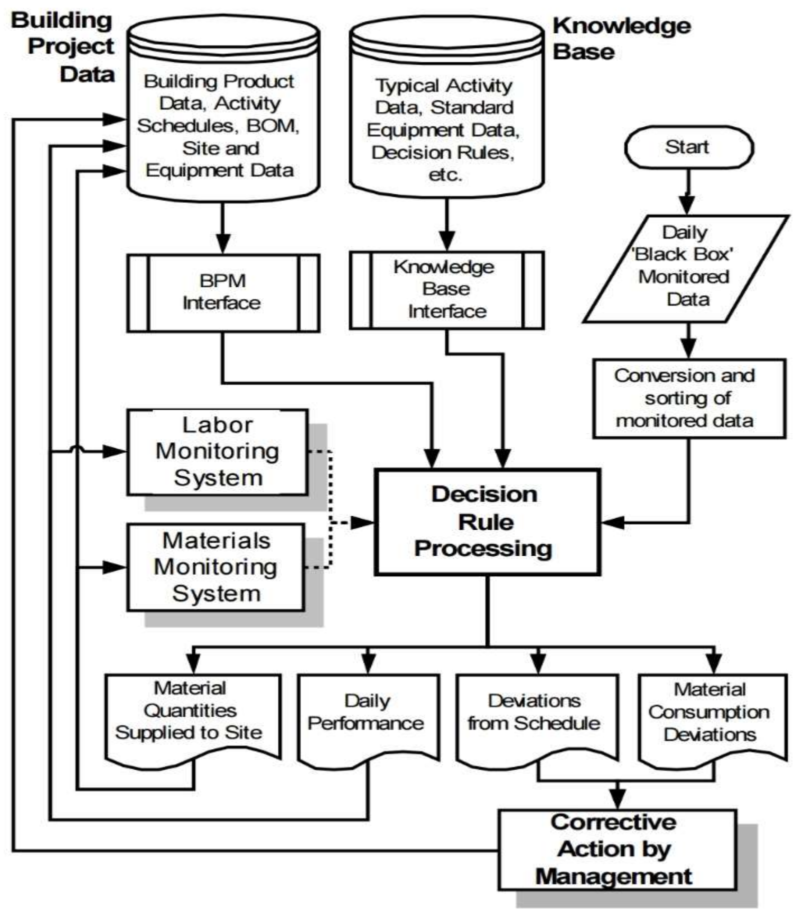


Figure 2.6 Construction Equipment Monitoring system (Sacks et al., 2003).

For this specific research, Sacks et al., 2003, targeted the typical case of construction tower cranes only (See Figure 3). Researchers concluded that such Computerized Construction Equipment Management System shall produce a number of benefits which include but are not limited to:

1. The information collected can be used to update project schedules.
2. Accurate quantities such as weights of materials supplied can be collected.
3. Potentially life-saying real-time location of crane when compared with the location of worker compared by GPS can be obtained.
4. Data regarding the availability of equipment for the material can be collected real-time, which would help in scheduling of activities.
5. Data can be used to make equipment efficient.

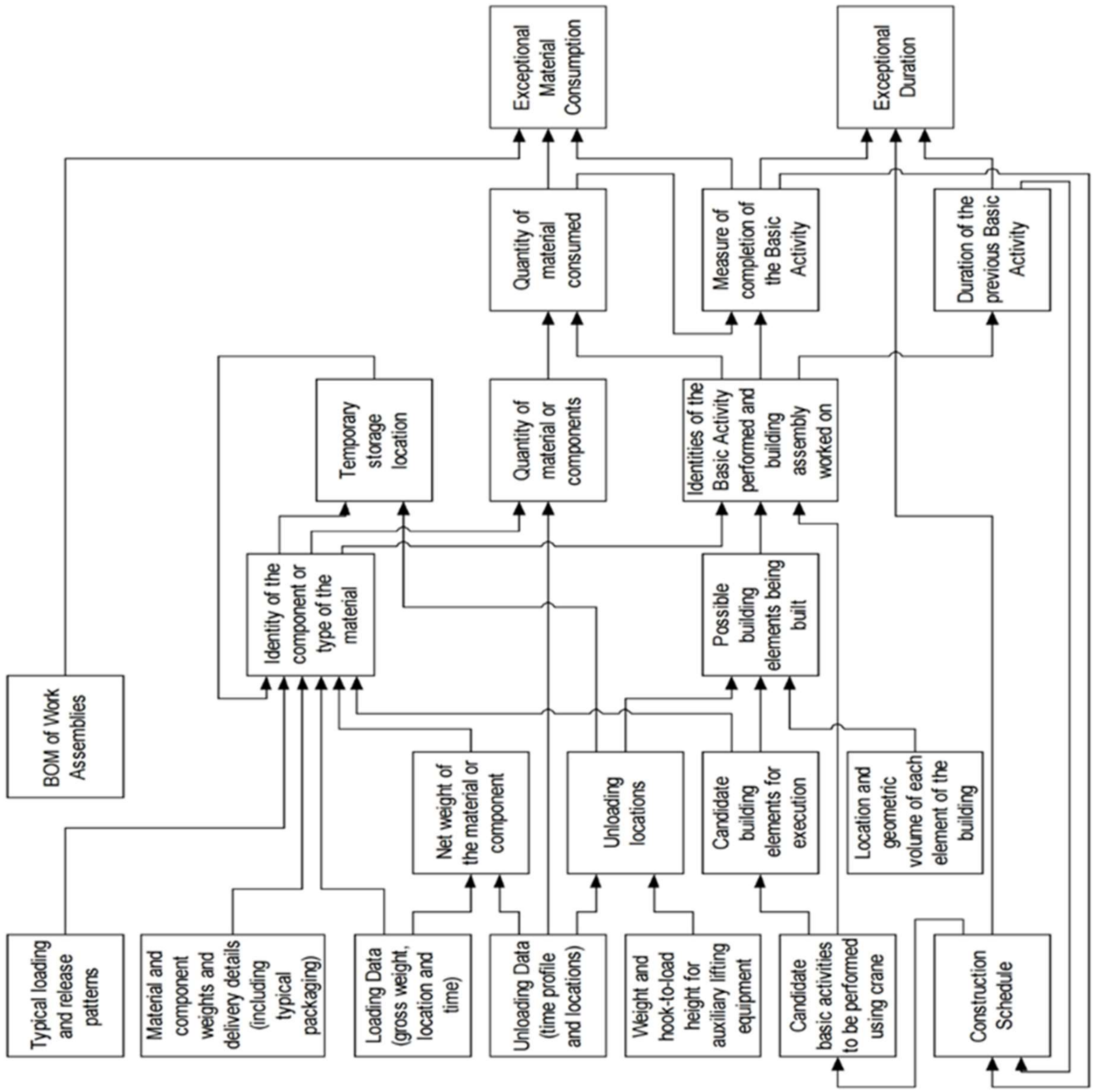


Figure 2.7 Rule Processing Flow (Sacks et al., 2003).

2.4. CMMS – A part of CEMS

Since 90s, the construction industry has started to focus on CMMS – Computerized Maintenance Management System. CMMS in construction industry is a software platform that usually allows a contractor to maintain all of his assets for all of the life cycle. It reduces the need for human input. It creates alerts and warnings to prevent construction equipment failure. Equipment managers can automate and schedule the maintenance using the software on their computer or mobile screens (Ironup.io, n.d.).

Chau et al., 2015, talk about the implementation of CMMS on a Design, Build and Operate Pillar point sewerage treatment works project. They argue that Asset Management is an important task in any project since it directly contributes to the performance and efficiency. Traditionally, as pointed out by former authors as well, it is done using a labor intensive and time-consuming approach of data logging, tracking and analyzing by experienced staff. They develop a new CMMS system which works on the philosophy enlisted:

1. Prediction and Prevention of Equipment Failure
2. Availability of Equipment
3. Maintenance based on condition gauged from continuous monitoring and assessment
4. Benchmarking Asset Performance
5. Capital and Operation expenses optimization

The proposed system utilizes CMMS and SCADA (Supervisory Control and Data Acquisition). All in all, the Asset management system which comprises of CMMS Package and SCADA Package would play an important role. In modern days, SCADA is a key element for process automation and data gathering. However, the SCADA system alone does not enable planning, scheduling, monitoring etc. And, that is where CMMS comes. CMMS is widely adopted and is utilized to keep the track record of all entities within the works. A database is maintained which comprises of an organization's maintenance operations and facilitates the equipment management, daily operation work, correction and preventive maintenance works. The proposed asset management system's architecture is presented in following figure.

The system, technically, is based on four layers called as field bus, control network, plant network and business network. The authors, based on a case study which utilized the afore-mentioned system, concluded that the system is beneficial and features the following maintenance management functions:

1. Entity Management (Equipment Costs and History Tracking)
2. Work Planning
3. PM Jobs
4. Maintenance, Repairs, and Operations (MRO) Inventory Management

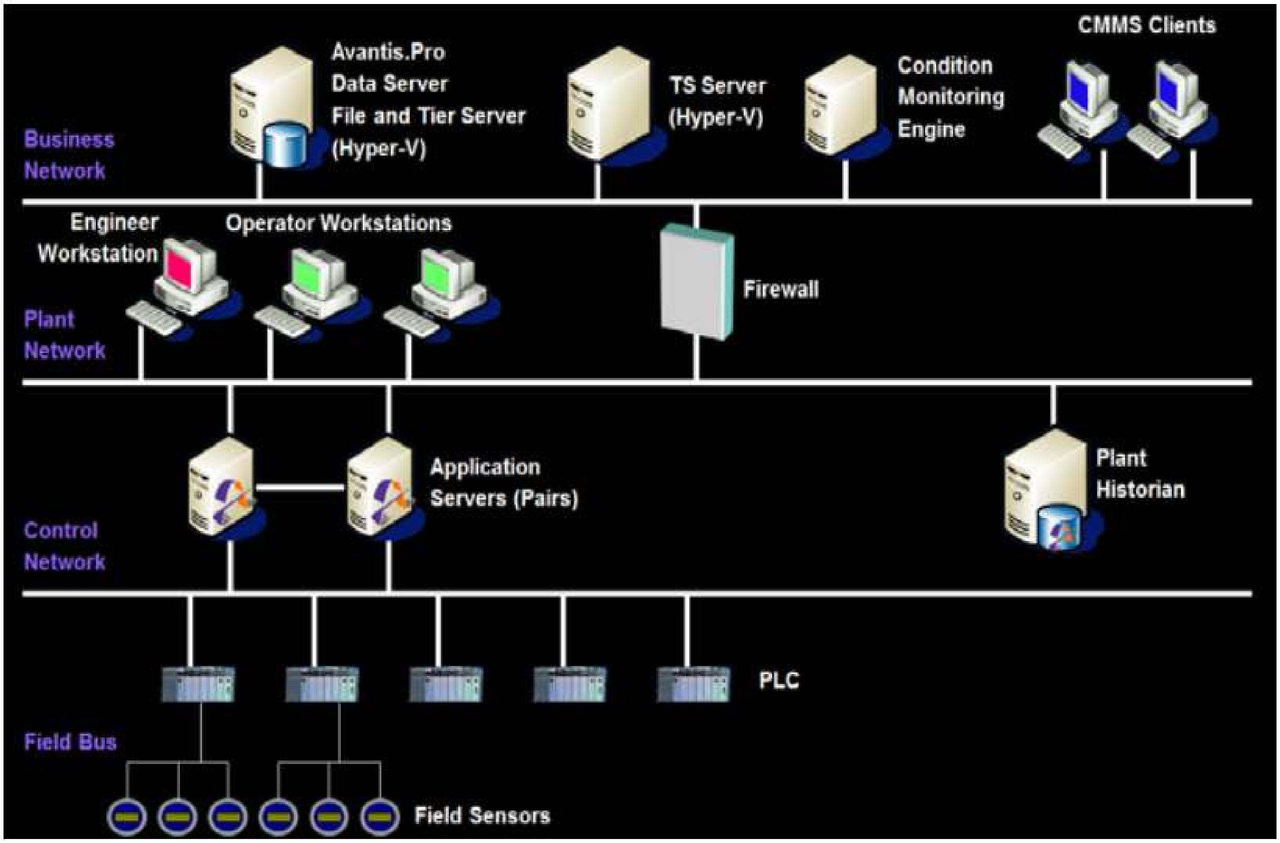


Figure 2.8 Asset management system network architecture (Chau et al., 2015).

Not only CMMS in construction is limited to research and to some particular projects, in fact, a number of companies have come to play by creating their own software programs which help make CMMS in Construction Easier. Ironup.io, Axxerion USA, Value Keep, and Max Panda are prime examples of companies which are offering their services and software in the field of CMMS.

2.5. Moving from CMMS to CEMS

Large contractors sometimes have to deal with a large fleet of equipment – the number can even go to three figures. At such stage, just a CMMS doesn't justify the needs of the contractor. Management decisions are required on not only maintenance but equipment acquisition, repair, allocations, operations, and even disposal. CEMS – Construction Equipment Management System – is something that deals with the Equipment Management in its all life cycle and not only limited to Maintenance as its predecessor (Fan & Simman AbouRizk, 2007).

There are multiple Construction Equipment Management systems available out there from big companies like AccuGrade® from Caterpillar Inc. (Caterpillar, 2021), or the GlobalTRACS® from QUALCOMM Inc. (Qualcomm, 2008). These Equipment Management Systems respectively enable automatic control of the finish grade, and integrate fleet data with the back office while transmitting the equipment conditions and operations data in real time.

The efficiency of such systems have been proven by a number of case studies. According to recent study in Russia, the usage of AccuGrade® produced benefits in reduction of time required for the work and consecutively the reduction of costs. As per the calculations, the usage of CEMS in this study resulted in 32% reduction in time required. And, as a result, fuel consumption decreased by 28%, and the volume of material displacement reduced by 16% (Sc et al., 2013).

Researchers on their own have also come up with different Construction Equipment Management Systems (CEMS). Fan & Simman AbouRizk, 2007, for example, have come up with an intelligent application system which uses data mining techniques which would collect and analyze the data from historical management decisions. In order to validate the model, they even deployed it for a case study and calculate the residual value of a heavy construction equipment with satisfactory results.

In another development, a number of researchers are working on Construction Equipment Management in the context of health and safety. The usage of computers and data mining techniques is again important in such tasks as well. The full body poses of construction equipment, for example, are identified using Computer vision and deep learning techniques which help us set standards and rules on the construction site for the health and safety of labors (Luo et al., 2020).

Building Information Modelling (BIM) is a relatively new technology that helps construction and project managers in a number of ways. BIM, as suggested by the research, is much more than a 3D model. In fact, it goes up to 7D, which, then includes Facility Management and Operation and Maintenance. This includes the equipment maintenance as well (Charef et al., 2018).

A literature analysis done by Ma & Ren, 2017, on the integrated application of GIS and BIM suggests that there have been a number of cases where BIM – a relatively new technology –

when combined with GIS can help in the management of construction equipment. This claim is further reinforced by the research conducted on the case study of construction of Subway station where limited underground space increases the risk equipment conflict, a risk early warning and management system by employing GPS receivers to capture location information of large construction equipment and integrating it to BIM (Brad Hardin, 2015; Hualin Du, Jianhua Du, 2015). As mentioned already, not much work is done in the field of equipment management when talking about Building Information Modelling (BIM). However, with the advancement in the field of construction management and a service-centered economy, the industry is moving towards service centered offering which are Product-service system (PSS) solutions.

A similar approach is also emerging in the realm of Building Equipment. A recent study by Fargnoli et al., 2019, integrates approaches based on BIM in a PSS context for the improvement of the management of maintenance operations of building equipment. Although the case study is only limited to Building elevators, the results show that such approaches can be a breakthrough in the construction industry when applied on construction equipment (Lee & Akin, 2011; Liu & Issa, 2012; Poór & Šimon, 2012). The study concluded that a number of benefits can be achieved – especially in the context of reduced equipment unavailability periods, lower costs, customer satisfaction etc. (Fargnoli et al., 2019).

2.6. Computerized Equipment Management in Developing Countries

Automation in construction with the advancement of technology and with the advent of CMMS, CEMS and BIM systems is, on one hand, helping solve the construction problems in developed countries. On the other hand, however, developing countries are still struggling to decide if their infrastructure and managers accept systems like BIM (Akmal Adillah Ismail et al., 2017; Enku, 2018). A number of researches suggest that delays in the construction projects in developing countries is a common thing. Although there are multiple factors which result in project delay but one of the many causes of construction project delays in developing countries is the underlying mismanagement of construction equipment. Most of the times the equipment is short, unavailable or faulty. This can greatly improve with the integration of CEMS in the traditional construction industry (Butler et al., 2013; Kumar Mittal et al., 2020; Sanni-Anibire et al., 2020; Wuala & Rarasati, 2020)

2.7. Technology in Construction Industry in Ethiopia

Ethiopia is Africa's second most populous country and therefore invests a huge amount of its GDP in the construction industry. Rapid construction and expansion has helped Ethiopia's rapid economic development. In the past decade, the government has been pouring approximately 16 % of its total GDP to construction industry. The current market value of the construction industry in Ethiopia is around US$7bn (Veitch, 2018).

Construction Industry in developing countries like Ethiopia face a number of problems that usually aren't even heard of in the developed countries. They are not limited to socioeconomic stress but also include the shortage resources, weak institutions, and inability to handle issues like the development of manpower and improving industry practices. (D. G. Mengistu & Mahesh, 2020; Ofori, 2002). A number of other research studies highlight the factors which cause the poor performance, health hazards, cost and time overrun of the construction projects. These factors include inadequate project management skills, poor equipment management and equipment unavailability (Gadisa & Zhou, 2020; Mersha & Mereta, 2017; NEGA, 2008).

Another study highlights a number of factors which need to be considered for the improvement in the construction industry in Ethiopia. The most important ones include the management of equipment and the application of technology in the construction industry (D. G. Mengistu & Mahesh,2020). However, there are a number of challenges that Ethiopian construction industry faces. Enku, 2018, in his thesis recognizes that the level of understanding regarding CEMS and other technological advances like BIM in Ethiopia is pretty limited. And, therefore, recommends steps such as addition of BIM into the academic curriculum, government sponsored pilot projects and training construction firms by government to improve the understanding of BIM. He further identifies the amount of benefits that systems like BIM – along with its equipment management part – could bring. He identifies 22 problems in a case study out of which 11 can easily be solved with a simple implementation of BIM. Interestingly, technologies like CMMS and CEMS have been implemented or at least talked of when it comes to manufacturing industries in Ethiopia (Ambaye, 2013; Hunegnaw, 2020). However, when it comes to construction industry, computerized construction equipment management systems are still a thing that professionals have to learn about.

2.8. Addis Ababa City Roads Authority (AACRA): A Review of Construction Performance and its Equipment Management System

The Addis Ababa City Road Authority (AACRA) is a governmental road construction organization which is established in March 15, 1998 by regulation No. 7/1998 to be administered by the board of directors to construct, maintain and administer Addis Ababa city's road and transportation infrastructure up to standard and to keep the road in safety and escalating road coverage so as to deliver the population facilitated traffic flow.

The organization is led by the Director General who monitors five different departments under his competent supervision. Which are then further managed by Deputy Director General (Mathewos, 2017). The authority is structurally organized as; general director and deputy general director offices, Main Process (i.e Traffic Engineering, Road and Transport Infrastructure Design, Road and Transport Infrastructure Construction and Maintenance, Road and Transport Infrastructure Administration, Plan and Program, Internal Audit, finance, procurement and property administration, communication affairs, Legal service and human resources), Sub Process, case teams and units. Equipment supply, administration and maintenance sub process is one of the sub processes found under Road and Transport Infrastructure Construction and Maintenance main process..

As a non-commercial governmental organization, the authority's mission is to build, maintain and administer Addis Ababa city roads with quality and on time basis by using asphalt, concrete, gravel, cobblestone and other low-cost technologies to facilitate the people's daily transportation activity.

Apart from building and maintaining efficient roads in the city, one of the biggest challenges for the authority is to maintain and manage its fleet of different types of construction equipment, trucks and vehicles. The authority has also a big work shop used to maintain the above-mentioned vehicles, trucks and construction equipment to keep them operational under heavy circumstances (road conditions, overloading, fuel quality, altitude, dust). To achieve maximum availability and reliability of equipment towards the road construction projects, it is clear that an effective equipment management system is required. The management of the authority therefore seeks the Equipment Management System (EMS) to administer this large fleet of equipment and also to perform organized equipment maintenance.

A cursive study of different case studies and research studies available online show that most of the road construction projects in Ethiopia, especially in Addis Ababa city face time and cost overrun (Amare, 2015; Mirga, 2019; Tesfa, 2016).

Although there are a number of factors which affect the cost and time of the projects especially when talking about the projects under AACRA, some of the most common factors are poor resource management, slow equipment movement, equipment allocation problems, low level of equipment's operator skills, low productivity and efficiency of equipment, lack of high technology mechanical equipment etc. (Amare, 2015; Mirga, 2019; Tesfa, 2016).

Other researches have suggested methods to improve the performance of Addis Ababa City Roads Authority (AACRA). Interestingly, most studies and researchers have pointed out the usage of technology and equipment planning and management to overcome such problems of the authority (Fekede et al., 2020; KEBEDE, 2010; Mathewos, 2017; H. Mengistu et al., 2020; TEKLU, 2020)

Improvement in the technicality of staff and equipment (Fekede et al., 2020), Training of officers, Data collection of equipment, planned maintenance of equipment, optimization of available equipment (Mathewos, 2017), computerized data collection (KEBEDE, 2010), development of data center, IT training for top management, addition of up-to-date software and hardware (TEKLU, 2020) and addition of decision making software (H. Mengistu et al., 2020) are some of the recommendations that were provided by the researchers who studied the organizational structure and performance of Addis Ababa City Roads Authority (AACRA).

CHAPTER 3- RESEARCH METHODOLOGY

This chapter focuses on the design and research method of the study. It presents the research approaches as well as the techniques for collecting data. Finally, the trustworthiness of the research regarding validity and reliability is discussed.

After considering the objectives of the research, the level of CEMS development and implementation in AACRA, the research questions, the limitations and the scope, the researcher felt the appropriateness of adopting both qualitative and quantitative data gathering techniques i.e., the survey method, using a structured questionnaire and researcher's observation as data gathering instrument supported by qualitative data which will be obtained through structured interviews. A combination of these research design is behind to provide more data to work with and ultimately a more accurate evaluation (O'Neill, 2006; Hemming, 2008).

Another reason for adopting both qualitative and quantitative data gathering techniques is the existence of little documentation on the subject matter which were surveyed during literature review by the researcher. It is therefore important to get to the source of primary information so that each method can complement and substantiate the other and making the findings more concrete. In short, the strengths of qualitative studies should be demonstrated for research that is exploratory or descriptive in nature and that stress on the importance of context, setting, and participants' frames of reference (Marshall and Rossman, 2006).

The research approach applied in this research was both exploratory and descriptive, in that the research focused on a specific research objective in the form of survey method, in order to provide a detailed description of the research process. The descriptive aspect of the research incorporated perspectives was drawn from both the participants in the research and those was drawn by the researcher from relevant literature. The method applied in this research was conducted in a manner that ensures that the research should satisfactorily answer the research questions.

3.1. Research Design

For the purpose of this research, after examining the objectives of the study and realizing lack of previous study and published literature on CEMS development and implementation in Ethiopia construction industries, an exploratory descriptive research design was chosen, as it can conclusively describe the characteristics and state-of-the-art of the population under study. Exploratory descriptive research suits best the current research since an exploratory study research will be performed when a researcher has little knowledge about the situation or has no information on how similar problems or research issues has been solved in the past (Sekaran, 2000). It embarks on investigating and finding the real nature of the problem. In addition, solutions and new ideas could surface from this type of research (Richardson, 2005).

A descriptive research on the other hand is a research that describes a phenomenon (Salkind, 2000), to document and describe the phenomenon of interest (Marshall and Rossman, 2006), providing a clear answer of who, what, when, where, why, and way (6 Ws) of the research problem and data are typically collected through a questionnaire survey, interviews or observation(s) (Gay and Diehl, 1992).

Since this research was adopting both quantitative and qualitative data gathering techniques, qualitative data was obtained through structured interviews and observation. Moreover, the interview and researcher's observation were an alternative method of collecting data survey (Babbie, 2007) and were a useful method of obtaining information and opinions from experts during the early stages of this research project (Walliman, 2006).

The existing management system was evaluated against data collected from field sites (workshop, garages and construction sites) in terms of equipment condition, utilization and performance. Visiting the research location and observing the onsite operations of the equipment management activities enabled the researcher to grasp the overall idea, gain some insights and form a general idea of the research objectives. It helped to consolidate and getting more definite and stronger information of the research being done. This understanding of the situation at the grassroots level after visiting some workshops under AACRA helped the researcher in the final formulation of the questionnaire that was not too ambiguous that respondents was not able to answer.

On the other hand, data for the quantitative method was obtained through the administration of a structured self-administrative questionnaire. An advantage of using self-administrative questionnaire is that they are an entirely standardized measuring instrument as the questions are always phrased exactly in the same way for all respondents (Sapsford, 2007). The biggest advantages of self-administrative questionnaires are that it is comparatively cheap and time saving for the researcher (Richardson, 2005).

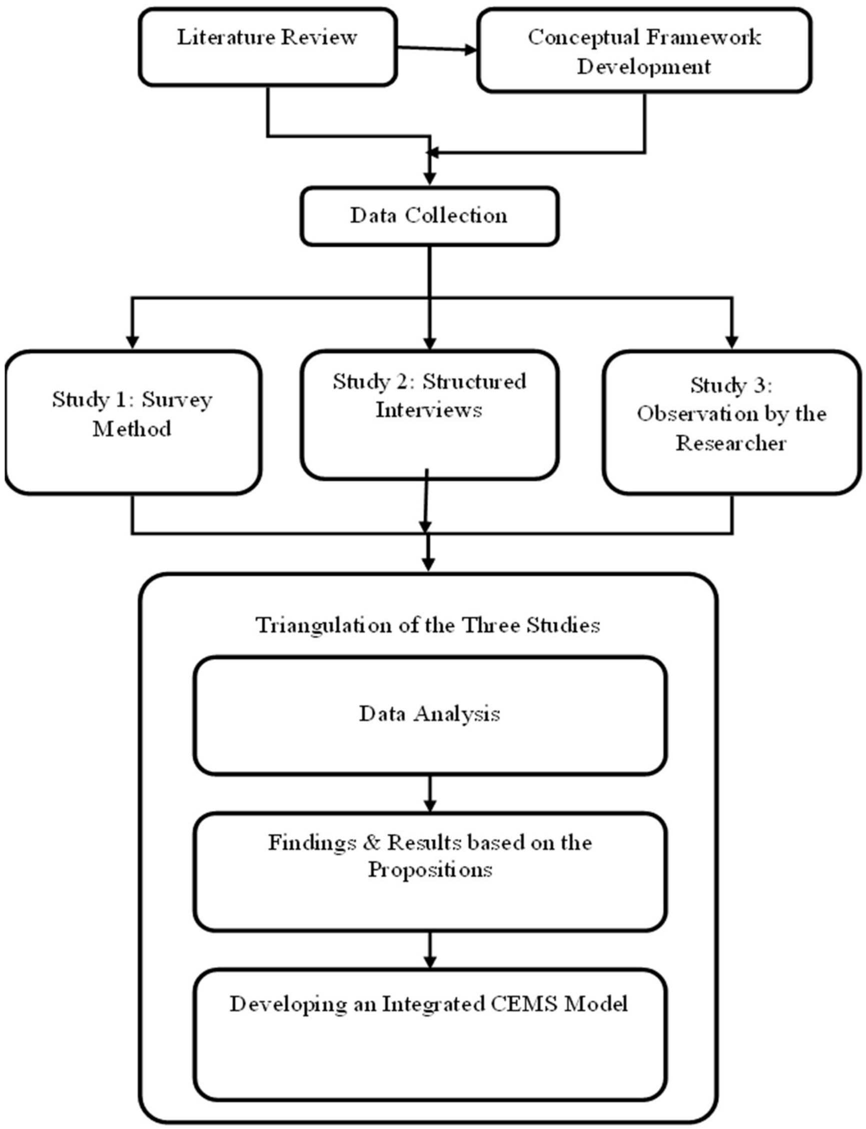


Figure 3.1 Research Design Process (by the Researcher).

3.2. Population and Sampling

By definition, population is the group to which a researcher would like the results of the study to be generalizable. It could also be set of all cases of interest (Richardson, 2005) and might be virtually any size or might cover almost any geographical area (Gay and Diehl, 1992). Theoretically, researchers could specify an even finer distinction of population called the study population (Wolfer, 2007).

Sampling involves decisions about which people, settings, events, behaviors and social processes to observe. Exactly what should be sampled in a particular study is influenced by the unit of analysis. The main concern in sampling is representativeness. The aim is to select a sample that should be representative of the population about which the researcher aims to draw conclusions. Representative samples are especially important in descriptive surveys that are used to estimate accurately the properties of the population (Blanche & Durrheim, 1999).

3.3.1 Population of the study

The population for this research, for both the qualitative and quantitative methods, was from AACRA employees. For the purpose of this research, the population sample was drawn from each directorate, departments and subprocess of the Authority related to equipment maintenance, administration and management. However, the researcher had the opportunity to determine the representative sample size from the new list of the Authority’s workforce before data collection stage of this research.

3.3.2 Determination of Sample Size

A sample is a subset of the population being studied (Richardson, 2005), which includes the process of selecting a few (samples) from a bigger group (the sampling population) to become the basis for estimating or predicting a fact, situation or outcome regarding the bigger group (Kumar, 1996). Samples should be as large as possible, in general the larger the sample the more representative and the more generalizable the results of the study are likely to be.

For quantitative survey design of this research***, Proportionate Stratified Random Sampling*** was used to stratify the total population (N= 205) of the Authority based on their homogenous characteristics in to ***four strata*** by “ main processes” i.e (*Traffic Engineering, Road and*

Transport Infrastructure Design Main Process, Road and Transport Infrastructure Construction and Maintenance Main Process, Road and Transport Infrastructure Administration Main Process and Support main process). Determining the sample size and dealing with non-response bias are essential. As shown in Table 3.1 below, ***sample size was determined*** using the following formulas to representative the total sample size (n) and each stratum sample size (n_i) from each stratum for the purpose of field survey (Mason et al, 1999).

Total Sample size (n), n = N*X / (X + N – 1)

Stratum Sample Size (n_i) = (Total Sample size (n))/ population size (N) X Stratum Size(L)

where, $X = Z_{\alpha/2}^2 * p * (1-p) / MOE^2$, and $Z_{\alpha/2}$ is the critical value of the Normal distribution at α/2 (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), MOE is the margin of error (MOE = 0.02551), p is the sample proportion (p = 0.5), and N is the population size (N= 205). The smaller the population, the higher the proportion of cases needed. For the population of 205 , a sample size of 134 was obtained, which is just over half the total population, is needed to obtain a confidence level of 95%. Then random samples were then selected from each stratum.

Table 3.1 Determination of sample size for survey

Stratum (L)	Clusters	Population Size	Stratum Sample size (ni)
1	Traffic Engineering, Road and Transport Infrastructure Design Main Process	54	35.29756098 ($n_i = 35$)
2	Road and Transport Infrastructure Construction and Maintenance Main Process	94	61.44390244 ($n_i = 62$)
3	Road and Transport Infrastructure Administration Main Process	35	22.87804878 ($n_i = 23$)
4	Support main process	22	14.3804878 ($n_i = 14$)
	Total	N= 205	n =134

Non-Probabilistic Purposive/ Judgmental Sampling method was chosen based on pre-determined criteria (*i.e managerial levels – top management, middle management, first-line management, and individual contributors for equipment administration, supply & maintenance*) to determine the sample size of respondents who participated in structured interview. As shown in Table 3.2, 8 (eight) respondents were selected to participate in a one-on-one interview method. This involved the selection of the required number of appropriate organizations that conform predetermined criteria based the judgment of the researcher.

Table 3.2 Determination of sample size for Structured Interview

Position	Hierarchy	Interviewee
Traffic Engineering, Road and Transport Infrastructure Design Main Process Director	Top Management	1
Road and Transport Infrastructure Construction and Maintenance Main Process Director	Top Management	1
Road and Transport Infrastructure Administration Main Process Director	Top Management	1
Support Main Process Director	Top Management	1
Equipment Supply, Administration And Maintenance Manager	Middle Level Management	1
Machineries And Vehicles Maintenance Case Team Head	Firs Line Management	1
Machineries And Vehicles Supply Administration Case Team Head	Firs Line Management	1
Spare Parts Supply And Finance Case Team Head	Firs Line Management	1
	Total (N)	n =8

3.3.3 Source of Data Collection (Primary and Secondary)

The method for collecting data on this research was structured interviews, questionnaires and observation. Interviews and questionnaires was used to gather specific results and to tap into the specific knowledge of these employees. Questionnaires ensure that the opinion of the people that were directly impacted by this research outcome were gathered. Structured interviews allow for direct contact with employees. The same questions were asked to all interviewees to ensure that data collected are consistent.

The existing management system was evaluated against data collected from field sites (workshop, garages, warehouses, construction sites) in terms of equipment condition, utilization and performance. Additional data was also collected from the maintenance center office(s), the Equipment Supply Administration and the Financial Administration.

3.3.4 Data Presentation and Analysis

Thematic principle was applied in the process of qualitative data analysis using ATLAS.ti v9. Software for the purpose of this research. The collected information was sieved, sorted, grouped and assembled in accordance with the question numbers that act as the coding system in order to solicit the emerging issues/points and to establish certain patterns in all the answers. The summarization of the collected information was done mainly based on typology and quasi statistics i.e. classified, grouped, themed or patterned and the number of times or frequencies a subject/topic was mentioned in the interview process. Data analysis for the survey questionnaire was done by using the common statistical software SPSS (Statistical Package for Social Science, version 23). All questions were individually analyzed, taking into considerations all the available factors and support through descriptive and inferential analysis.

The UML model was used to further determine the technical requirements of the Equipment Management System (platform, front end, physical infrastructure), as well as the organizational requirements in terms of staffing, level of skills and operating procedures. UML modelling used to define the system elements: actors/users, business processes, functional components, interfacing requirements, database structure. The results of the evaluation was analyzed using standard SWOT (Strengths, Weaknesses, Opportunities, Threats) techniques for business process evaluation and BPM. The limitations of the existing system were highlighted while at the same time the functional requirements of the new Equipment Management System was determined.

3.3.5 Data Validity and Reliability

The term validity means that the measurements are correct, i.e. the instrument measures what is intended to measure and that it measures this correctly (Goddard & Melville, 2001). Validity of a measurement instrument is the extent to which the instrument measures what it is supposed to measure. It takes different forms, each of which is important in different situations (Leedy & Ormrod, 2001).

In this research, an in-depth study of the extent of CEMS development and implementation done through the literature review, coupled with the preliminary field work that had gauged the level of CEMS development and implementation in AACRA, had helped in the fine tuning of the questionnaire development. The extensive discussions held with the various quarters of the professionals and experts in the subject area, these are project managers, construction equipment managers, engineers and academicians that helped and contributed to ensure adequate content validity to the level of CEMS selection, design, development and successful implementation.

The questionnaires were sent to selected experts in the area to check on the validity of the instrument. They evaluated the validity of the instrument for face (logical) and content validity as and to finally evaluate the appropriateness of the issues covered, again based on the level of CEMS development and implementation in Ethiopian companies' context and related major barriers and key success factors. All completed questionnaire by the experts were returned. As the objective of the experts' evaluation was to ensure that respondents understood the instructions, the questions being asked, the terminologies used, no misleading questions, clarity was observed and that the instruments used were reliable to the subject being studied, the returned questionnaires were looked at thoroughly for more corrective inputs.

All input in the form of comments, suggestions, ideas, proposals, corrections and views were taken into consideration to improve, improvise and upgrade the level of reliability of the instrument. To ensure that the measures and variables developed as the instruments in the questionnaire were appropriate, the instrument was tested for its reliability. Prior to the actual data gathering exercise, reliability test was done on the data collected from the pilot study. The outcome of this exercise was a new set of questionnaire that were be used for the actual survey, that were conducted in September 2021. In the process of report writing and for the purpose increasing the credibility of qualitative data, the process of member checking was done vigorously. Follow up phone calls and e-mail communications were made to the interviewees, both to clarify and verify their statements and to validate whatever that they have said. Respondents' validation were important to improve accuracy, validity and transferability of the information from the interview transcript. More often the process of validation was concerned with ensuring that their comments or thought have been correctly described and interpreted.

3.3.6 Ethical Considerations

The interviewees and survey participants were given a clear written description of the purpose, scope and intended outcomes of the research. The type of information required for the research was clearly stated as the policy for anonymity and confidentiality of the Authority. The research was carried out in a way that was ensured confidentiality of the individual participants in the surveys. The individuals who participated in the research will be named in the research, nor will the interviewees and the questionnaires will be anonymous.

The research interview questions and survey questionnaire were designed only for the purpose of this research. This is because confidential information were discussed in the interviews and also commented upon in the questionnaires, this information were not included in a way which will breach confidentiality in the research.

CHAPTER 4 - RESULT AND DISCUSSION

4.1. Quantitative Data Analysis

4.4.1. *Frequency Analysis*

This section is structured to meet the objectives of the study and its findings. The analysis was carried out by SPSS version 21. The graphs were constructed for the representation of the responses given by respondents. Chi-square test for independence was applied to look for the association between the demographic variables and assets inventory, tools supply management, consumeable controls, assets maintenance, hour accounting, spare parts control, purchase requisition, and fleet management. Factor analysis using principal component analysis (PCA) was developed to assess the prevailing factors in the study and the variables involved in these factors. Significant variables were selected in each factor whose loadings/correlations are greater than 0.5. This method was used to collect an important type of validity evidence. Factor analysis helps researchers explore or confirm the relationships between survey items and identify the total number of dimensions represented on the survey. (Knekta, E., Runyon, C., & Eddy, S. (2019).Since our study includes 8 factors and our factor analysis using PCA proposed 9 factors which shows similarity among survey items and dimensions/factors proposed by factor analysis.

From the study, it was observed that 56 respondents belong to Equipment supply, administration, and maintenance work, 43 respondents belong to the Machineries and vehicles maintenance case team, 16 belong to the Machineries and vehicles supply administration case team and 15 belong to the Spare parts supply and finance case team. There are 50% of the respondents who have less than 5 years of experience, 22 % are between 5-10 years of experience, 9% each has 11-15 and 16-20 years of experience while only 10% have more than 20 years of experience. 49 respondents of the survey conveyed that they have less than 5 years in their current position. while 36 of the total respondents said that they have spent 5-10 years in the same position. 21 of the respondents conveyed the fact they spent 11-15 years in the same position they are working and 8 said they served more than20 years in the same position when they started their job. 56 of the respondents said degree is their highest education qualification, 27 conveyed that diploma/ advanced diploma is their highest qualification and 25 said they TVET/10+2 is their highest level of education, and 20 said they postgraduate degree is their highest qualification level. Following is the graphical representation of the study with their interpretations.

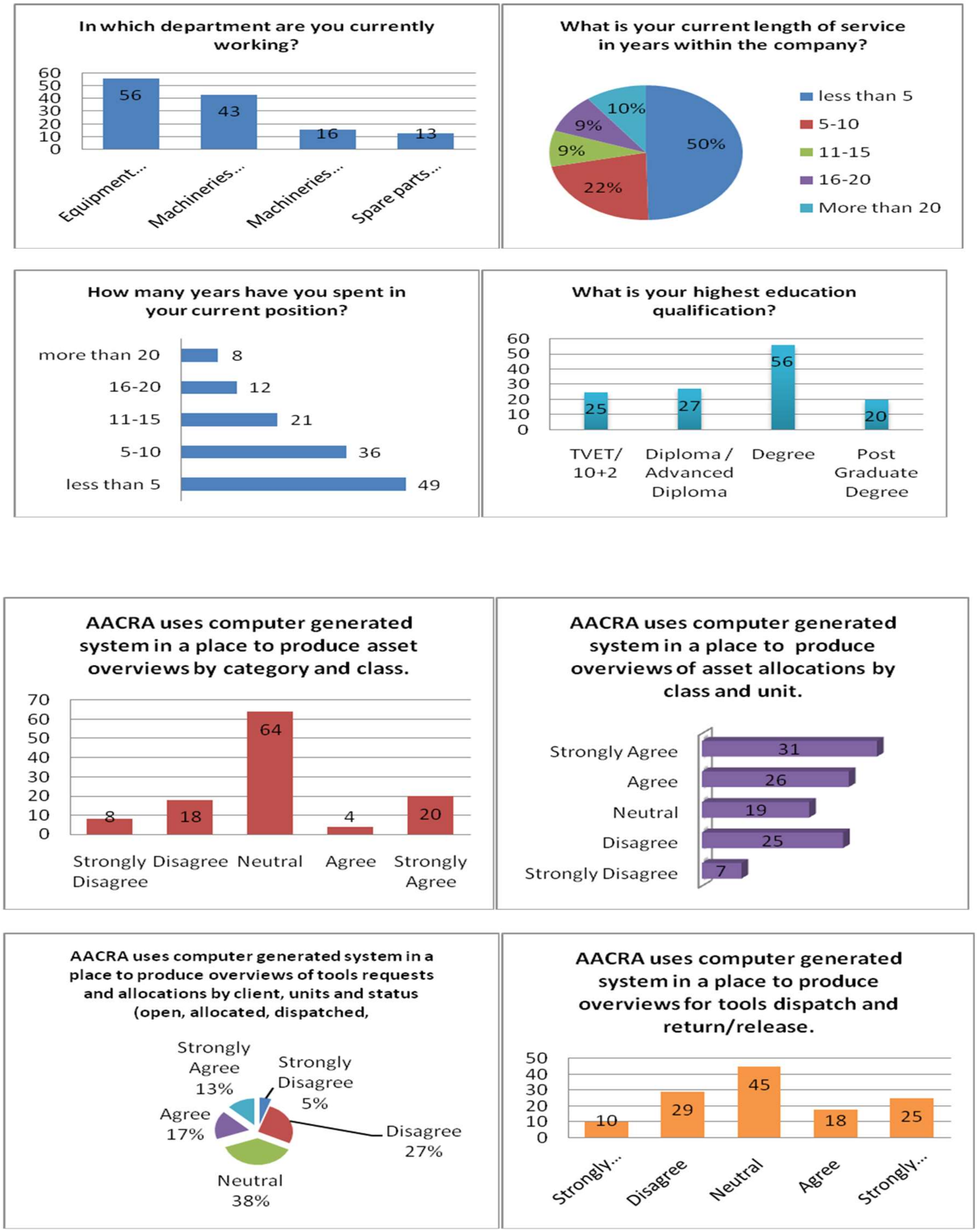


Figure 4.1 Frequency graphical representation and interpretations

From the study, it has been concluded that 47.8% (n = 64) remained neutral while giving the opinion that AACRA uses the computer-generated system in a place to produce asset overviews by category and class while 14.9% (n = 20) strongly agreed with it. 23.1% (n = 31) strongly agreed that AACRA uses the computer-generated system in a place to produce overviews of asset allocations by class and unit and 19.4% (n = 26) only agreed with this fact. While giving an opinion about the statement that AACRA uses the computer-generated system in a place to produce overviews of tools requests and allocations by the client, units, and status (open, allocated, dispatched, returned), 35.8% (n = 48) remained neutral while 16.4% (n = 22) agreed with it. 33.6% (n = 18) remained neutral while giving the decision that AACRA uses the computer-generated system in a place to produce overviews for tools dispatch and return/release and 18.7 % (n = 25) strongly agreed with this fact. When respondents asked that AACRA uses the computer-generated system in a place to produce schedules of tools allocation (future) and utilization (past), 40.3% (n = 54) strongly agreed with this statement while only 4.5 % (n = 6) strongly disagreed with it and 25.4% (n = 34) remained neutral. 17.9 % (n = 24) strongly disagreed, 24.5% (n = 33) and 16.4% (n = 22) strongly agreed with the opinion that AACRA uses computer-generated system in a place to produce up-to-date stock reports (balance) at any time. 11.9 % (n = 16) strongly disagreed, 32.1% (n = 43) strongly agreed that AACRA uses computer-generated system in place to produce transaction overviews (in/out) by consumable and class. 23.9% (n = 32) strongly agreed that AACRA uses computer-generated system in a place to produce counting sheets for inventory and stock checks while only 5.2 % (n = 7) strongly disagreed with this fact. While giving decision that AACRA uses computer-generated system in a place to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task, 21.6% (n = 29) strongly agreed and 20.9 % (n = 28) strongly disagreed with it. AACRA uses the computer-generated system in place to produce up-to-date overviews of work orders on hand by workshop/discipline and by the technician, including planned completion dates, this fact was strongly supported by 23.1% (n = 31) respondents and 24.6% (n = 13) remained neutral in it. Only 3.7 % (n = 5) strongly agreed that AACRA uses the computer-generated system in place to produce overviews of work orders completed including schedule compliance (late/on time) by workshop/discipline and by a technician and 33.6% (n = 45) disagreed with it.

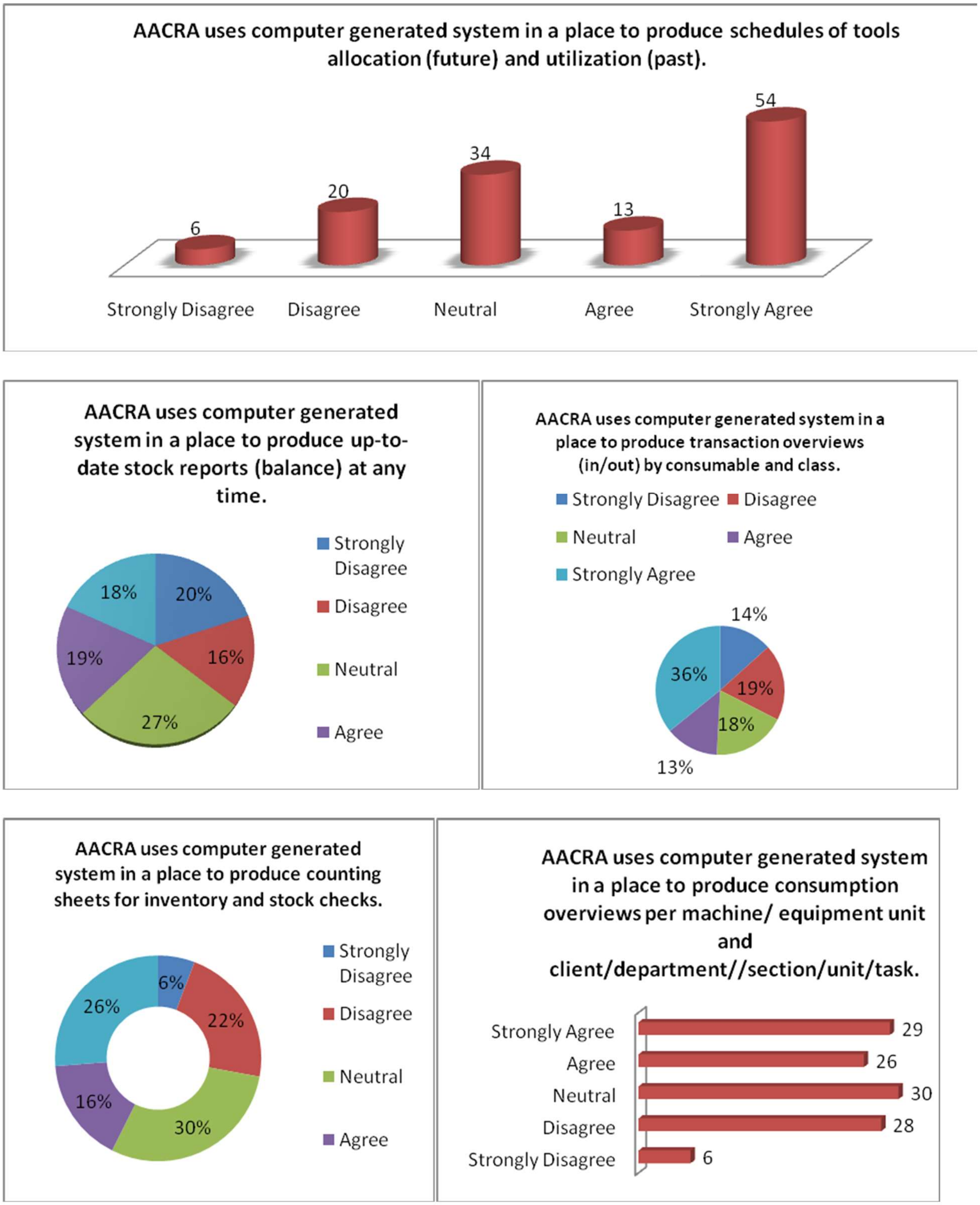
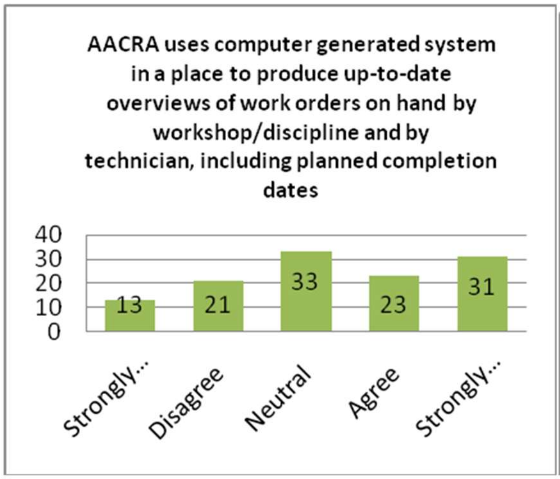
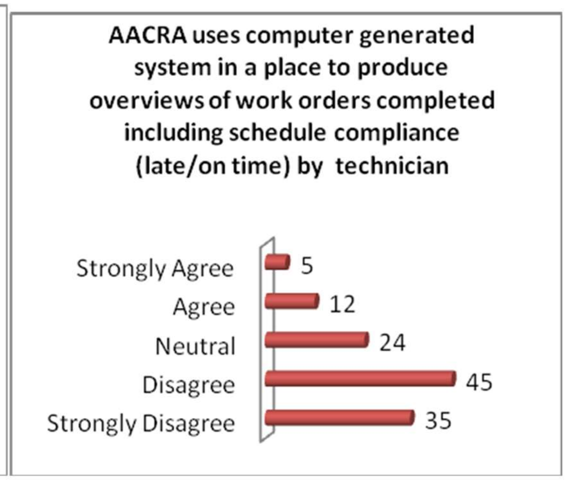
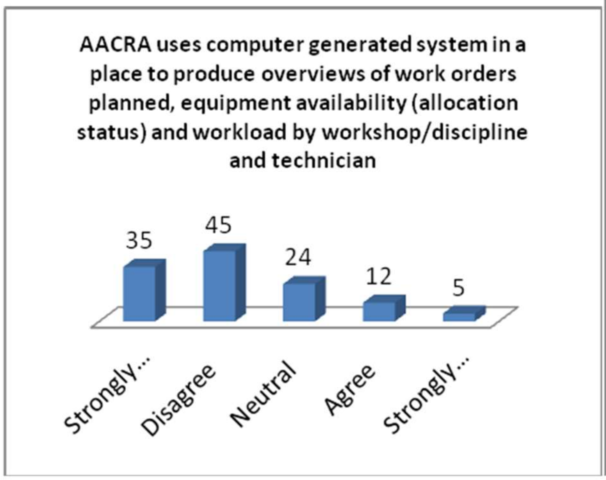


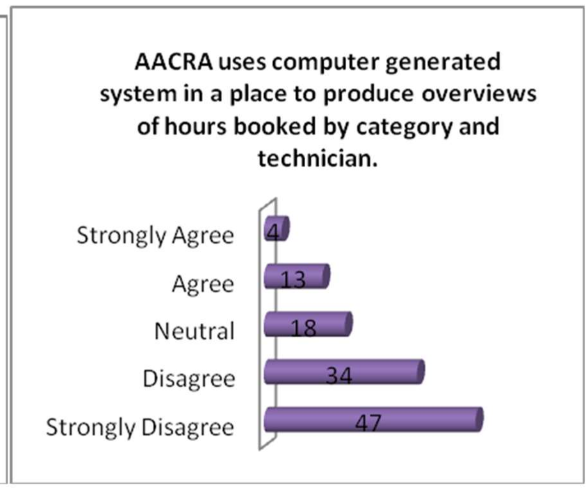
Figure 4.2 Frequency Graphs

AACRA uses the computer-generated system in a place to produce overviews of work orders by order type (breakdown, scheduled maintenance, predictive maintenance) and by asset unit was strongly supported by only 6 % (n = 8) respondents and not supported by 35.8% (n = 48) of the respondents. 35.1% (n = 47) strongly disagreed that AACRA uses the computer-generated system in place to produce overviews of hours booked by category and technician and only 3% (n = 4) strongly agreed with it. 50.7% (n = 68) disagree that AACRA uses computer-generated systems in a place to produce monthly overtime reports and only 1.5 % (n = 2) strongly agreed with this. AACRA uses computer generated system in a place to produce reports with productivity and sick leave/absence statistics was strongly agreed by 4.5% (n = 6) of the respondents while strongly disagreed by 32.8%(n = 44). 45.5% (n = 61) strongly disagreed that AACRA uses computer generated system in a place to produce stock reports (balance and value) by (sub)group and stock location, as well as overall total stock levels, calculate depreciation and only 3% (n = 4) strongly agreed with this fact. While giving an opinion about that AACRA uses computer generated system in a place to produce transaction overviews by spare part and (sub)group, client/requestor, asset type, and the unit, budget, 17.9% (n = 24) strongly disagreed, 10.4% (n = 14) remained neutral and only 1.5% (n = 2) strongly agreed. 9.7% (n = 13) strongly agreed and 29.1% (n = 39) strongly disagreed that AACRA uses computer generated systems in a place to produce stock reviews for non-, slow, and fast-moving items, analyzing stock value and turnover. AACRA uses computer generated system in a place to produce categorized stock lists with item codes for lookup/reference by technicians and administrators was strongly supported by 14.2 % (n = 19) and not strongly supported by 19.4% (n = 26) of the respondents. 35.1% (n = 47) strongly disagreed with the fact that AACRA uses computer generated system in a place to produce overviews of purchase requisitions by status, showing requestor and/or work order details, supplier and date requested/promised/delivered while only 2.2% (n = 3) strongly agreed with it and 13.4% (n = 18) remained neutral. 36.6% (n = 49) strongly disagreed with the opinion that AACRA uses computer generated system in a place to produce categorized supplier lists, 32.1 % (n = 43) also strongly disagreed that AACRA uses computer generated systems in a place to produce fleet-level asset inventories (acquisition value, depreciation, current value, salvage value) and 26.9 % (n = 36) strongly disagreed with the fact that AACRA uses computer generated system in a place to produce overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.









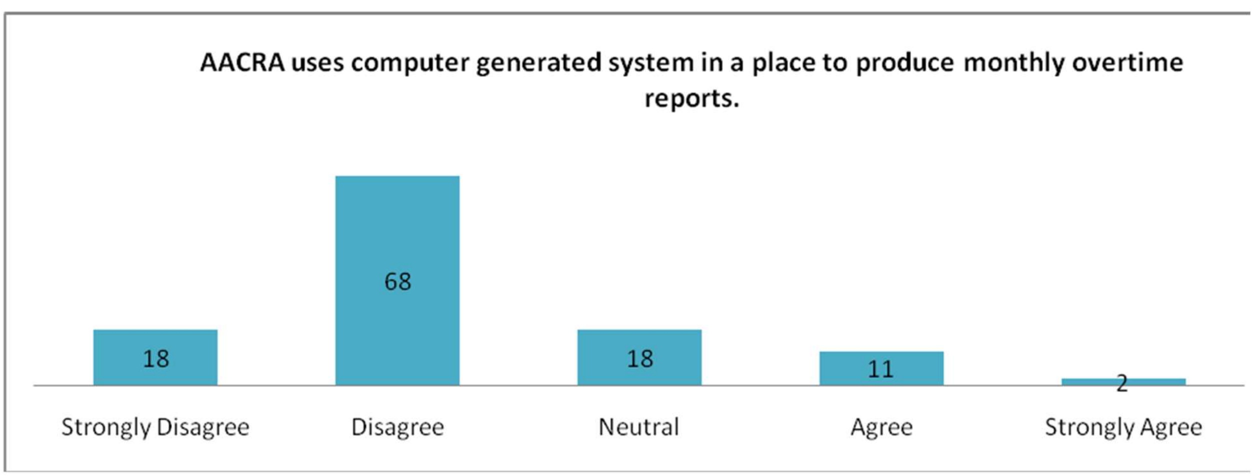


Figure 4.3 Frequency graphical representation and interpretations

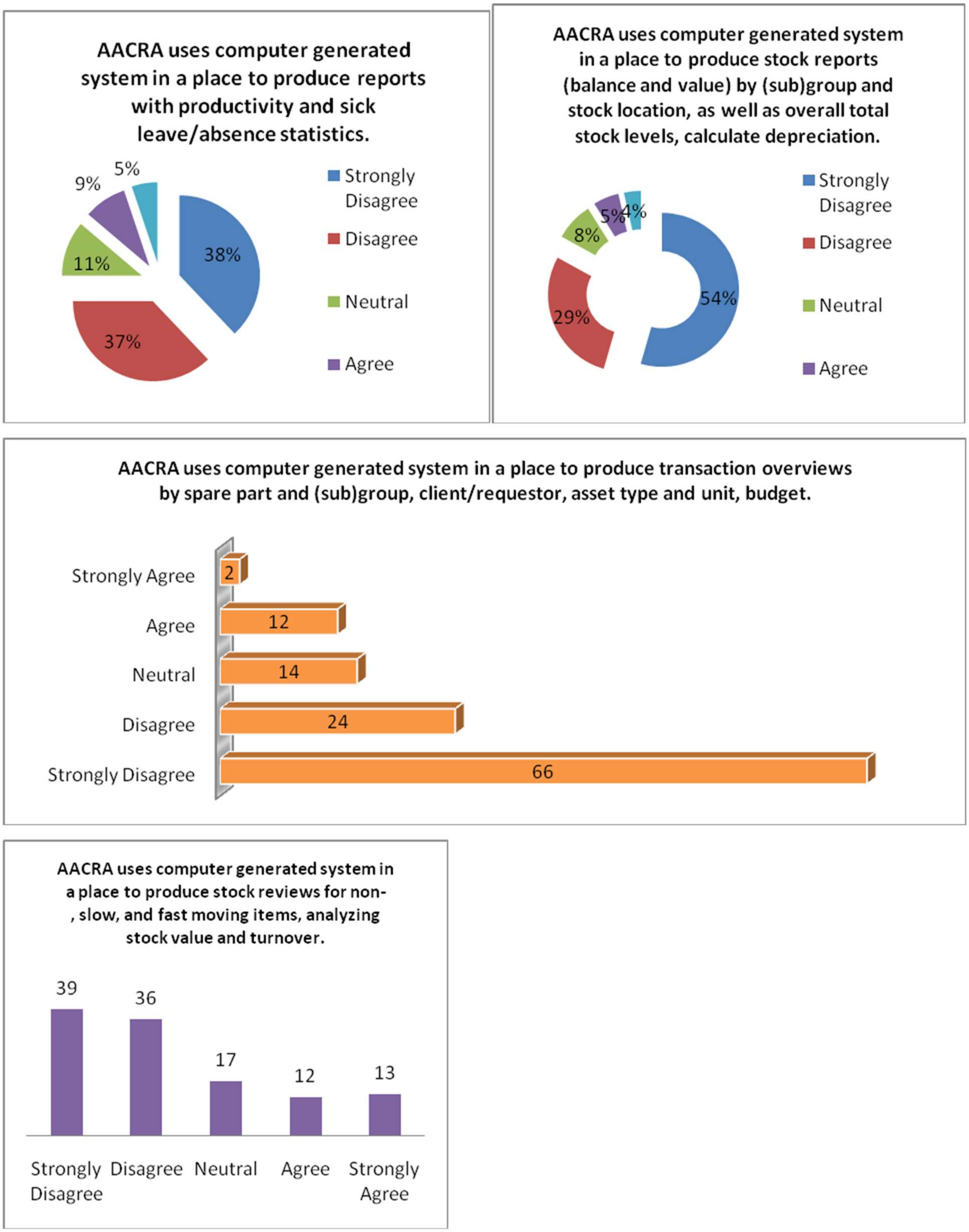


Figure 4.4 Frequency graphical representation and interpretations

From the study, it has been concluded that 47.8% (n = 64) remained neutral while giving the opinion that AACRA uses the computer-generated system in a place to produce asset overviews by category and class while 14.9% (n = 20) strongly agreed with it. 23.1% (n = 31) strongly agreed that AACRA uses the computer-generated system in a place to produce overviews of asset allocations by class and unit and 19.4% (n = 26) only agreed with this fact. While giving an opinion about the statement that AACRA uses the computer-generated system in a place to produce overviews of tools requests and allocations by the client, units, and status (open, allocated, dispatched, returned), 35.8% (n = 48) remained neutral while 16.4% (n = 22) agreed with it. 33.6% (n = 18) remained neutral while giving the decision that AACRA uses the computer-generated system in a place to produce overviews for tools dispatch and return/release and 18.7 % (n = 25) strongly agreed with this fact. When respondents asked that AACRA uses the computer-generated system in a place to produce schedules of tools allocation (future) and utilization (past), 40.3% (n = 54) strongly agreed with this statement while only 4.5 % (n = 6) strongly disagreed with it and 25.4% (n = 34) remained neutral. 17.9 % (n = 24) strongly disagreed, 24.5% (n = 33) and 16.4% (n = 22) strongly agreed with the opinion that AACRA uses computer-generated system in a place to produce up-to-date stock reports (balance) at any time. 11.9 % (n = 16) strongly disagreed, 32.1% (n = 43) strongly agreed that AACRA uses computer-generated system in place to produce transaction overviews (in/out) by consumable and class. 23.9% (n = 32) strongly agreed that AACRA uses computer-generated system in a place to produce counting sheets for inventory and stock checks while only 5.2 % (n = 7) strongly disagreed with this fact. While giving decision that AACRA uses computer-generated system in a place to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task, 21.6% (n = 29) strongly agreed and 20.9 % (n = 28) strongly disagreed with it. AACRA uses the computer-generated system in place to produce up-to-date overviews of work orders on hand by workshop/discipline and by the technician, including planned completion dates, this fact was strongly supported by 23.1% (n = 31) respondents and 24.6% (n = 13) remained neutral in it. Only 3.7 % (n = 5) strongly agreed that AACRA uses the computer-generated system in place to produce overviews of work orders completed including schedule compliance (late/on time) by workshop/discipline and by a technician and 33.6% (n = 45) disagreed with it.

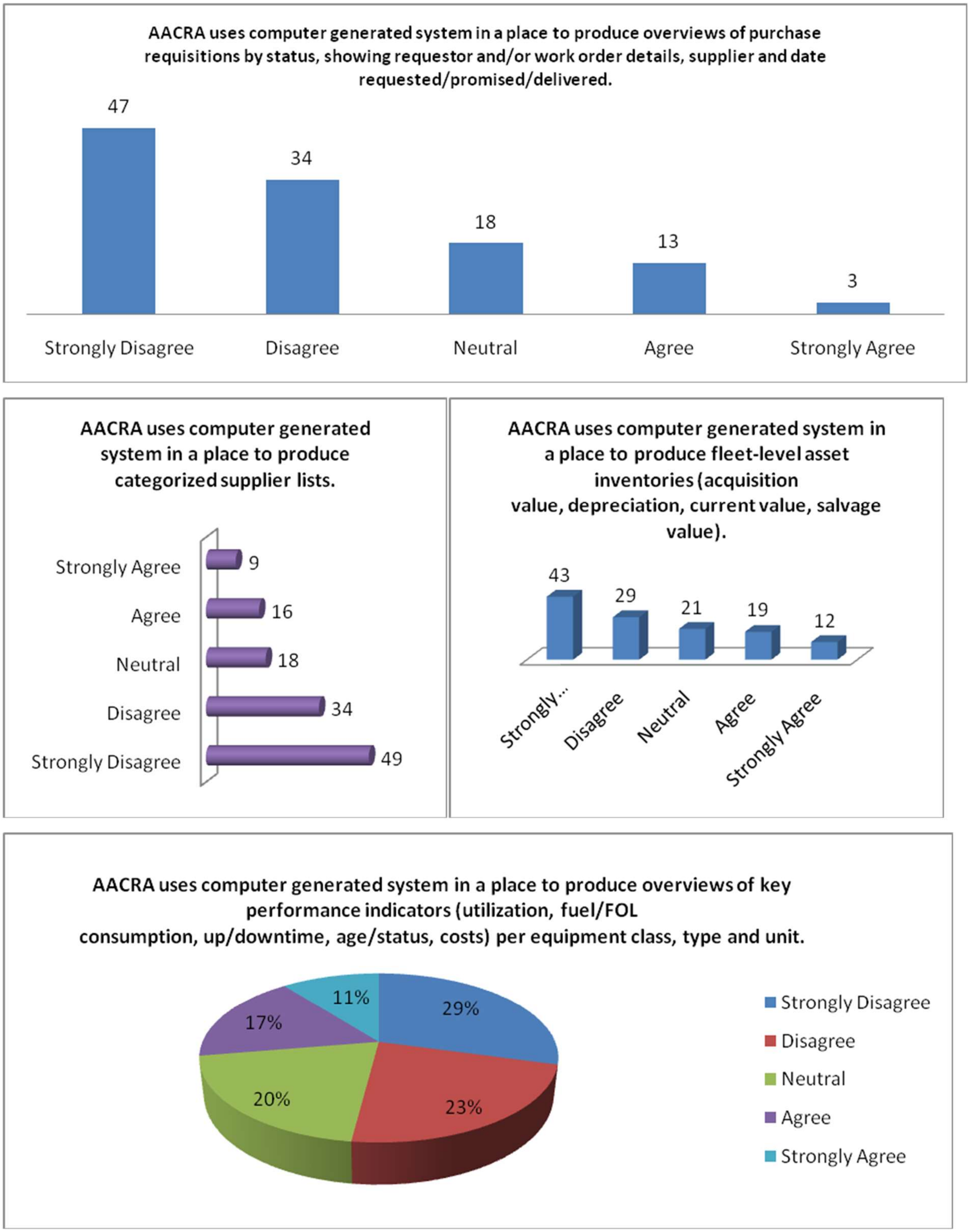


Figure 4.5 Frequency graphical representation and interpretations

AACRA uses the computer-generated system in a place to produce overviews of work orders by order type (breakdown, scheduled maintenance, predictive maintenance) and by asset unit was strongly supported by only 6 % (n = 8) respondents and not supported by 35.8% (n = 48) of the respondents. 35.1% (n = 47) strongly disagreed that AACRA uses the computer-generated system in place to produce overviews of hours booked by category and technician and only 3% (n = 4) strongly agreed with it. 50.7% (n = 68) disagree that AACRA uses computer-generated systems in a place to produce monthly overtime reports and only 1.5 % (n = 2) strongly agreed with this. AACRA uses computer generated system in a place to produce reports with productivity and sick leave/absence statistics was strongly agreed by 4.5% (n = 6) of the respondents while strongly disagreed by 32.8%(n = 44). 45.5% (n = 61) strongly disagreed that AACRA uses computer generated system in a place to produce stock reports (balance and value) by (sub)group and stock location, as well as overall total stock levels, calculate depreciation and only 3% (n = 4) strongly agreed with this fact. While giving an opinion about that AACRA uses computer generated system in a place to produce transaction overviews by spare part and (sub)group, client/requestor, asset type, and the unit, budget, 17.9% (n = 24) strongly disagreed, 10.4% (n = 14) remained neutral and only 1.5% (n = 2) strongly agreed. 9.7% (n = 13) strongly agreed and 29.1% (n = 39) strongly disagreed that AACRA uses computer generated systems in a place to produce stock reviews for non-, slow, and fast-moving items, analyzing stock value and turnover. AACRA uses computer generated system in a place to produce categorized stocklists with item codes for lookup/reference by technicians and administrators was strongly supported by 14.2 % (n = 19) and not strongly supported by 19.4% (n = 26) of the respondents. 35.1% (n = 47) strongly disagreed with the fact that AACRA uses computer generated system in a place to produce overviews of purchase requisitions by status, showing requestor and/or work order details, supplier and date requested/promised/delivered while only 2.2% (n = 3) strongly agreed with it and 13.4% (n = 18) remained neutral. 36.6% (n = 49) strongly disagreed with the opinion that AACRA uses computer generated system in a place to produce categorized supplier lists, 32.1 % (n = 43) also strongly disagreed that AACRA uses computer generated systems in a place to produce fleet-level asset inventories (acquisition value, depreciation, current value, salvage value) and 26.9 % (n = 36) strongly disagreed with the fact that AACRA uses computer generated system in a place to produce overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.

4.4.2. *Reliability Analysis of the Study*

Cronbach's alpha is used for calculating reliability coefficients for survey instruments that use Likert-type response sets. Cronbach's alpha coefficient ranges from 0 to 1.0 with higher values denoting increased reliability(Gliem, J. A., & Gliem, R. R. (2003). The criterion for an acceptable By using SPSS version 21, table 1 has been produced for the checking of Cronbach's alpha.

Table 4.1 Cronbach's Alpha

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.778	0.778	24

Since the value of Cronbach alpha is 0.778 which is at the acceptable level. It shows that the survey conducted is reliable and the questionnaires have been collected by respondents by keeping reliable standards of Likert-type responses.

4.4.3. *Factor Analysis for the Validity of the study*

To test for factor or internal validity of a questionnaire in SPSS factor analysis has been applied. If the factor structure is similar to what was proposed in study (number of factors, pattern of factor loadings, etc.) then we have evidence of validity. factor analyses with PCA extraction, the scree plot to determine the number of factors, and Varimax rotation. Factor analysis is a statical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. From the study, nine factors have been extracted which contributed significantly to the study. Scree-plot has also been used to graphically look for the significant factors which have been extracted from the study. The principal component analysis (PCA) method has been adopted to extract the significant factors. PCA extracted 9 factors from the 24 factors which contributed significantly in the study and they showed almost 61 % variation of the total. From table 2, it can be observed that the KMO measure of sampling adequacy which is 0.693 showing good adequacy of sampling. Bartlett's Test of Sphericity in table 3 should be rejected to perform the factor analysis. It can be seen that the p-value is 0.000 which leads to the rejection of the null hypothesis that our correlation matrix is identity.

Table 4.2 : KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.693**
Bartlett's Test of Sphericity	Approx. Chi-Square	581.940
	df	276
	p-value	0.000

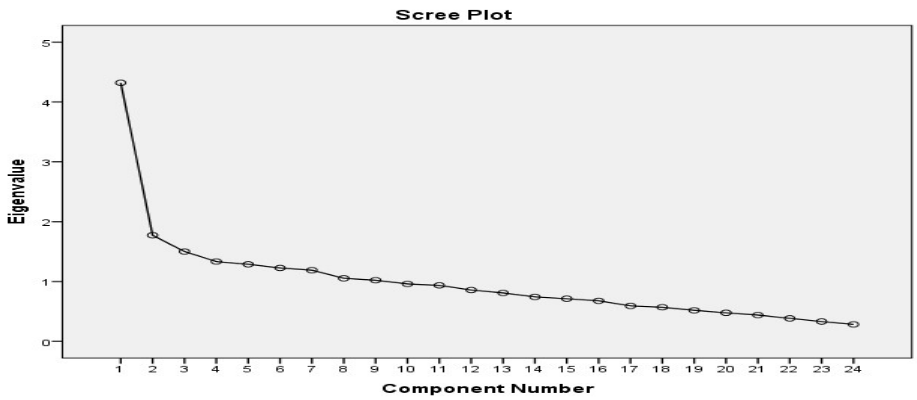


Figure 4.6 : Scree Plot

The scree-plot graphs the eigenvalue against the factor number. From the above figure, it can be seen that there is a slight tilt after 9 factors and then the line is almost flat with the same sequence showing that our study includes 9 factors among the 24 factors. From the analysis, it has been computed that the percentage cumulative variation which has been contributed in the study is 61.276% of the total by the 9 components or factors. Following are the nine factors together with their loadings/correlations.

Table 4.3 : Factor Analysis Table

Factor 1 : Asset maintenance and hour maintenance

AACRA uses computer generated system in a place to produce up-to-date overviews of work orders on hand by workshop/discipline and by technician, including planned completion dates.	0.588
AACRA uses computer generated system in a place to produce overviews of work orders completed including schedule compliance (late/on time) by workshop/discipline and by technician.	0.733
AACRA uses computer generated system in a place to produce overviews of work orders planned, equipment availability (allocation status) and workload by workshop/discipline and technician.	0.604
AACRA uses computer generated system in a place to produce overviews of work orders by order type (breakdown, scheduled maintenance, predictive maintenance) and by asset unit.	0.504
AACRA uses computer generated system in a place to produce monthly overtime reports.	0.538

Factor 2: Asset inventory, consumable and spare parts control

AACRA uses computer generated system in a place to produce overviews of asset allocations by class and unit.	0.352
AACRA uses computer generated system in a place to produce up-to-date stock reports (balance) at any time	0.696
AACRA uses computer generated system in a place to produce stock reviews for non-, slow, and fast moving items, analyzing stock value and turnover.	0.660

Factor 3: Consumable and spare parts control

AACRA uses computer generated system in a place to produce transaction overviews (in/out) by consumable and class.	0.430
AACRA uses computer generated system in a place to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task.	0.528
AACRA uses computer generated system in a place to produce stock reports (balance and value) by (sub)group and stock location, as well as overall total stock levels, calculate depreciation.	0.738
AACRA uses computer generated system in a place to produce categorized stock lists with item codes for lookup/reference by technicians and administrators.	0.397

Factor 4: tools supply and management

AACRA uses computer generated system in a place to produce overviews of tools requests and allocations by client, units and status (open, allocated, dispatched, returned)	0.656
AACRA uses computer generated system in a place to produce overviews for tools dispatch and return/release.	0.678

Factor 5: Hour accounting and purchase requisition

AACRA uses computer generated system in a place to produce overviews of hours booked by category and technician	0.730
AACRA uses computer generated system in a place to produce reports with productivity and sick leave/absence statistics.	0.598
AACRA uses computer generated system in a place to produce overviews of purchase requisitions by status, showing requestor and/or work order details, supplier and date requested/promised/delivered.	0.508

Factor 6: fleet management

AACRA uses computer generated system in a place to produce fleet-level asset inventories (acquisition value, depreciation, current value, salvage value).	0.743
AACRA uses computer generated system in a place to produce overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.	0.618

Factor 7: tools supply and administration and consumable control

AACRA uses computer-generated system in a place to produce schedules of tools allocation (future) and utilization (past).	0.764
AACRA uses computer generated system in a place to produce counting sheets for inventory and stock checks.	0.523

Factor 8: spare parts control and purchase requisition

AACRA uses computer-generated system in a place to produce transaction overviews by spare part and (sub)group, client/requestor, asset type and unit, budget.	0.813
AACRA uses computer generated system in place to produce categorized supplier lists	0.466

Factor 9: Asset inventory

AACRA uses computer-generated system as a place to produce asset overviews by category and class.	0.813

4.4.4. *Interpretations of the Factor and their loadings*

Nine factors have been extracted from the study. The first factor includes the asset and hour maintenance. AACRA uses computer systems in place to produce up-to-date overviews of work orders on hand and schedules compliance by workshops/ discipline and technicians. It also uses these systems to produce work orders planned, equipment availability (allocation status), and work order type (breakdown, scheduled maintenance, predictive maintenance). ACCRA also uses CEM to produce the monthly overtime reports. The factor analysis has combined the asset and hour maintenance in one factor due to their joint contribution to the study. This factor contributed 9.294% of the 61.267% variation. FA included asset inventory, consumables, and spare parts control in the second factor. CEM produces asset allocations by class and unit, updates stock reports at any time, and produces reviews for non-, slow, and fast-moving items, analyzing stock value and turnover. There joint study as the second factor contributed 7.514% of the total 61.267% variation. The third factor proposed by FA using PCA (principal component analysis) is consumable and spare parts control. Usage of CEM by AACRC to produce transaction overviews (in/out) by consumable and class, consumption overviews per machine/ equipment unit and client/department//section/unit/task, stock reports (balance and value) by (sub)group, and stock location, as well as overall total stock levels, calculate depreciation and categorized stocklists with item codes for lookup/reference by technicians and administrators has contributed 7.381% in the total of 61.26% of the variation. The fourth factor alone has been categorized as tools supply and management which contributed 7.004 % of the total variation. FA proposed the fifth factor as hour accounting and purchase requisition by PCA. CEM utilization overviews of hours booked by category and technician, reports with productivity and sick leave/absence statistics. and overviews of purchase requisitions by status, showing requestor and/or work order details, supplier and date requested/promised/delivered. This factor jointly contributed 6.920% of the total variation. fleet management has been extracted by PCA as the sixth factor and contributed 6.371% in the total variation. Factor analysis extracted the seventh factor as tools supply and administration and consumable control. AACRA uses CEM to reproduce schedules of tools allocation (future) and utilization (past) and counting sheets for inventory and stock checks. This joint factor contributed 5.836% to the total variation. FA by using PCA proposed the eighth factor based on the loadings/correlations among spare parts control and purchase requisition.

This factor shows that CEM produces transaction overviews by spare part and (sub)group, client/requestor, asset type and unit, budget with the correlation of categorized supplier lists. it contributed 5.768% and the last factor which is asset inventory in which CEM used by AACRA to produce asset overviews by category and class contributed 5.188% in the total variation. From the factor analysis, it can be examined that the factors proposed in the study are almost same as our study of factor analysis by PCA. our study is validated on the basis of factor analysis.

4.4.5. *Association analysis of demographic variables with factors for the selection, development, and implementation of an Integrated computerized equipment management system (CEMS) functionalities*

Chi-square analysis is applied to check the association of demographic variables with the assets inventory, tools supply management, consume able controls, assets maintenance, hour accounting, spare parts control, purchase requisition, and fleet management.

Table 4.4 : Association between factors with the demographic variables

Factor	Variables	Chi-square value	p-value
AACRA uses computer generated system in a place to produce asset overviews by category and class.	What is your current length of service in years within the company?	43.264	0.000
AACRA uses computer generated system in a place to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task.	In which department you are working?	40.489	0.000
AACRA uses computer generated system in a place to produce overviews of tools requests and allocations by client, units and status (open, allocated, dispatched, returned)	In which department you are working?	50.690	0.002
AACRA uses computer generated system in a place to produce up-to-date overviews of work orders on hand by workshop/discipline and by technician, including planned completion dates.	In which department you are working?	107.256	0.000
AACRA uses computer generated system in a place to produce reports with productivity and sick leave/absence statistics	In which department you are working?	46.678	0.001
AACRA uses computer generated system in a place to produce overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.	In which department you are working?	41.069	0.020
AACRA uses computer generated system in a place to produce overviews of work orders completed including	What is your current length of service in	41.876	0.001

schedule compliance (late/on time) by workshop/discipline and by technician	years within the company?		
AACRA uses computer generated system in a place to produce overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.	What is your current length of service in years within the company?	48.937	0.000
AACRA uses computer generated system in a place to produce overviews of work orders by order type (breakdown, scheduled maintenance, predictive maintenance) and by asset unit.	How many years you have spent in your current position?	41.445	0.001
AACRA uses computer generated system in a place to produce categorized stock lists with item codes for lookup/reference by technicians and administrators.	How many years you have spent in your current position?	39.003	0.002
AACRA uses computer generated system in a place to produce monthly overtime reports.	What is your highest level of education?	45.001	0.008

Association analysis using chi-square test of independence was performed and p-value was observed as decision criteria compared with 0.05 level of significance. The chi-square test statistic value together with their respective p-values has been mentioned in table 3. From table 3 it can be observed that current length of service in years within company has been found statistically associated with asset inventory (p-value 0.000*** and χ^2 = 43.264), asset maintenance (p -value 0.001*** and χ^2 = 41.876) and fleet management (p-value 0.000*** and χ^2 = 48.937). Type of department of respondents has been observed statistically associated with consumable control (p -value 0.000*** and χ^2 = 40.489), total supply management (p-value 0.002***and χ^2 = 50.690), asset maintenance (p -value 0.000*** and χ^2 = 107.256), hour accounting (p -value 0.001*** and χ^2 = 46.678) and fleet management (p -value 0.020** and χ^2 = 41.069). Asset maintenance (p -value 0.001*** and χ^2 = 41.445) , Spare parts control (p -value 0.002** and χ^2 = 39.003) has been observed statistically significantly associated with the years spent in the current position, while hour accounting (p -value 0.008** and χ^2 = 45.001) has association with the highest level of education of respondents.

4.4.6. *ANOVA (Analysis of variance)*

The technique ANOVA has been used to check that whether the findings of our study are significant or not (Agresti & Finlay, 2009; Tuckman, 1999). It has been concluded from the study that mean response of respondents working in different departments are statistically significant about tools supply and management [F = 2.982, p-value = 0.014], asset maintenance [F= 4.519, p-value = 0.001], spare parts control [F= 2.2483, p-value = 0.035] and fleet management [F= 1.966, p-value 0.038]. The following figures are showing the difference among the average responses of employees working in the different departments about significant factors.

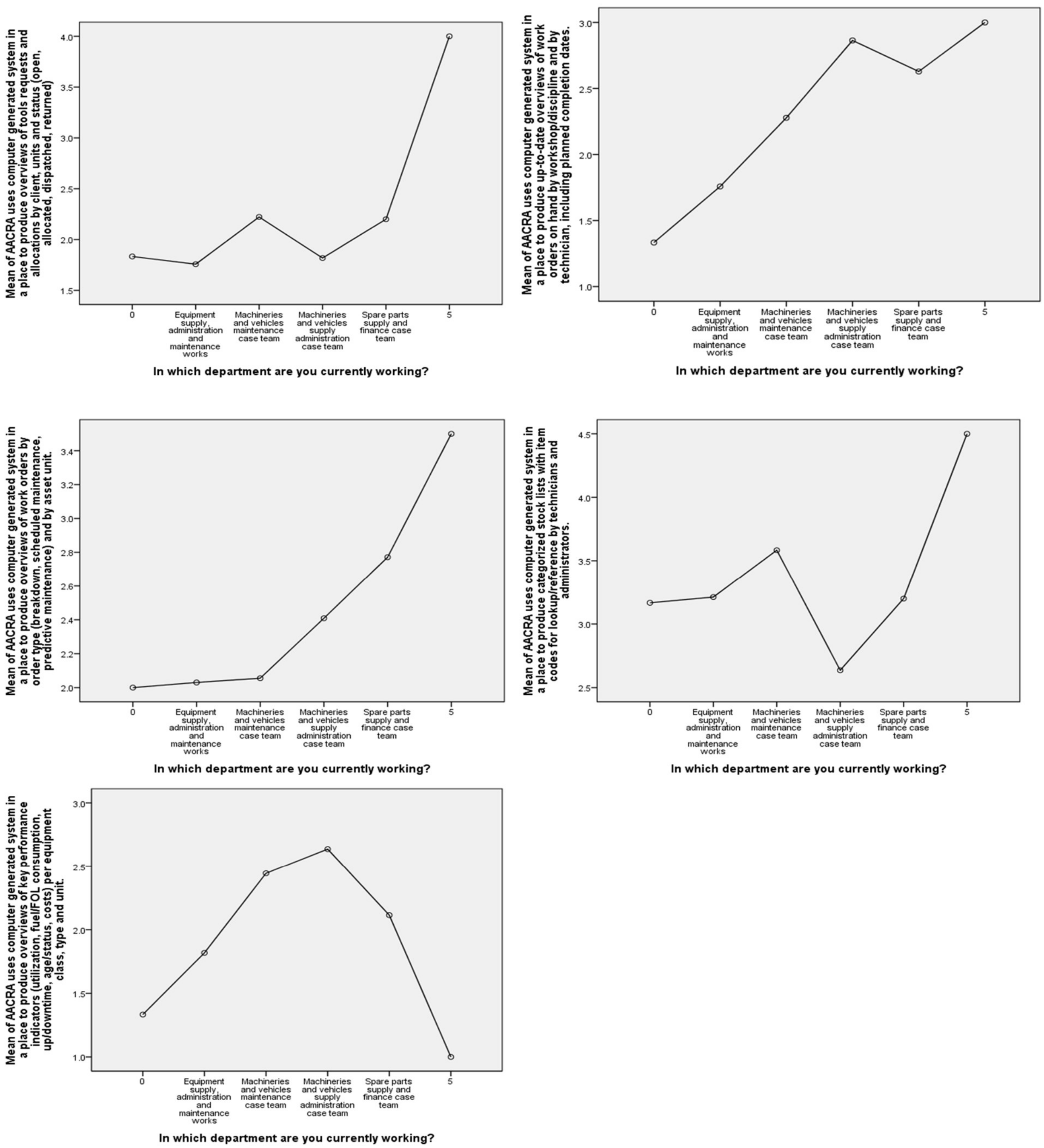


Figure 4.7 : ANOVA Variance Figures

It has been concluded from the study that the mean response of respondents having different lengths of service is statistically significant about asset inventory [F = 7.0.80, p = 0.000]. asset maintenance [F = 4.787, p-value = 0.000] and fleet management [F = 3.892, p-value = 0.003]. The following figures show the average response of people having different lengths of service about the significant factors.

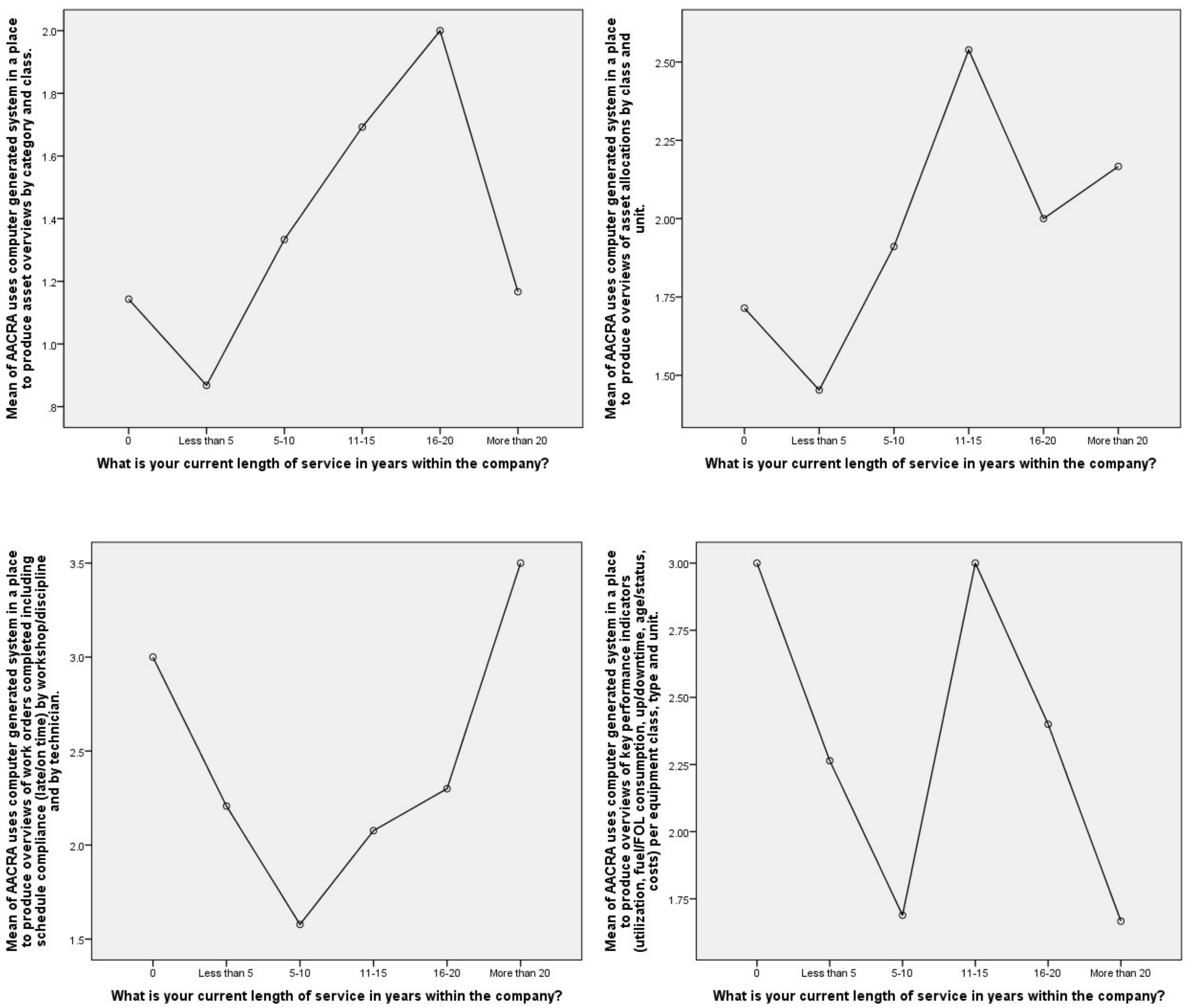


Figure 4.8 : Variance Plots

4.4.7. *Conclusion of the Quantitative Analysis and Findings*

This study analyzed the value of major critical success factors for the selection, development and implementation of an Integrated computerized equipment management system (CEMS) functionalities based on the proposed and developed Integrated Equipment Management Conceptual Framework Model for Addis Ababa Roads Authority(AACRA). The reliability of the survey was checked by Cronbach alpha which showed that our questionnaire is reliable to use. The validity of the survey was examined by factor analysis. Factor analysis proposed 9 factors and our study had 8 factors which almost confirms the relationship between the study factors and dimensions of factor analysis which is 9 From the study, it was observed that there most of the respondents belong to Equipment supply, administration, and maintenance work. Half of the respondents have less than 5 years of experience. while a major portion of the respondents has spent 5-10 years in the same position. Most of them have a degree as their highest educational qualification. Most of them remained neutral that AACRA uses CEM in a place to produce asset overviews by category and class. Respondents also strongly agreed that AACRA uses CEM in a place to produce overviews of asset allocations by class and unit. Most of them disagreed while giving an opinion about the statement that AACRA uses CEM in a place to produce overviews of tools requests and allocations by the client, units, and status (open, allocated, dispatched, returned). Also, they remained neutral while giving the decision that AACRA uses CEM in a place to produce overviews for tools dispatch and return/release. They also strongly agreed when respondents asked that AACRA uses CEM in a place to produce transaction overviews (in/out) by consumable and class. Many agreed that CEM produces counting sheets for inventory and stock checks. CEM to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task was also agreed by most of them, respondents. AACRA uses the computer-generated system in place to produce up-to-date overviews of work orders on hand by workshop/discipline and by a technician, including planned completion dates, this fact was strongly supported by many respondents, However, mostly disagreed that AACRA uses CEM to produce overviews of work orders completed including schedule compliance (late/on time) by workshop/discipline and by technician. AACRA uses the computer-generated system in a place to produce overviews of hours booked category and technician was also strongly disagreed by the respondents. Also they disagreed that system used by AACRA produce monthly overtime reports and strongly disagreed also that they produce reports with productivity and sick leave/absence statistics. AACRA uses the computer-generated system in a place to produce categorized stocklists with item codes for lookup/reference by technicians and administrators was strongly disagreed. Most of the respondents strongly disagreed that they produce overviews of purchase requisition by status, showing requestor and or work order details supplier and data requested /promised/delivered. Many disagreed with the fact that these system used by AACRA produce transactions overviews by spare parts and sb groups client requestor asset type unit and budget. Mostly disagreed that such systems used by AACRA produce categorized supplied list and fleet level asset inventories. However mostly strongly disagreed with the opinion that AACRA uses computer-generated system in place to produce categorized supplier lists, Also many strongly disagreed that AACRA uses CEM in place to produce fleet-level asset inventories (acquisition value, depreciation, current value, salvage value) and overviews of key performance indicators (utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type, and unit. Significant factors were analyzed using the ANOVA technique. Significant factors of our study included tools supply and management, asset maintenance, spare parts control, asset maintenance fleet management, and asset inventory.

4.5. Qualitative Analysis and Key findings

Qualitative data collection was entirely carried out by the researcher who has the required level of knowledge in the subject of the research. The interview participants were given a clear written description of the purpose, scope and intended outcomes of the research. These are, the type of information required for the research were clearly stated as the policy for anonymity and confidentiality of AACRA, the research were carried out in a way that ensured confidentiality of AACRA itself and the individual participants in the interview. The target respondents in the organization were not named in the research & interviewees are anonymous. The findings below were extracted from qualitative data themes which were summarized from the structured interviewee data which were collected during survey.

4.5.1. *Structured Interview Analysis*

All the face-to-face in-depth interviews were recorded and transcribed. Afterwards, the researcher had the possibility to comment on the verbatim transcriptions (Appendix C). While reading through the transcriptions (including the transcription of the reflection session of the interview participants) and notes, short memos were taken between the quotes as a part of a preliminary analysis, coding or sense making, of the findings. After interview verbatim transcription, the researcher performed the initial thematic analysis using ATLASti. Version 9 qualitative data analysis software tool to group the codes given for each and particular interview questions into themes. The detailed tabulated identified codes and themes (Table 4.5) of the qualitative data were analyzed using ATLASti.

Table 4.5 : Identified Codes and Themes from Interview Verbatim Transcriptions

Questions	Identified Codes	Themes
1. Are there documented Policies, Programs and Procedures regarding Equipment Management System in AACRA?	Availability of documented policies	- Polices - Programs - Procedures
	Availability of documented programs	
	Availability of documented procedures	
	Availability of active updating programs	
	Availability of documented shop functions and SOP	
	Availability Work Process effectiveness review and evaluation	
2. Do you have a clear mission and quality statement which addresses and supports Equipment Management System?	Availability of mission statement	- Mission - Quality statement
	Availability of clear objectives	
	Availability of strategies	
	Availability of organizational chart and structure	
	Availability of function statement	
	Availability of Job description	
3. In your opinion what are the problems, if any, with the equipment maintenance and administration staff with regard to equipment maintenance structures, competency and training?	Availability of management and leadership training	- Management training - Planner training - Craft training
	Availability of supervisors, dispatchers, foremen and planner training	
	Availability of technicians, Operators and drivers training	
	Availability of refreshment training	
4. What percentage of the annual budget goes to equipment maintenance and management?	Do you plan annual fleet and maintenance budget	- Budget planning - Reporting and feedback - Effective control
	Do you have cost reporting & budget documentation	
	Do you formally identifying and presenting long-range requirements for renewals and replacement to management	
	Do you Plan annual fleet and maintenance budget	
5. In your opinion does AACRA perform the following types of maintenance and if yes, what problems, if any, do you think the company experiences with performing these types of maintenance?	Do you use Corrective Maintenance	- Effective strategies - Strategy assessment
	Do you use Predictive Maintenance Strategy	
	Do Use Planned Maintenance Strategy	
	Do you use Reliability Centered Maintenance	

Questions	Identified Codes	Themes
	Strategy	
6. Do you have computerized equipment management system (CEMS) within AACRA ? If any, what are the constraints using the system?	Adequacy of computerized equipment management system	- Maintenance Information Systems - Software/ hardware
	Report design and utilization	
	Facility and equipment reports	
	Availability of easy to use maintenance management system	
	Availability of in house developed systems for equipment management (expert systems)	
7. Do you have an effective way to generate and track work orders?	Availability of standard work request format.	- Priority system - Work order system and procedures - Emergency & shutdown scheduling - Planning procedures
	Availability of standard work order.	
	Availability standard inter- shop order	
	Availability of carryover authorization	
	Immediate response and decision on maintenance capability within shop, outsource or onsite maintenance	
8. How do you verify the work was done efficiently and correctly?	Using performance measurement methods	- Performance measures - Continuous improvement - Maintenance process re-engineering
	Report summaries preparation	
	Using engineered performance standards to estimate man hours on work orders	
	Conducting improvement studies	
9. Are you able to access historical information on the last time, which was done by the maintenance department, by whom, and for what condition?	Availability of maintenance history records	- maintenance history records - equipment history records - spare part history records - Inventory system
	Availability of equipment history records	
	Spare parts information records	
	Computerized inventory system	
10. How are your spare-parts inventories managed and controlled? Do you have either excess inventories or are you consistently waiting for parts to arrive?	Periodic inventory review	- Inventory polices - Control procedures - Warehousing
	Documentation of spare parts and material usage on work order sheet.	
	Spare parts availability and control	

Questions	Identified Codes	Themes
11. Do you have an organized system to store documents (electronically) related to Operations & Maintenance procedures, equipment manuals, and warranty information?	Availability of detail and complete specifications	- Specification - warranties & cost information - manuals & documentation
	Coding and classification of equipment	
	Availability of initial cost and warranties	
	Service contract and standardization	
	Availability of load rating, manuals and documentation	
12. Do you believe that the actual equipment maintenance cost (labor, downtime, overtime, spare part and other related costs) is tracked and controlled by your office or department without any restrictions	Establishing periodic budget execution planning	- Budget execution plan - Budget control plan
	Identifying works in the budget plan.	
	Controlling budget against expenditure	
13. In your opinion are there any other problems with the equipment management system at the company that affects the overall equipment effectiveness (OEE), which is not covered in the above questions?	Safety awareness	- Maintenance - Safety - Environment
	Use of personal safety equipment	
	Securing emergency safety kit with in working places	
	Availability of fire extinguisher at different locations	
	Proper location of emergency evacuation system	
	Periodic safety assessment	
	Awareness of maintenance impact on the environment	
	Consider the environment when developing equipment management strategies.	

All arguments were grouped into relevant codes, and added or skipped categories if needed. In case there was a confusion on grouping of arguments in to codes, cross-referencing was made with interviewees through telephone call and agreement was reached about the grouping of the arguments into codes. The categorized rationales were grouped in to codes and overarching themes using ATLASti. software. Consensus meeting(conference) was held with all interviewee to validate the software generated themes in which all most interviewees were participated. During this meeting additional questions on the overarching themes were raised, namely questions about the number of identified themes, items used in the in-depth interview, practical suggestions from the interviewees and observed hiatus on site. These questions were discussed and agreed to proceed between the researcher and the interviewee.

The overarching themes containing the categorized coded rationales were given back to the interview participants, in the form of a textual description accompanied by bar graphs and plots depicting the word length, number, frequency and statically analysis of the reported rationales. The total interview verbatim transcribed word count from interview questions is 2837, the identified in vivo codes from these transcribed word counts are 60 and 37 themes are finally identified from the in vivo codes that are categorized for each interview questions (Table 4.6). After thematically analyzing the data of the in-depth interview, 37 (thirty-seven) overarching themes were identified from all 13 questions that covered the interview of all interviewee and from 61 identified codes using ATLASti. The thematic analysis is triangulated to frequency measurements in order to increase representativeness of the data and increase reliability. In qualitative analysis frequency measurements were necessary to perform meaningful statistical analyses because the study aimed to investigate and identify problems rapidly with high measurement frequency (i.e. temporal resolution) without compromising compliance.

Figure 4.9: In vivo generated Interview Codes Spiral Word Cloud

The qualitative study shows that AACRA lacks effective control on its equipment which is 4.96%, there is poor planning procedures in AACRA which is contributed 4.11% and AACRA also is still struggling on usage of proactive computer aided maintenance information system which is 1.99% while almost all other findings are the same which ranges from 1.14% to 1.43%. From the qualitative analysis, it can be examined that the outcome in the study are almost same as our study of quantitative analysis.

Table 4.6 : In vivo generated word transcription & identified Themes

Interview Question	#	identified Themes	Word Length	Number of Transcription	% of occurrences
Q1	1	Polices	4	1	1.14%
	2	Programs	5	1	1.14%
	3	Procedures	6	1	1.14%
Q2	1	Mission	6	1	1.14%
	2	Quality statement	6	1	1.14%
Q3	1	Management training	9	1	1.14%
	2	Planner training	8	1	1.14%
	3	Craft training	7	1	1.14%
Q4	1	Budget planning	7	1	1.14%
	2	Reporting and feedback	2	2	1.28%
	3	Effective control	3	35	4.96%
Q5	1	Effective strategies	6	3	1.43%
	2	Strategy assessment	3	5	1.71%
Q6	1	Maintenance Information Systems	3	7	1.99%
	2	Software/ hardware	6	1	1.14%
Q7	1	Priority system	10	2	1.28%
	2	Work order system and procedures	2	2	1.28%
	3	Emergency & shutdown scheduling	13	1	1.14%
	4	Planning procedures	12	29	4.11%
Q8	1	Performance measures	9	2	1.28%
	2	Continuous improvement	7	1	1.14%
	3	Maintenance process re-engineering	6	10	1.42%
Q9	1	maintenance history records	2	3	1.43%
	2	equipment history records	10	1	1.14%
	3	spare part history records	9	1	1.14%
	4	Inventory system	8	1	1.14%
Q10	1	Inventory polices	5	1	1.14%
	2	Control procedures	14	1	1.14%
	3	Warehousing	5	2	1.28%
Q11	1	Specification	4	1	1.14%
	2	warranties & cost information	5	2	1.28%
	3	manuals & documentation	6	1	1.14%
Q12	1	Budget execution plan	7	5	1.71%
	2	Budget control plan	10	1	1.14%
Q13	1	Maintenance	8	1	1.14%
	2	Safety	12	3	1.43%
	3	Environment	4	1	1.14%
	Total	**37 Themes are identified from 61 In vivo codes with a word length of 2837**			

4.6. Integrated Computerized Equipment Management System Model

4.6.1. Introduction

It follows from the findings summarized in the previous chapter that the management of the equipment owned and used by the Addis Ababa City Roads Authority can be improved in a number of ways. Major improvements can be made in the area of equipment scheduling, allocation and utilization. Other areas of improvement are related to the expression and inventory of long term needs, the acquisition of equipment and fuel control.

One of the most important challenges is to lift AACRA's equipment management effort to a higher level of monitoring and control, which is commonly referred to as Fleet Management since it is concerned with the composition and efficiency of a fleet of equipment units as a whole. Fleet Management, in turn, is driven by performance metrics aimed towards targets for availability, utilization and life cycle costs. Although the targets may vary between different types of public and private organizations and their operational objectives, the principles applied in Fleet Management are the same all over the world and have been uncontroversial since their introduction a few decades ago. It is a matter of common sense that the Addis Ababa City Roads Authority urgently adopts these principles. The typical resource constraints inherent to being a Public Service Provider in a developing country can be no reason for not doing so. On the contrary: they are a good reason for AACRA to apply the world's most successful practices in fleet- and equipment management, so as to make the best possible use of the limited resources that are available.

Central to the improvement of AACRA's equipment management is therefore the introduction of a fully integrated Equipment Management System (EMS) that is capable of handling performance metrics and which offers some practical level of Fleet Management functionality. Integrated in this case means that the system should cover the full circle of justification, specification, acquisition, assignment, scheduling, utilization, maintenance and disposal of equipment. This rest of this chapter describes the specifications of the Equipment Management System and the conceptual framework it is based upon.

4.6.2. Conceptual Frame Work

The design of the proposed Computerized Equipment Management System is based on the following four concepts and principles of Best Practice equipment management. They are Equipment Inventory, Equipment Supply and Utilization, Equipment Maintenance and Fleet Management. Together they define the system's main objectives and functionalities.

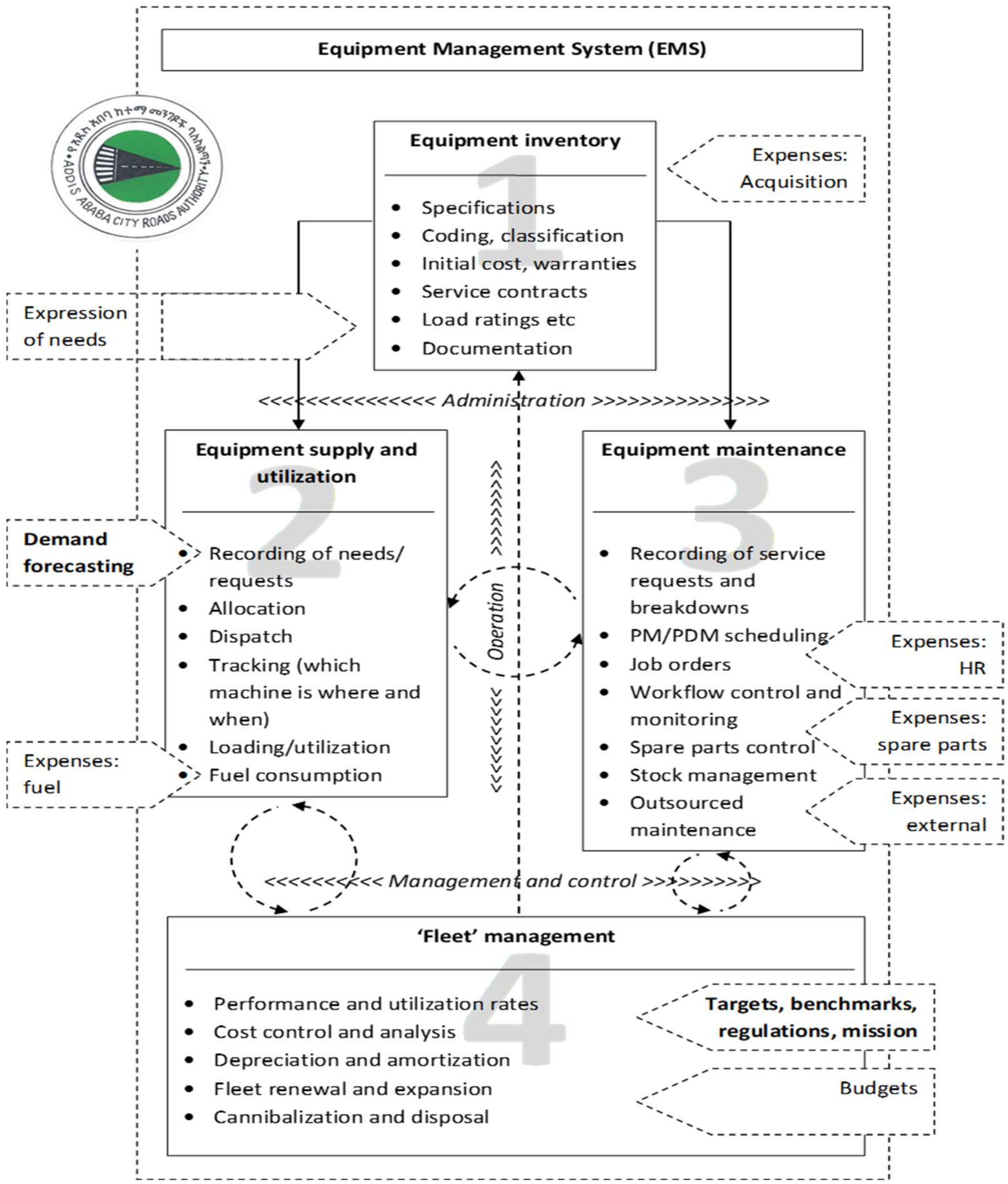


Figure 4.10: Conceptual Framework Model Developed by the Researcher

4.6.3. System Design principles and functionality

The Computerized Equipment Management System (CEMS) proposed should consist of integrated modules for equipment supply and administration (including cost charge backs), maintenance, consumables and spare parts control and provide fleet-level functionality with regard to equipment utilization and life-cycle cost analysis. The system must be secure, maintainable, flexible, scalable and user-friendly.

A system as described above requires careful professional development. It involves not only structural design of hardware (architecture and configuration) and software (platform and interfacing), but also the definition of procedures. Procedures are supported by forms; forms in an integrated computerized system are not just pieces of paper, but interactive carriers of information. They combine up- and down streams of information so as to be beneficial for (all) users, facilitate data integrity and consistency and are as easy as possible to fill out and feed back into the system. This paragraph summarizes the functionality of the main parts (sub systems) of the Computerized Equipment Management System.

4.6.3.1. Sub system 1: Equipment inventory

This part of the system is the foundation upon which the rest of the system is built. It contains the most important primary data such as equipment classes and units. It is also the portal to a digital library of manuals, drawings and catalogues. The equipment inventory is also the platform for condition monitoring, inspection results and their follow up, as well as for scheduling preventive maintenance by equipment class or unit.

4.6.3.2. Sub system 2: Equipment supply and administration

The main function of this part is the allocation and scheduling of equipment units, following the identification of needs (equipment requests) and the definition of clients, projects and tasks. An equipment allocation can (or should) be made long ahead in time and will take effect by dispatch through an equipment transfer. Release or return of equipment to the pool is also an equipment transfer. The allocation of equipment drives the creation of task sheets, fuel-, lubricant- and filter vouchers and equipment daily service sheets for operator-performed preventive maintenance.

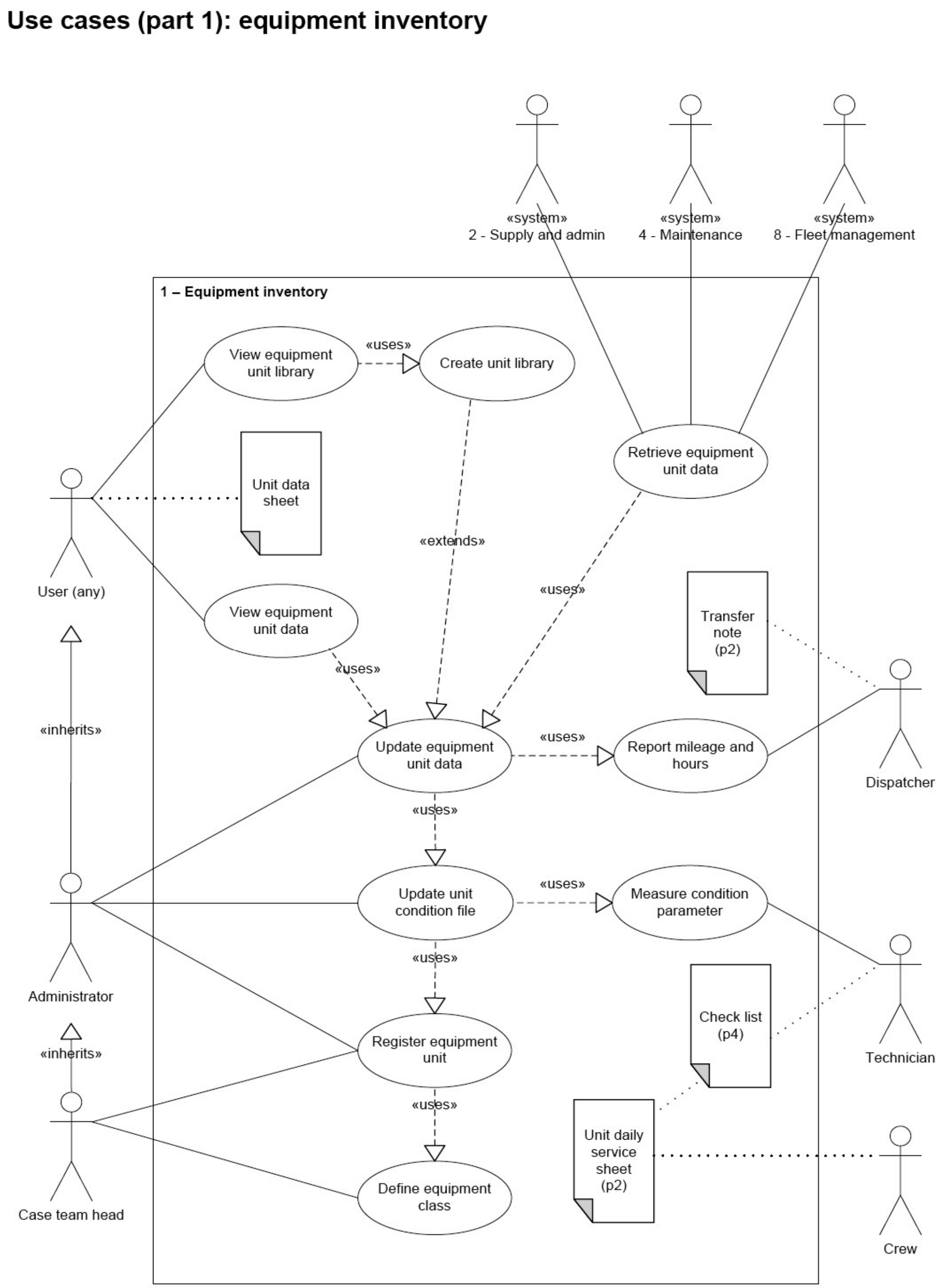


Figure 4.11: Equipment Inventory Subsystem Model Developed by the Researcher

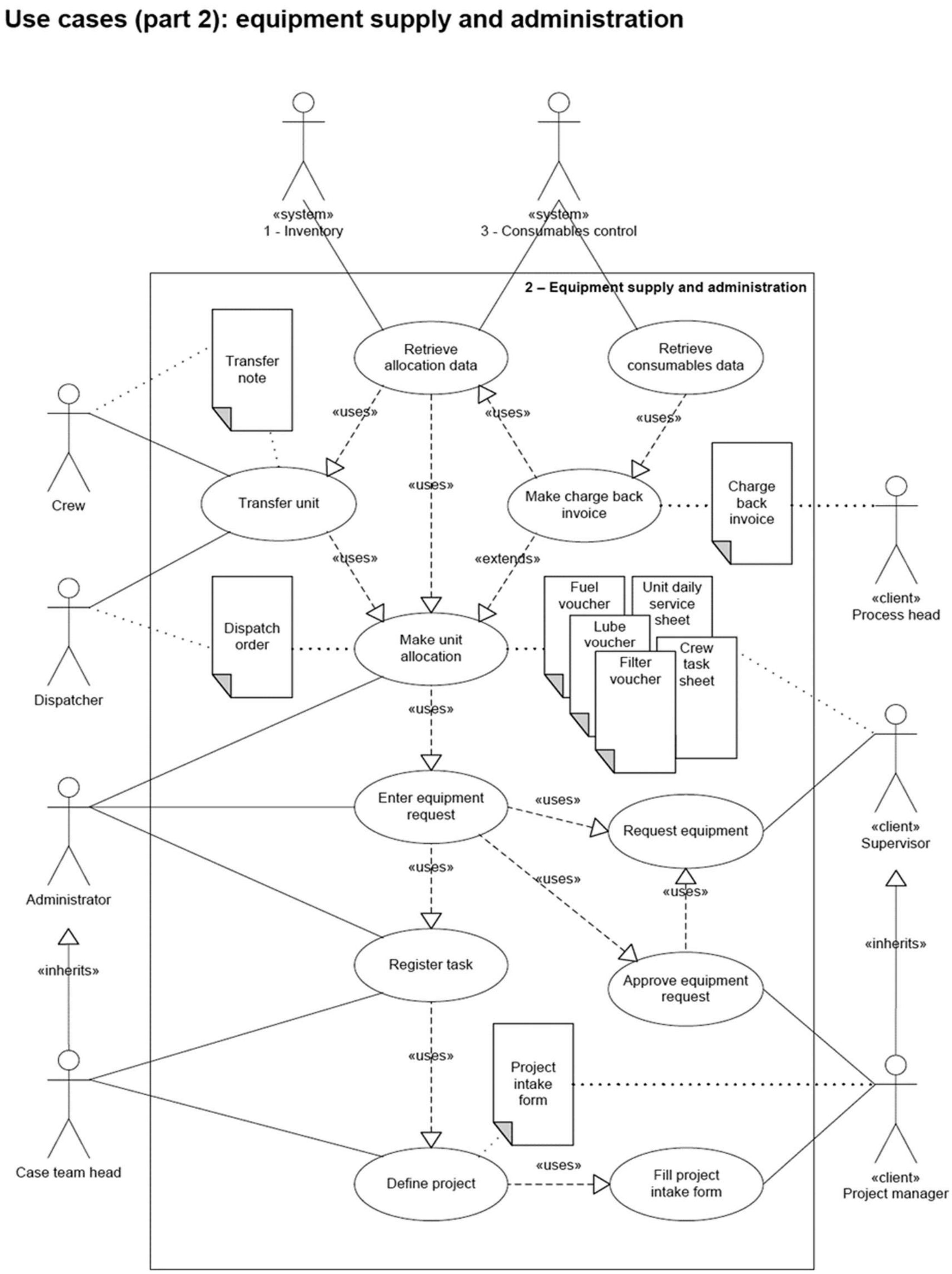


Figure 4.12: Equipment Supply & Administration Subsystem Model Developed by the Researcher

4.6.3.3. Sub system 3: Consumables control

This sub system handles the process of requesting, approving and issuing of fuel and other fast moving consumables (oil, lubricants, filters and if appropriate, tires). It anticipates that buffer stocks are kept and replenished regularly under framework contracts with preferred suppliers. The objective is to keep the buffer stocks small by making replenishment relatively fast and easy. The framework contracts themselves are treated as a normal purchase transaction that is processed by the Procurement Support Process.

4.6.3.4. Sub system 4: Equipment maintenance

Service requests and maintenance jobs are routed via shop orders into work orders for individual technicians. Work orders are scheduled and workflow progress is monitored on an individual basis and workload is tracked on shop-level. The work of the Mobile Garage Team(s) is also retrospectively entered into the system, while Mobile Service Calls are routed quickly through short channels but nevertheless registered. Service requests and maintenance jobs are always related to a particular equipment unit. When necessary, the unit is allocated for downtime through sub system 3. A class of ‘other jobs’ makes it possible to assign more general work orders (such as cleaning the workshop) to technicians. Work orders come with parts vouchers if the need for a particular part can be foreseen. Especially in the case of planned preventive maintenance, the system is capable of making timely parts reservations.

4.6.3.5. Sub system 5: Hour accounting

This part of the system keeps track of the workload (hours planned) and productivity (hours spent and approved) for maintenance technicians and other personnel if appropriate. It includes absence in different categories (sick leave, paid/unpaid annual leave, unauthorized etc). The sub system is week-oriented and focused towards weekdays and their (English/Amharic) names, to facilitate work order scheduling and clear communications between supervisors and technicians.

Use cases (part 3): consumables control

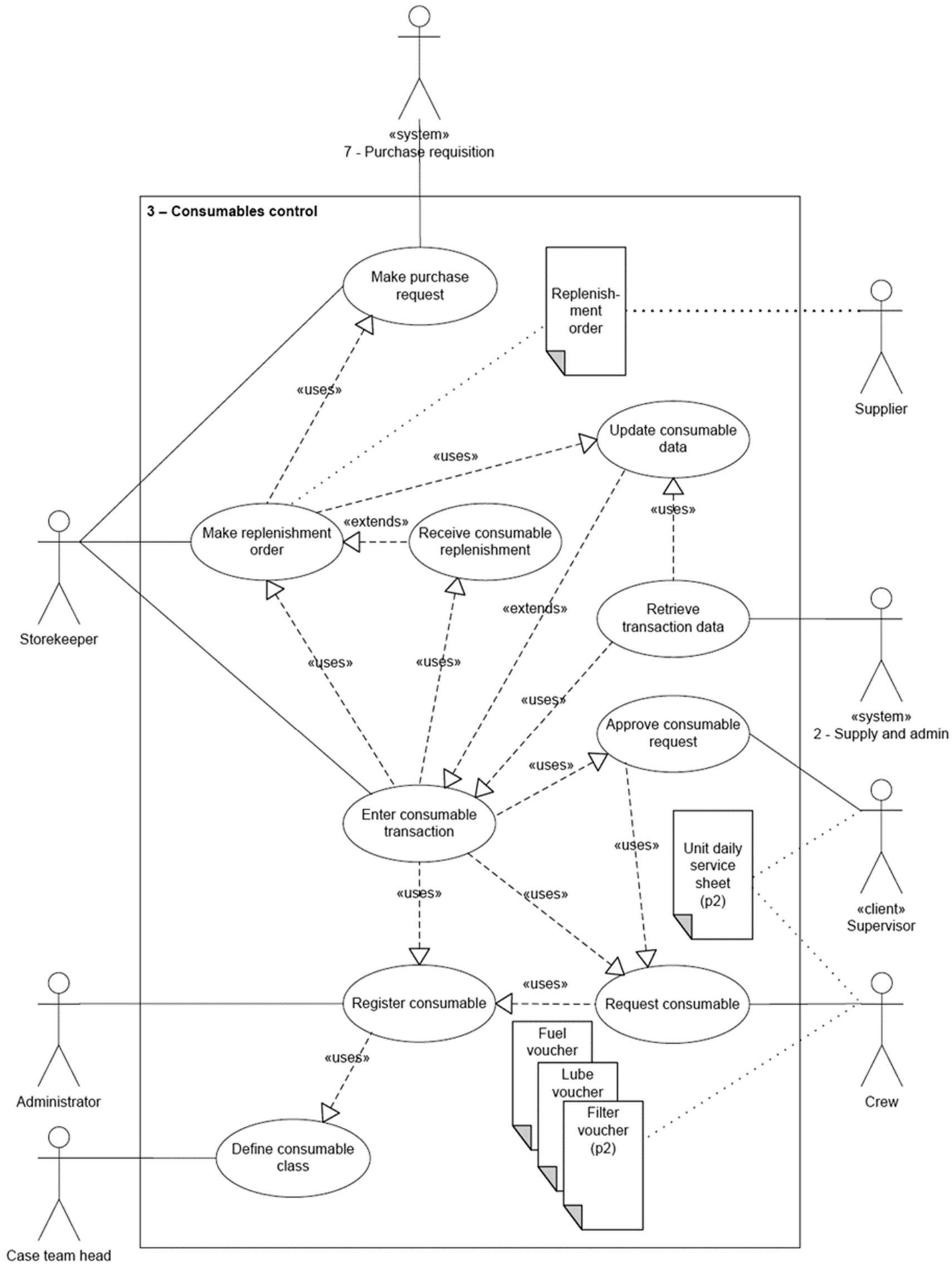


Figure 4.13: Consumable Control Subsystem Model Developed by the Researcher

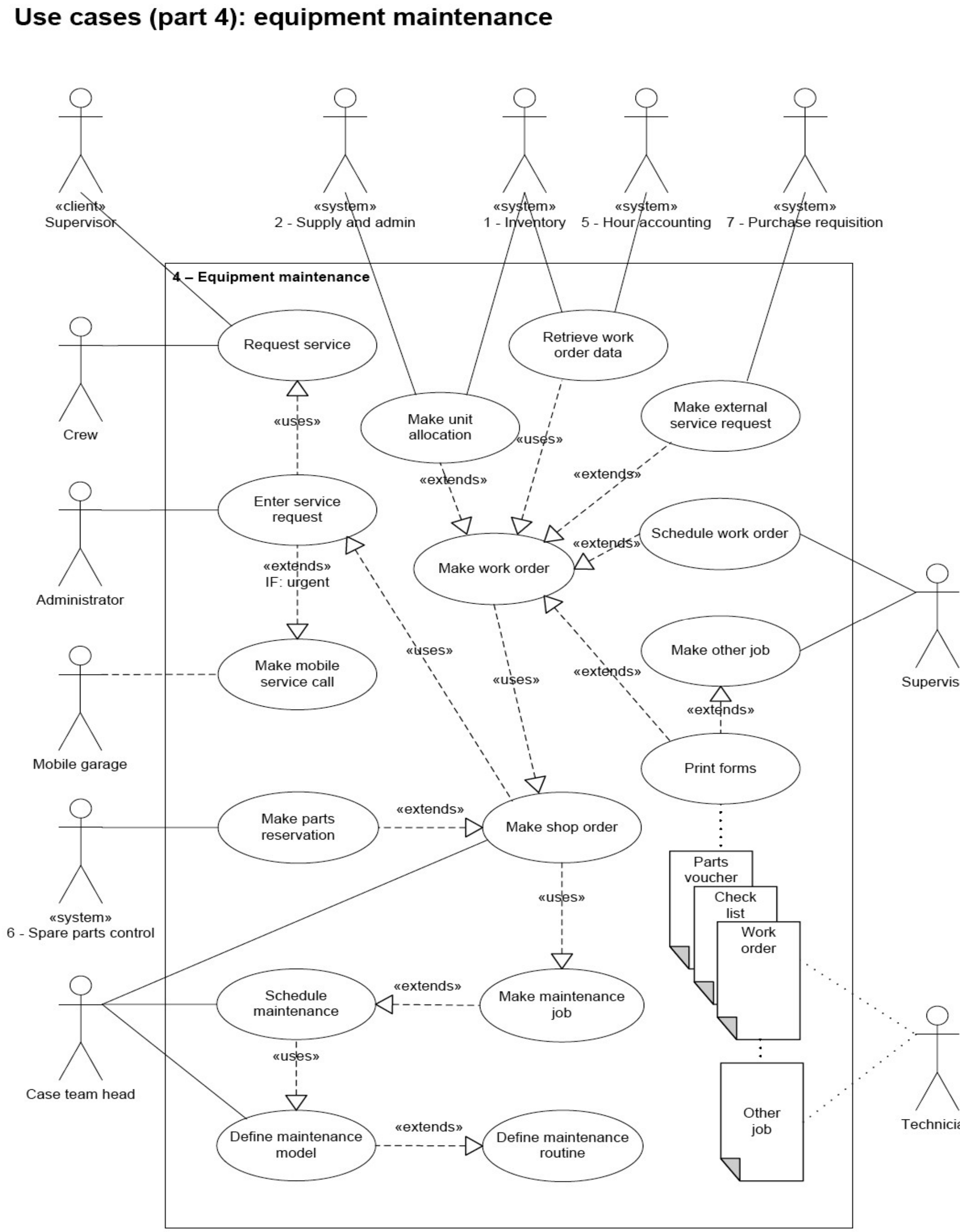


Figure 4.14: Equipment Maintenance Subsystem Model Developed by the Researcher

Use cases (part 5): hour accounting

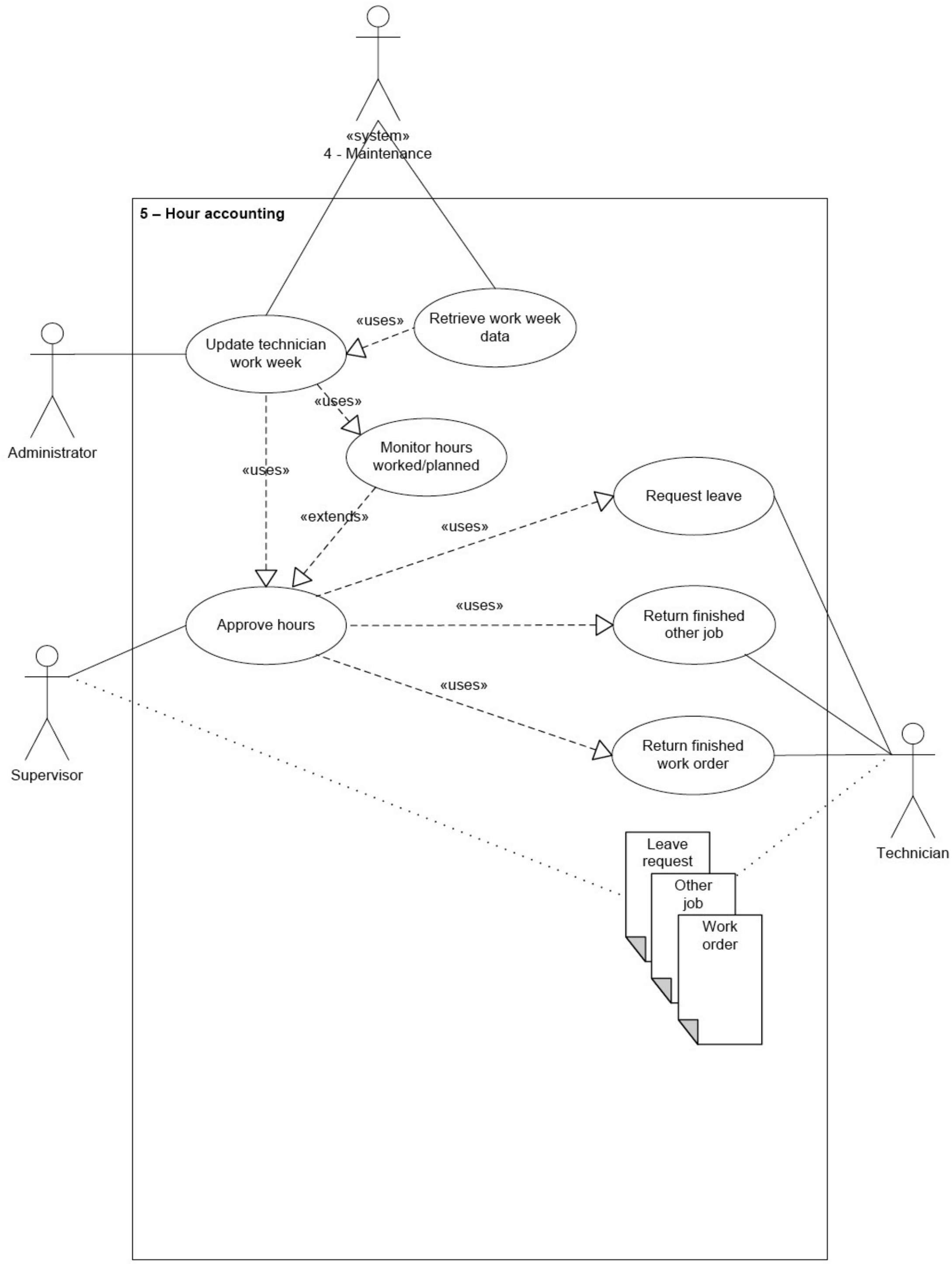


Figure 4.15: Hour Accounting Subsystem Model Developed by the Researcher

4.6.3.6. Sub system 6: Spare parts control

This sub system assists the management of spare parts stocks and their timely replenishment by minimum stock levels and forecasting. Spare parts requests are routed towards parts transactions or purchase requests in the case of stock-out or deliberate zero-stock items. Parts reservations can be made by the Maintenance sub system, but only for a limited period of time. The objective is to back-track spare parts transactions via work orders to equipment units. A class of ‘other requests’ makes it possible to issue spare parts for more general use, but only upon sufficient authorization.

4.6.3.7. Sub system 7: Purchase requisition

Purchase requests for spare parts (sub system 6), consumables (sub system 3) and external services (sub system 4) are forwarded to and executed by the Procurement department, but registered and monitored in the EMS as well. The main purpose of this sub system is the management of suppliers of technical materials and services. Supplier assortment, part codes etc. are related to equipment units and classes and vice versa to facilitate the ordering and purchasing processes. Purchase invoices and item line prices are also entered into the system to increase purchase control and to facilitate stock valuation and budgeting.

4.6.3.8. Sub system 8: Fleet Management

Fleet Management sub system calculates accurate performance metrics on the basis of equipment utilization (up time, down time and idle time) and life cycle costs (fixed-, operating- and maintenance costs) and ageing of equipment classes and units; the fleet metrics must provide all information necessary for the definition of charge back rates and decisions about equipment retirement/disposal and replacement.

Use cases (part 6): spare parts control

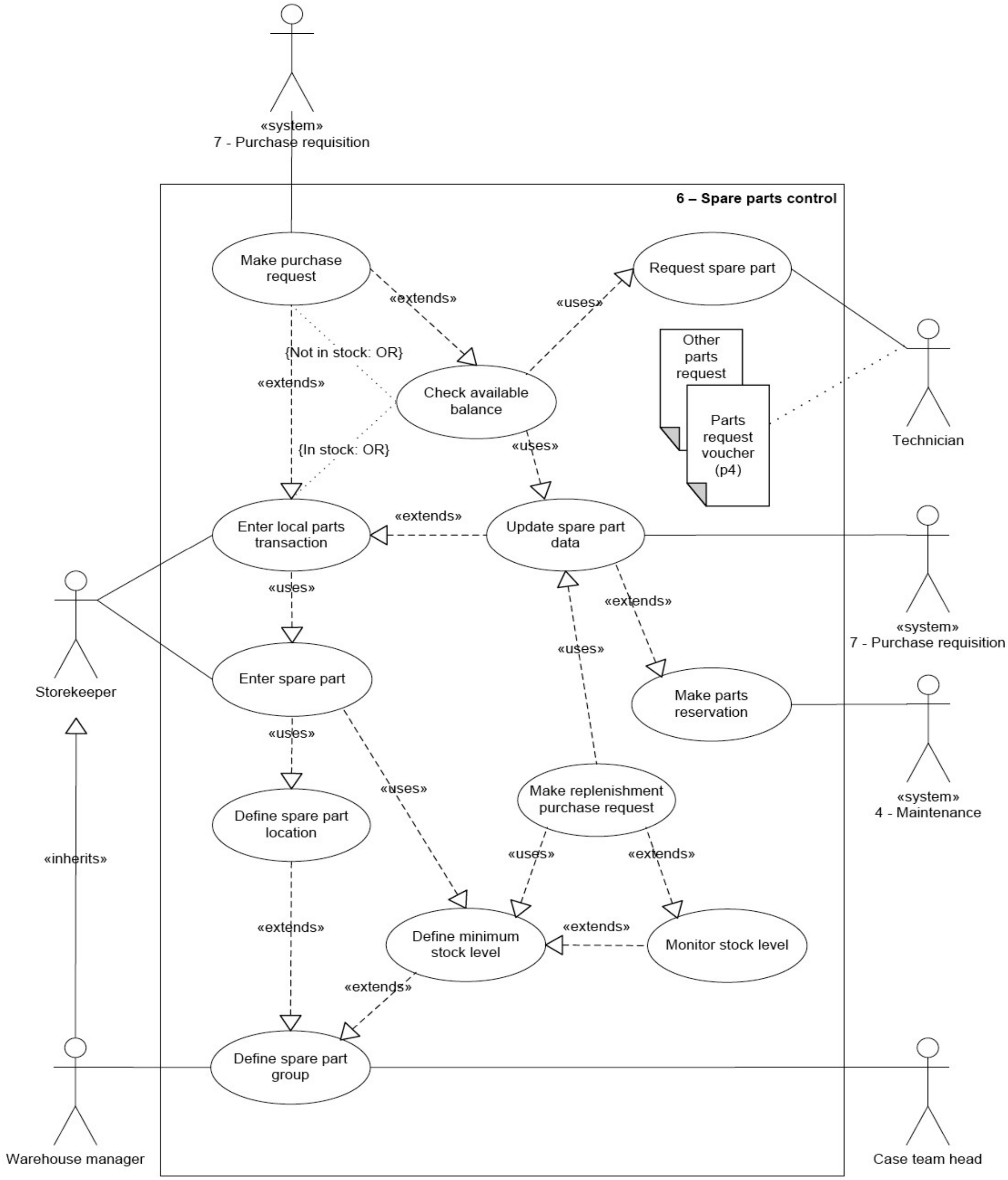


Figure 4.16: Spare Part Control Subsystem Model Developed by the Researcher

Use cases (part 7): purchase requisition

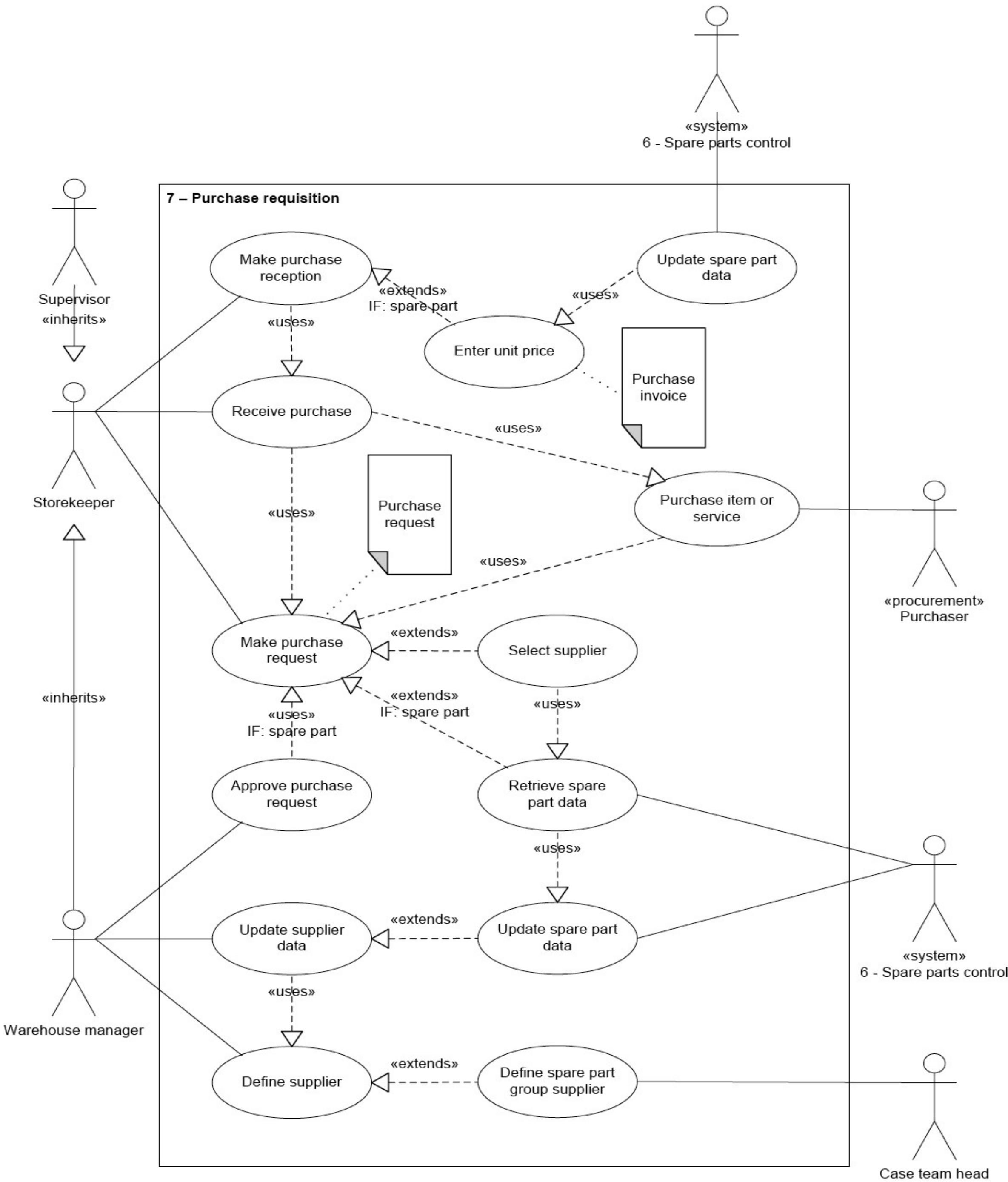


Figure 4.17: Purchase Requestion Subsystem Model Developed by the Researcher

Use cases (part 8): fleet management

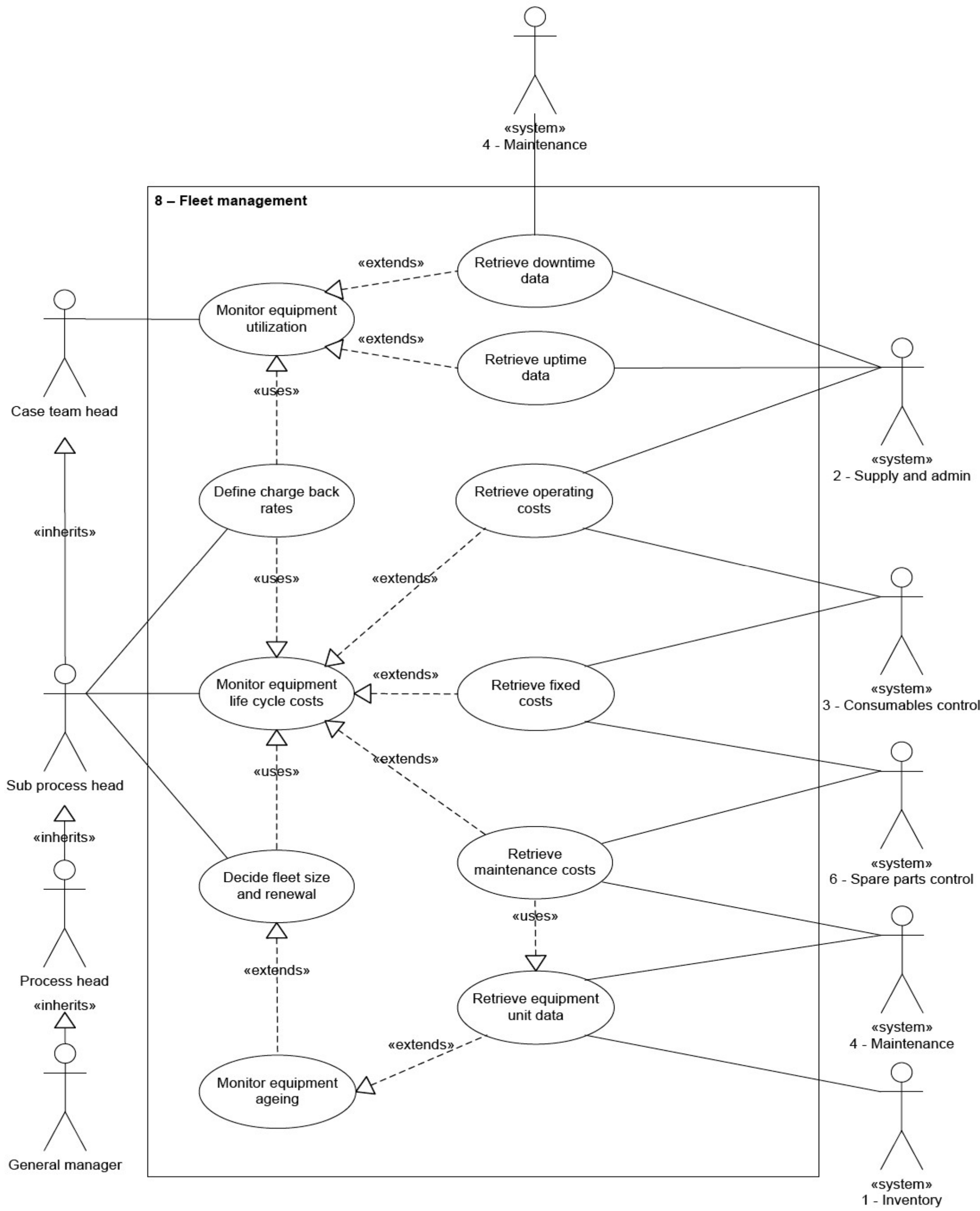


Figure 4.18: Fleet Management Subsystem Model Developed by the Researcher

4.6.4. Proposed system modules and their requirements

The *development* of an integrated Computerized Equipment Management System goes far beyond the scope of this Study and it is another study by itself, however the System should cover the full circle of justification, specification, acquisition, allocation, scheduling, maintenance and disposal of equipment. The proposed system modules are:

- to have an effective and efficient system for **Equipment Inventory**, including coding and classification and the recording of essential equipment unit data; the inventory must also provide access to technical documentation
- to have an effective and efficient system for **Equipment Supply and Administration**, which must be capable of processing equipment requests, allocating, scheduling and dispatching equipment units and their crew towards construction projects, as well as producing charge back invoices
- to have an effective and efficient system for **Consumables Control**, which must handle the requesting, approving and issuing of fuel, oil and lubricants, as well as the on-charging of their costs to the equipment user
- to have an effective and efficient system for **Equipment Maintenance**, which must be capable of processing work orders that are initiated by service requests (repairs) and maintenance models (scheduled services); the system must handle the routing and monitoring of work orders over different workshops and ensure the timely release of equipment for maintenance by full integration with the Equipment Supply Administration
- to have an effective and efficient system for **Hour Accounting** which keeps track of the workload and productivity of maintenance technicians; hours worked must be allocated via work orders to equipment units so as to calculate the labor component of maintenance costs
- to have an effective and efficient system for **Spare Parts Control**, which must handle the stock management and inventory of spare parts in different warehouses, as well as the requesting, approving and issuing of spare parts, including the registration of their use in/on particular equipment units so as to calculate the materials component of maintenance costs
- to have an effective and efficient system for **Purchase Requisition** for the direct procurement of technical parts, materials and services, follow up of their status; the system must maintain accurate information about suppliers and prices
- to have an effective and efficient system for **Fleet Management**, which calculates accurate performance metrics on the basis of equipment utilization (up time, down time and idle time) and life cycle costs (fixed-, operating- and maintenance costs) and ageing of equipment classes and units; the fleet metrics must provide all information necessary for the definition of charge back rates and decisions about equipment retirement/disposal and replacement.

CHAPTER 5 – CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study employed an in-depth methodological approach and, therefore, the research output is based on the findings derived from both the literature review and the results of the data analyses carried out in AACRA on equipment management operations. The key results and conclusions on the impact of CEMS on equipment supply, administration and maintenance at a conceptual and theoretical level are presented accurately and concisely in a way that answers the study objectives and are summarised below:

I. To assess the impact of CEMS in equipment supply, administration and maintenance efficiency and performance process in AACRA

By adopting a qualitative and quantitative approach, this study has provided an empirical assessment of the efficiency and performance of equipment management system in AACRA. The study shows that Addis Ababa City Roads Authority (AACRA) clearly has a great interest in equipment supply, administration and maintenance and has achieved a lot in the matter so far. Nevertheless, its efficiency and performance in terms of vehicle/equipment utilization, availability and reliability yet to be done. Whereas technical skills, manpower, materials and equipment are appropriately available, the equipment supply, administration and maintenance sub process lacks essential tools for equipment management to make optimal use of its resources. Given the span of control over different project sites locations and the evident relevance of maintenance and fleet management for the authority's core business, equipment management has thus far received remarkably little attention – both in terms of policy as well as IT resources.

II. To Identify the most common decision elements for CEMS integrations that enables the system workable in the context of AACRA.

The second objective of the research was to identify the most common decision elements for CEMS integrations that enables the system workable in the context of AACRA. This objective was addressed by undertaking a critical and extensive review of relevant literature on equipment management and system design for companies like AACRA engaged in road construction projects. By adopting the most comprehensive CEMS performance measure and decision element indicators, eight major decision elements were identified and were developed into a survey questionnaire. Qualitative structured interview questions with a theoretical concept and constructs that measure the impact and performance of the CEMS were also counter referenced with quantitative data on various on-going and current AACRA equipment management system with management team of ACCRA to draw on their experience and identify the most common decision elements. The reliability of the survey was checked by Cronbach alpha which showed that the questionnaire is reliable to use. The validity of the survey was examined by factor analysis. Factor analysis proposed 9 factors (decision elements) while the study had 8 factors (decision elements) which almost confirms the relationship between the study factors and dimensions of factor analysis.

III. To develop a detailed CEMS model with functional and technical requirements using Unified Modelling Language (UML).

This research objective led to the review of relevant literature, theories and models on CEMS for establishing the necessary constructs, theoretical framework and conceptual model in evaluating the equipment management effectiveness and performance in AACRA. Though the most established studies on the subject area lack the needed theoretical backing and underpinning. The identified gaps from the extensive literature review formed the basis of the main constructs identified were the eight factors consisting of the most common decision elements addressed under objective two. In the context of this study and by focusing on the factor indicator approach in assessing and evaluating CEMS performance and effectiveness as well as the main concepts identified, an evaluative measurement model (framework) was established using UML (see chapter 4). This aided an overall coherent approach for the systematic assessment of the contribution of the CEMS functionalities and features for AACRA.

The research findings demonstrate that the responses from the study generally concur with the research results affirming that, the findings, from the practical and theoretical perspective of the equipment management operations through the use of the computerized platform and modern IT solutions in AACRA are valid and accurately represent the CEMS infectiveness in the Authority. The faster implementation of CEMS and integration of IT knowledge with the existing products and the constant improvement of IT systems to provide a platform for offering efficient and effective use of equipment supply, administration and maintenance is urgent need for improvement in practice. This proves that real-time monitoring and interaction with fleet management are necessary to optimal fleet operation and provide a fast response to construction project needs. The implementation of a new CEMS based on this study's proposed model is a delicate interplay of various organizational factors.

5.2 Recommendation

It is recommended that the Addis Ababa City Road Authority (AACRA) implements an **Integrated Computerized Equipment Management System** that combines common Computerized Maintenance Management System (CMMS) functionality with spare parts management and a Computerized Fleet Management System (CFMS).

The primary **core** of any such equipment management system should be a versatile module for maintenance control (workflow management and PM) that actively supports the technical department with the **planning, routing and monitoring** of maintenance and repair works on all equipment and vehicles and fleet operations management that actively support **equipment supply and utilization**, **fuel supply, distribution and control**, **equipment inventory, cost control and analysis**. It should therefore contain a detailed database of the equipment/ vehicles (specs/age/mileage) and their functional parts, an expandable set of maintenance models with checklists for inspections and routine interventions, clear and mutually exclusive categories for job types and failure causes as well as a true projection of the department's organizational structure.

At the front end, the system's **workflow tool** must have a user-friendly interface for entering the department's hundreds of daily job orders without delaying their implementation, a single-click facility for routing and authorizing the jobs and a graphical **monitor** that shows both **workload** (by section/staff) as well as service **availability** (up and down times by equipment).

In addition to the fleet and maintenance control / workflow management module, the system should contain modules for **time accounting** (man-hours) and **materials accounting** (spare parts). Both modules must be interfaced with the planning function so as to routinely check the availability of man-hours and spare parts for planned work. Closed job orders must contain a cost calculation of hours and materials used. It is advised that the actual storekeeping (stock management) be done outside of the equipment management system, just as human resource management (the keeping of personnel files) is generally done outside of operational software. However, a strong interface must facilitate the **reservation/locking of spare parts** and the forecasting of their use.

Finally, the fleet management system should have a module for **vehicle/equipment allocation** which allows for a clear overview of the whereabouts of each and every construction machineries/vehicles against a timeline. This includes location (project sites), duty (utilization) and condition (fixed qualitative and quantitative parameters). The module would be the most important bridge between the maintenance case team and the equipment supply and administration case team, and must therefore be suitably **interfaced with operational software** (line management system). The two systems need to emulate the authority's core business in different ways: the primary concern of the maintenance case team is a/an vehicle/equipment (regardless of utilization), whereas the primary concern of the equipment supply and administration case team is supply and utilization.

Although it can be difficult to make **financial benefits** clearly visible in budget-driven organizations and public enterprises, systems for maintenance- and fleet management are known to **pay back their initial cost** in short time. **Direct benefits** are seen in the *efficiency* of technical work: e.g. reduction of overtime and rationalization of spare parts stocks and the use of tools and equipment. The **indirect benefits** are usually much larger and result from the increased *effectiveness* of technical work: higher production- and service levels through better plant- and asset availability.

However, the introduction of computer systems in operational organizations is always a delicate matter. Many implementations fail because of a discrepancy between the software's features and requirements on the one hand and the organization's needs and capacity on the other. Computer systems should **not be implemented for the sake of computerization only**; they must fulfill a specific demand for support with part of a process that as such is carried out by humans. This is especially true for equipment management.

In the case of the Addis Ababa City Roads Authority this means that the chosen software package **must not complicate** the process of technical maintenance and fleet management or increase bureaucracy; it must also not require a reorganization to use the software to its full extent. Rather, the software must simplify the implementation and administration of technical work and assist with the further development and fine-tuning of the authority's equipment management strategy. It is therefore recommended that the AACRA chooses a versatile software package that can be **customized** to the company's organizational structure, its technical constraints and possibilities and the expertise already available in its workforce. Summarizing the above, the recommended implementation of an integrated computerized equipment management system should take into account the following **remarks and considerations**:

- The system must be equipped with base data that truly reflect the technical nature and requirements of all vehicle types, based on engineering analysis of specifications, operating conditions, historical data and experience of the authority's equipment supply, administration and maintenance sub process.
- The level of detail of the base data must allow for a precise control of all technical work and support dynamic models for preventive maintenance.
- The system should process the entire workload of the technical department including repairs, preventive maintenance, component modifications and work for third parties (on-charged).
- The system should be networked over the three spare part warehouses (if cannot be merged together at the main maintenance center), head quarter (HQ) especially to procurement, finance and human resource, but not require full time connectivity to be minimally functional in each location.
- The system should provide relevant management information at different levels of detail for the different layers in the organization, both through on-line user accounts as well as by hard copy multiple reports (daily, quarterly, yearly, and historical).
- The system should include a module for equipment/vehicle allocation that facilitates the communication between the equipment supply and administration case team and construction equipment planning team under the road construction sub process as well as

project managers at every site and optimizes the utilization and availability of the equipment/vehicle.

- The system should have a module for time-accounting of technical staff that allows for performance monitoring, job evaluation and motivational measures/incentives.
- The system should be interfaced with the company's stock management system, allowing for availability checks, stock reservations, forecasting and eventually stock mutations.
- The system's requirements should keep pace with the possibilities within the authority’s growing IT-environment and infrastructure, while its implementation should not exceed the available capacity to manage and maintain specific software packages.
- It must, however, remain possible to integrate the equipment management system in a larger MIS environment at any stage, with proper interfaces towards operations (Amharic and English langue interface, Simple user interface, Simplicity of error messages, High security levels, and Local technical support), administration and finance.

Implementing an equipment management system that meets these requirements will **empower the equipment supply, administration and maintenance sub process** of the Addis Ababa City Road Authority (AACRA) to make full use of their capacity, skills and resources. With the appropriate management support this will increase the authority’s quality of service, and its return on fixed assets. Apart from the fact that the equipment management system as such is a **necessary tool** for the **equipment supply, administration and maintenance sub process** to fulfill its increasingly challenging responsibilities, its implementation is also a **logical first step** in the modernization of the authority’s business processes through the application of information technology. A **solid base in equipment management** will create optimal conditions for a computerized approach of line management. The improved and streamlined administration of the authority’s core functions (operations and technical maintenance) will provide firm ground for the necessary computerization of the executive layers (administration and finance). The final objective must be a Management Information System that is **beneficial to all layers** of the organization, so that it will be supported and duly maintained by everyone involved. The recent history of worldwide corporate development gives enough evidence to suggest that management information systems better be rolled out '**bottom-to-top**' rather than 'top-down'.

5.3 Limitation of the study

Identifying the limitations of any research helps improve its acceptance and the general applications of the findings. There are some potential limitations that should be borne in mind in the interpretation and generalization of the findings of this research. The focus of the empirical aspects of this study was entirely based on the experiences of AACRA. The convergence of the findings with general body of knowledge and supported by the validation results further reinforce the credibility of the research findings. It is very important to acknowledge the limitation which the relatively narrow population frame considered in the study imposes. Though limiting the sample frame to Equipment Supply, Administration and Maintenance Directorate assessing the overall equipment management ineffectiveness draws its theoretical strength from mainstream project management, management and human resource practice on site. It can be contended that practically, some related issues of equipment pooling and cost charge backs, task based consumables and spare parts distribution and operator-performed preventive maintenance ineffectiveness that happen in specific construction project may not come to the attention of the ESAM department. Additionally, various professionals may experience communication problems unique to their related tasks and core functions either than the team equipment supply and administration unit .

Hence expanding the sampling frame to have included all the project team participants on equipment management could have enriched the findings and increased its potential generalization. Additionally, the cross validation of the results in the model suggested that, indeed these findings are critical if equipment inventory, equipment supply and administration, equipment maintenance and fleet management on integrated equipment management system should be effective. As hinted by Hair et al.(2014& 2013) and Kline (2010) that most statistical analytical approach and tools are affected by issues of multicollinearity, sampling inconsistencies, measurement errors, analytical bias which are likely to impact on the results and the potential conclusions to be drawn from the findings. However, notwithstanding the potential of these highlighted above, it can be suggested that the demographic profile of the respondents in experience, knowledge & understanding on the subject matter and consistencies registered in the statistical analysis indicate some degree of reasonable credibility and trustworthiness in the results from the survey.

5.4 Future Research Work

There are a number of recommendations for future research work around equipment management system in research that follow from our findings, and would benefit from further research, including realist evaluation to extend and further test the model the researcher has developed here:

1. Research to develop a prototype/pilot project or simulation based on the proposed models to develop the main functionalities of the CEMS on a suitable platform.
2. Further research might compare, the selection, design, development and implementation of CEMS based on the proposed model for large private and public construction companies.
3. Research to develop approaches and carry out a full cost–benefit analysis of equipment management in general and CEMS in particular through numerical analysis to improve the profitability and cost reduction of equipment management on the construction projects.

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Appendix A- Structured Survey Questionnaire

Thesis Title

“ Development of An Integrated Computerized Construction Equipment Management System (CEMS) For Addis Ababa City Roads Authority ”

Dear Respondent,

You are herewith invited to participate in an academic research study conducted by ZERIHUN TARIKU HUNEGNAW, a student in in Jimma University, Department of Civil and Environmental Engineering.

The main objective of this research work is to design and specify an integrated Equipment Management System (CEMS) model for Addis Ababa City Roads Authority (AACRA).

All your answers will be treated as confidential, and you will not be identified in any of the research report emanating from this research. Your participation in this study is very important to us. You may however choose not to participate and you may also withdraw from the study at any time without any negative consequences.

Please answer the questions in the attached questionnaire as completely and honestly as possible. As a result, every of your opinion thereon has valuable credit to the usefulness and outcome of the research. This should not take more than 15-20 minutes of your time.

The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of our findings on request.

Yours sincerely

Zerihun Tariku Hunegnaw
Msc student, Jimma University, Department of Civil and Environmental Engineering
Tel: +251911434644, email: zerihuntariku@yahoo.com

I, ____, herewith give my consent to participate in the study. I have read the letter and understand my rights with regard to participating in the research.

__________________________ ______________________

Respondent’s signature **Date**

Structured Survey Questionnaire

Please provide the following information regarding your work situation by marking an **X** in the appropriate box. Please feel free to write any comments in the comments field. If the question does not apply or you do not have the information necessary to answer, then leave the line blank.

Section A - Biographical Information

This section of the questionnaire refers to background or biographical information. Although I am aware of the sensitivity of the questions in this section, the information allows me to compare groups of respondents. Once again, I want to assure you that your response will remain anonyms.

1. In which department are you currently working?

Equipment supply, administration and maintenance works	1
Machineries and vehicles maintenance case team	2
Machineries and vehicles supply administration case team	3
Spare parts supply and finance case team	4

2. What is your current length of service in years within the company?

Less than 5	1
5-10	2
11-15	3
16-20	4
More than 20	5

3. How many years have you spent in your current position?

Less than 5	1
5-10	2
11-15	3
16-20	4
More than 20	5

4. What is your highest education qualification?

Less than grade 10	1
TVET/10+2	2
Diploma/advance diploma	3
Graduate degree	4
Postgraduate degree	5

SECTION B – MAIN STUDY QUESTIONNAIRES

This questionnaire is to measure the value of major critical success factors for the selection, development and implementation of an **Integrated computerized equipment management system (CEMS) functionalities** based on the proposed and developed Integrated Equipment Management Conceptual Framework Model for Addis Ababa Roads Authority(AACRA). Please indicate whether you strongly disagree, disagree, are neutral, agree or strongly agree with the statements that the model proposes.

SN	Module / functionality	Ref	Survey questions	Strongly Disagree	Disagree	Neutral	Agree	Strongest Agree
1	**Asset Inventory**	1.01	AACRA uses computer generated system in a place to produce asset overviews by category and class.	1	2	3	4	5
		1.02	AACRA uses computer generated system in a place to produce overviews of asset allocations by class and unit.	1	2	3	4	5
2	**Tools supply & Administration**	2.01	AACRA uses computer generated system in a place to produce overviews of tools requests and allocations by client, units and status (open, allocated, dispatched, returned)	1	2	3	4	5
		2.02	AACRA uses computer generated system in a place to produce overviews for tools dispatch and return/release.	1	2	3	4	5
		2.03	AACRA uses computer generated system in a place to produce schedules of tools allocation (future) and utilization (past).	1	2	3	4	5
3	**Consumables control**	3.01	AACRA uses computer generated system in a place to produce up-to-date stock reports (balance) at any time.	1	2	3	4	5
		3.02	AACRA uses computer generated system in a place to produce transaction overviews (in/out) by consumable and class.	1	2	3	4	5
		3.03	AACRA uses computer generated system in a place to produce counting sheets for inventory and stock checks.	1	2	3	4	5
		3.04	AACRA uses computer generated system in a place to produce consumption overviews per machine/ equipment unit and client/department//section/unit/task.	1	2	3	4	5
4	**Asset maintenance**	4.01	AACRA uses computer generated system in a place to produce up-to-date overviews of work orders on hand by workshop/discipline and by technician, including planned completion dates.	1	2	3	4	5
		4.02	AACRA uses computer generated system in a place to produce overviews of work orders completed including	1	2	3	4	5

SN	Module / functionality	Ref	Survey questions	Strongly Disagree	Disagree	Neutral	Agree	Strongest Agree
			schedule compliance (late/on time) by workshop/discipline and by technician.					
		4.03	AACRA uses computer generated system in a place to produce overviews of work orders planned, equipment availability (allocation status) and workload by workshop/discipline and technician.	1	2	3	4	5
		4.04	AACRA uses computer generated system in a place to produce overviews of work orders by order type (breakdown, scheduled maintenance, predictive maintenance) and by asset unit.	1	2	3	4	5
5	**Hour accounting**	5.01	AACRA uses computer generated system in a place to produce overviews of hours booked by category and technician.	1	2	3	4	5
		5.02	AACRA uses computer generated system in a place to produce monthly overtime reports.	1	2	3	4	5
		5.03	AACRA uses computer generated system in a place to produce reports with productivity and sick leave/absence statistics.	1	2	3	4	5
6	**Spare parts control**	6.01	AACRA uses computer generated system in a place to produce stock reports (balance and value) by (sub)group and stock location, as well as overall total stock levels, calculate depreciation.	1	2	3	4	5
		6.02	AACRA uses computer generated system in a place to produce transaction overviews by spare part and (sub)group, client/requestor, asset type and unit, budget.	1	2	3	4	5
		6.03	AACRA uses computer generated system in a place to produce stock reviews for non-, slow, and fast moving items, analyzing stock value and turnover.	1	2	3	4	5
		6.04	AACRA uses computer generated system in a place to produce categorized stock lists with item codes for lookup/reference by technicians and administrators.	1	2	3	4	5
7	**Purchase requisition**	7.01	AACRA uses computer generated system in a place to produce overviews of purchase requisitions by status, showing requestor and/or work order details, supplier and date requested/promised/delivered.	1	2	3	4	5
		7.02	AACRA uses computer generated system in a place to produce categorized supplier lists.	1	2	3	4	5
8	**Fleet management**	8.01	AACRA uses computer generated system in a place to produce fleet-level asset inventories (acquisition value, depreciation, current value, salvage value).	1	2	3	4	5
		8.02	AACRA uses computer generated system in a place to produce overviews of key performance indicators	1	2	3	4	5

SN	Module / functionality	Ref	Survey questions	Strongly Disagree	Disagree	Neutral	Agree	Strongest Agree
			(utilization, fuel/FOL consumption, up/downtime, age/status, costs) per equipment class, type and unit.					

Comment Box: if you have any comment please feel free to write below. If the box is not enough use any paper and attach with this questioner

Appendix B- Structured Interview Questions

Date………………….

Dear Madam/Sir:

This letter is to ask your consent to participate in an interview question. I assure you there is no risk involved in your participation. If you have any questions concerning the study, you can raise it at any time. For further information, please contact me, the principal researcher: **Zerihun Tariku Hunegnaw** using my cell phone +251911434644 or email zerihuntariku@yahoo.com

I am a Masters student in Jimma University, Department of Civil and Environmental Engineering, conducting a research study entitled ***" Development of An Integrated Computerized Construction Equipment Management System (CEMS) For Addis Ababa City Roads Authority "*** under the supervision of Dr. Dr. Bahiru Bewket (PhD) & Ato Abebe Eshetu (Msc). The main objective of this research work is to design and specify an integrated Equipment Management System (CEMS) model for Addis Ababa City Roads Authority (AACRA). The specific objectives are to:

1. Study the existing management system
2. find out the limitations of the existing management system
3. propose the new Computerized Equipment Management System Model

I would like to know whether you would be willing to participate in the Interview Questions in which you will be expected to answer questions that is presented to you by the researcher. The Interview process will take about 15- 20 minutes. With your consent, I will record the session since it enables me to capture all the information forwarded by informants. Although participating in this study might not benefit you directly, you can make a considerable contribution to identify appropriate criteria for decision makers to focus on and improve the equipment management practice in Addis Ababa City Roads Authority (AACRA). I will, upon request, also provide you a copy of the structured interview questions.

You only have to participate if you choose to do so. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. The results of the study will appear in the final thesis, but none of the participants' names will be disclosed. The information obtained from you through the Interview discussion will only be used for the purposes of this study and it will be confidential. The only people who will be allowed to access the audio-records and the transcriptions are I and my Advsior and Co-advisor, who is there to check whether or not I am doing the study correctly. The audio-recorded and transcribed data will be kept safe in my office for five years from the completion of the study, and then be discarded with great care.

Yours sincerely

Zerihun Tariku Hunegnaw
Msc student, Jimma University, Department of Civil and Environmental Engineering
Tel: +251911434644, email: zerihuntariku@yahoo.com

Structured Interview Questions

Interviewee: ________________________ Interviewee Position: _________________
Department: ________________________ Section (if any): _________________
Venue: ________________________ Time: ________________________
Interviewer: Zerihun Tariku, email: zerihuntariku@yahoo.com , tel: +251911434644
Advisor: Dr. Bahiru Bewket (PhD)
Co-Advisor: Ato Abebe Eshetu (Msc)

Q.#	QUERY	REMARK
1	Do AACRA have a Clear mission and quality statement which addresses/supports Equipment management?	
2	Are there documented Policies, Programs and Procedures regarding Equipment Management System?	
3	What are the major problems regarding the existing Equipment Management System at managerial level?	
4	The Current study identifies underlying problems, Assesses the existing system and finally gives recommendations. What are the future plans to implement a reliable Equipment management system?	
5	What does Fleet renewal, expansion and Disposal Policies of AACRA look like?	
6	Do you review and evaluate your Equipment rental and purchase guidelines towards standard guidelines Periodically?	
7	Do the GM and/or D-GM –office receives reports regarding maintenance activities, fuel supply, distribution and control	
8	Is there Periodic Management Evaluation and Comparison between Contract and own asset Performance at AACRA client Council level?	
9	Is there a structured Identification and presentation of Long term requirements for renewals and replacements of the Equipment to the top level management?	

10	Do you believe that AACRA follows appropriate maintenance Philosophy? Is there a plan to introduce Proactive Strategy Programs to AACRA?	
11	What does the annual budgeting for fleet and maintenance look like?	
12	What is AACRA's view towards Computerized Equipment Management System (CEMS)?	
13	What are the challenges you are facing in terms of equipment purchase, utilization, maintenance and disposal at AACRA level?	

14. ADDITIONAL COMMENT BOX

Jimma University Department of Civil & Environmental Engineering	
Appendix C- Verbatim Transcription: Semi Structured interview	
Student	***Zerihun Tariku Hunegnaw, Student Number RM8667/10***
Research Title	**Developing An Integrated Computerized Construction Equipment Management System (CEMS) For Addis Ababa City Roads Authority**
Advisor/s	**Dr. Bahiru Bewket (PhD) & Ato Abebe Eshetu (Msc)**
Location & Time	**Addis Ababa, November, 2021**
Interview Questions	**Interview Extracts**
Q1	Apart from a trend mutually understood by the employees of the maintenance center and interlinked sub process at Head office, there are no policies, programs and procedures regarding Equipment management which any relevant personnel or manager can refer to whenever needed. AACRA does not have written policies and procedures that direct managers to identify and report underutilized equipment or instructs managers on what corrective action to take if they suspect or detect underutilized equipment. Without clearly defined authority and responsibility to identify, report, and act upon underused or idle equipment, the maintenance center likely retains underused or unneeded equipment in its heavy equipment fleet. Keeping underused and idle equipment in the fleet is inefficient, causing unnecessary expenses associated with storing and maintaining that equipment and preventing the authority from converting the asset to cash and using it for other priorities.
Q2	AACRA has a clear mission and vision statement for the purposes of its establishment. Though a separate statement regarding Equipment management system is not in place, the management has a strong willingness to address the issue of Equipment management. The Addis Ababa City Road Authority is structurally organized as; general manager and deputy general manager offices, Main Process (i.e. Traffic Engineering, Road and Transport Infrastructure Design, Road and Transport Infrastructure Construction and Maintenance, Road and Transport Infrastructure Administration, Plan and Program, Internal Audit, finance, procurement and property administration, communication affairs, Legal service and human resources), Sub Process, case teams and units. Equipment supply, administration and maintenance sub process is one of the sub process found under Road and Transport Infrastructure Construction and Maintenance main process. Currently the Authority has no clear organization structure due to new Business Process Re-engineering (BPR) review and study that is going on to take over the old BPR structure implemented before two years and currently in use. Establishment of clearly defined maintenance visions, goals and objectives, formal maintenance process documentation (policy and procedures), clarification of maintenance job roles and responsibilities, and following all the maintenance procedures is mandatory for better equipment management.

Q3	Currently AACRA's existing complex construction equipment demands a number of professional skills. If mechanics lack equipment specific -item training (type rating), then their "repairs" may be ineffectual or, leads more expensive premature failures. Likewise, equipment operators must understand how to obtain maximum efficiency and safety from their equipment, and this requires more deliberate instruction than the "learn as you go" approach. No matter where they obtain their knowledge, skills, and abilities (KSA) whether from local training institutes (like ERA), equipment dealers, or their employers (coaching) operators must prevent unnecessary, improper wear on their assigned equipment. The involvement of Equipment Supply, Administration and Maintenance sub process regarding training activities is less; for instance, there was a request of 23 candidates for short term training from different department but ESAM sub process did not request any candidates for 2013 E.C budget year. In 2020 G.C operation training was given for 8 operators but not on Equipment management. The training currently given to AACRA's technical personnel is the basic training which is conducted in Ethiopia Road Authority (ERA) training center to have basic operator license. In a modern equipment management system the maintenance personnel should be trained for specific equipment in purchase time. Numerous human resources studies have demonstrated that good training programs lead to less personnel turbulence and higher morale. The costs avoided thereby are significant and such cost savings are additive with expenses reduced or eliminated through the better maintenance programs which, in turn, also result from effective training. Thorough training of maintenance personnel substitutes for highly formalized procedural rules. Besides encouraging a greater sense of employee responsibility from job enlargement and enrichment, better-trained mechanics and foremen provide greater tasking flexibility and staffing depth for the organization. More employee skills equal more value to the AACRA. All personnel who have any role in attaining high standards of equipment maintenance must be well trained. It is clear that job satisfaction has a direct relationship with the efficiency of the technician; hence a job satisfaction survey needs to be done periodically to study the existing situation on the ground and come up with a solution. This also helps o control the annual turnover of especially skilled manpower. There is no financial motivation mechanism for the employees, which is also another technique for maximizing the efficiency of the employees. Of course there is no a fixed set of criteria put to award and recognize a certain employee annually, AACRA gives certificates of recognition for one employee from each section/case team. Previously they were directly selected by the management; the recent experience is the employees themselves vote for the ones.
Q4	Currently in AACRA there is available Annual plan on fleet and maintenance budget, Cost reporting of annual maintenance work but reliable and measured the standard cost controlling, especially on labor hour, tools and facility cost. Budget documentation regarding equipment management Established periodic budget execution plan Controlling budget against expenditure regarding parts Limitations are Controlling budget against fuel and lubrication There is no evaluation on how works are identified in each year budget plan. There is no long term requirements for new equipment purchase enquiry and replacement of existing equipment with standard LCC analysis

Q5	Corrective maintenance/Breakdown maintenance is a system in which equipment/vehicle is run or operated until breakdown. This "Fire Fighting" maintenance culture is currently followed in most of the times by the AACRA maintenance center. PREVENTIVE MAINTENANCE (PM) is done to prevent the occurrence of failures and to detect them before they develop to break down or disturbances in operation (product/service). Preventive maintenance has become a term with broad definition. The generic definition of PM is any planned maintenance activity that is designed to improve equipment life and avoid any unplanned maintenance activity. In its simplest form it can be compared to the service schedule for vehicle. There are certain tasks scheduled at varying frequencies, all designed to keep the vehicle from experiencing any unexpected breakdowns. There is a lubrication program that makes sure that equipment/vehicles are lubricated routinely and properly with the appropriate lubricant on field and at the maintenance center. Operating personnel have most of the responsibility for preventive maintenance work that is done while equipment is on project but is not supported by standard checklist and operator trouble report. There is a trial on schedule maintenance implementation on site and from discussion with technical personnel there is no consistent program and controlling system accompanied by a feedback report. There is no clear guidelines governing projects and maintenance case team so that Projects deliver Equipment for scheduled maintenance. There should be measurements to monitor the performances and the results of the Preventive Maintenance Process. Implementing Predictive maintenance (PDM) immediately in AACRA case is difficult since it requires high initial cost for purchasing of PDM tools, sensors, training the staff, shop arrangement for Non Destructive Test (NDT) purpose. Therefore, a gradual introduction of modern techniques of Predictive maintenance (PDM) and ultimately full blown PDM which supports the coming maintenance program and policy should be included in the future plan of AACRA.
Q6	The Computerized Equipment Management System (CEMS) is a multi-level system, which contains an equipment asset register with an excellent level of information on the equipment itself and also on the checking, testing and examination requirements relating to each piece of equipment. One of the key strengths in the Information Technology area is the use of CEMS, which is fully integrated with Purchasing and Accounts. CEMS is a very intuitive user friendly maintenance package that is capable of being used by production and trades personnel and supports the fundamental requirements of the maintenance business process. It also has a recording function for the appropriate checks, tests and examinations as well as a diarized schedule that prompts those with responsibilities to carry them out. The Computerized Equipment Management System (CEMS) can be interrogated by those with operational management responsibilities and those with Head Quarter (HQ) functions to monitor whether the appropriate systems are being maintained. The Computerized Equipment Management System (CEMS) also recognizes the mobile nature of equipment within the Service and contains the necessary flexibility for the transfer of equipment between stations and other locations such as repair workshops. In the AACRA context, there is no any computerized system easy to use the Equipment Management System i.e. equipment management software (fleet or maintenance). Microsoft office tools are currently being used for report writing and financial analysis. Appreciable Excel data base recording of the spare parts exists at Shiromeda Warehouse. It also facilitates to easily trace the locations of the parts as they are well registered manually and digitally. No Computerized Equipment management system is currently under use in AACRA maintenance center.
Q7	Well-structured record-keeping systems and data handling designed to support the functions of equipment management system are essential if the organization is to operate efficiently and effectively and able to account for their decisions and actions. AACRA's Equipment management- fleet and maintenance operation have got so many data recorded to confirm specific task done in a planned fashion, on the basis of a clear understanding of the organizations functions and requirements. Currently there are good start-ups guidelines for equipment data handling/Paper based record keeping/ on maintenance work flow at AACRA's maintenance center, but it lacks effectiveness and it is not inclusive of all the necessary parameters like labour hour, responsible person, and specific shop assignment.

Q8	At AACRA existing conditions, there are some performance measurement trial to set working skilled labor hour to accomplish a specific maintenance work. But those measurements are not technically feasible and seem to have been done for completeness of the BPR study document. The assigned hours are not standardized skilled labor hour. A number of reports like skilled labor hour spent by the technician are available. Those reports does not meet the standard of modern Equipment Management System(EMS) .They are not also properly analyzed using different variables of Key Performance Indicators(KPI's)
Q9	Well-structured record-keeping systems and data handling designed to support the functions of equipment management system are essential if the organization is to operate efficiently and effectively and able to account for their decisions and actions. AACRA's Equipment management- fleet and maintenance operation have got so many data recorded to confirm specific task done in a planned fashion, on the basis of a clear understanding of the organizations functions and requirements. Currently there are good start-ups guidelines for equipment data handling/Paper based record keeping/ on maintenance work flow at AACRA's maintenance center, but it lacks effectiveness and it is not inclusive of all the necessary parameters like labour hour, responsible person, and specific shop assignment.
Q10	This area is a major contributor to the lack of maintenance productivity in the company. The time wasted while trying to find parts for maintenance technicians makes up one of the largest portions of the lost productive time. Estimates suggest that over 50% of all lost maintenance productivity is related to inventory and purchasing practices. This problem is even further compounded by the fact that in almost half of all companies, maintenance has no control, or even input, over its inventory and purchasing policies. Therefore, order policies and storage policies are made by individuals who may not understand how maintenance inventory is different from operations or production inventory. This lack of understanding creates stock outs and overstocks, both of which are unnecessary expenses that weaken AACRA's competitive position. While a stock out is considered a nuisance to maintenance, what is its true cost? What is the cost of downtime or lost production that is caused by a stock out? This cost can be considerable, but it is totally not a factor considered in AACRA"S stocking decisions -a major flaw in ACCRA'S maintenance inventory and procurement functions. During the Shiromeda warehouse, so many obsolete spare parts are kept unseen for years. The Authority is expected to make decisions on their disposal mechanisms. There is well organized inventory management system in AACRA level except lack of automation and lack of disposal of salvage and obsolete equipment. In addition, shiromeda warehouse is organized with a proper usage of manual stock index but the two warehouses found in AACRA maintenance center and Augusta is not properly managed.The other clear problem observed in AACRA spare part management is the stock control activity. Even though the control is done manually involving many stock control staff and also time taking, it is efficient for controlling purpose only. For instance a mechanic in central garage wants accusation of a spare part from shiromeda warehouse, S/he initiates part request and go to AACRA main office for confirmation of part in stock control department. After confirmation of the part, having signed on PRV (part request voucher) the mechanic will go to shiromeda ware house to collect the part. From the above process, one can deduce that the driver lost almost one full day time to get a single part. Availability of skilled mechanic and equipment become less and downtime will be created. Hence, wrong location of the warehouses from the maintenance center and stock control department has created increased down time of the equipment.

Q11	In the case of AACRA digital libraries are sections that provide the resources to mechanics, maintenance planners, operators, fleet dispatchers, purchasing and procurement and others to select, structure, offer, interpret, distribute, preserve the integrity and ensure the persistence over time collections of digital technical manuals like trouble shoot manual, operation manuals, Illustrated part catalogue, service bulletin, rental procedures and specification that they are readily and economically available for use. Currently AACRA owned variety of equipment for road construction purpose and also their maintenance and operation become sophisticated due to technology advancement but the organization's maintenance and operation personnel are not traveling to cope up with it. The reason behind this is training and updating their information to recently purchased equipment. To perform the latter, there are so many technical manuals and bulletins distributed from the manufacturer, this manuals and documentations exist but scattered located at different places viz. shiromeda warehouse, different offices and shops .Due to this fact , the mechanics and operators follow their own experience, procedures and techniques ultimately leading to repetitive failures and poor workmanship. This also creates low quality maintenance activity. To mention from wrong practices of AACRA, Purchasers take comparable part from disassembled equipment with the part which is going to be purchased for the only reason that they do not have the Illustrated Part Catalogue (IPC) containing the Part Identification number. So as a recommendation AACRA should organize Manual and digital technical library by collecting the existing manuals and resources which are at hand and fulfilling the rest hard and soft copy of technical materials for every type of equipment in its own inventory list.
Q12	Coordination between each department is always there to do the job as efficient as we can. As a standard, all departments have to have a clear job guidelines, procedures and coordination in order to meet the company goal and target. Each case teams shall develop capital acquisition, operations and maintenance, and disposal strategies based on the findings of an ongoing and systematic assessment of the physical condition, functionality, utilization, and financial performance of their assets against established targets based on appropriate benchmarks.

Q13	1) Increased maintenance workloads Cannibalizations increase the workload of equipment maintenance personnel because, typically in the heavy-duty construction machineries, actions to repair cannibalized items take at least twice as long as normal repairs. Thus, a direct cost of cannibalizations is the additional personnel hours required to remove and replace a part. In the process, personnel must also check or repair other parts removed to gain access to the cannibalized part. For a typical assembly repair, the inoperative part is removed and a new part is installed. For a typical assembly cannibalization, the workload is doubled: the inoperative part is removed, a working part is removed from the cannibalized assembly, and the working part is installed on the recipient assembly and a new part is installed on the cannibalized assembly. 2) Potential effects on morale Evidence suggests that cannibalizations have a negative effect on morale because they are seen as routinely making unrealistic demands on maintenance personnel. It has been reported that cannibalization is counterproductive and has a “huge” impact on morale. Cannibalizations are performed at any time, day or night, and often very quickly to meet operational requirements. In these cases, maintenance personnel must continue working until the job is done, without additional pay. 3) Potential for mechanical side effects To remove a component, maintenance personnel often must remove other components to gain access. This increases the risk of maintenance induced damage to the equipment. Additionally, cannibalizations do not replace a broken part with a new one, but with a used one. Therefore, cannibalizations do not restore a component to its full projected life expectancy, but rather increase the chance that the component will break down prematurely and decrease the reliability of end item wear-out estimates.