



**Identification and Analysis of causes of poor service quality in fleet
maintenance facility in Ethiopian construction Works Corporation**

By

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This is to certify that the above declaration made by the author is correct to the best of my knowledge.

Dr. Ameha Mulugeta

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Abstract

The construction industry in Ethiopia covers 70% of the capital budget and is ranked second after the agriculture sector for creating job opportunities for millions of people. Many studies showed that in construction company fleet availability and reliability takes a lot of share in the accomplishment of projects with planned cost, quality level, and within the scheduled time. The basic objective of fleet maintenance service is providing the service with high quality, reasonable price, timely delivery, and considerate service. Lack of continuous quality improvement program resulted in high maintenance cost spent, high downtime, high frequency of maintenance, and overall customer dissatisfaction and complaint as presented in the case company. Hence, this research aimed to structurally analyze the maintenance service quality factors in the fleet maintenance facility of a construction company for efficient and effective decision-making on fleet maintenance service quality improvement. The research is an applied research type that followed an empirical study design methodology and has taken the main/ central maintenance facility of Ethiopian Construction Works Corporation as a case company. Using the primary and secondary sources of data, the research has identified seven major service quality factors and nineteen customer service requirements. MCDM tools; interpretive structural modeling (ISM) and Fuzzy TODIM with the integration of quality function deployment tools have been used for the qualitative and quantitative data analysis. Based on the analysis, the result has shown that; “Maintenance facility layout and Ambiance”, “Machine and maintenance tools”, and “Spare part and material availability” are the most critical service quality factors and have high relation with the most prioritized customer requirements which are; “maintenance personnel with friendly & good behavior”, “willingness of the staff to give enough explanation & advise”, “a reliable and error-free maintenance service” and “reasonable and fair maintenance service pricing”. Hence, these quality factors need high consideration while developing fleet maintenance service strategies and policies because they have a high effect in meeting customer needs and for the improvement of service quality in the case company.

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Acronyms

COQ	Cost of Quality
ECWC	Ethiopian Construction Works Corporation
FMEA	Failure Mode and Effect Analysis
FRM	Final Reachability Matrix
HOQ	House of Quality
IRM	Initial Reachability Matrix
ISM	Interpretive Structural Modeling
MCDM	Multi-Criteria Decision Making
QFD	Quality Function Deployment
RCA	Root Cause Analysis
SSIM	Structured Self-Interaction Matrix
TODIM	TOMada de Decis~ao Iterativa Multicrit´erio
TQM	Total Quality Management

CHAPTER ONE

INTRODUCTION

1.1. Background and justification of the study

According to Weckenmann et al. (2015) stated: independent of the type of offer, including material goods as well as immaterial services or their combination, in today's market, each organization has a competitor which provides the same product or service. Therefore to assure the fitness of an organization in this competition, the company should provide service or products of high quality, i.e. a high degree to which a set of inherent characteristics fulfills requirements. In this regard implementation of quality management tools and techniques provide a significant contribution to the achievement of the overall company's service or product quality objective. According to Barone (2020), quality management is the act of overseeing all activities and tasks that must be accomplished to maintain a desired level of excellence. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement. Hence, as Nair (2006) indicated there is an increased level of interest in quality management irrespective of the sectors of the economy such as manufacturing, service, health care, education, and government. The article also stated that it is now widely believed that the underlying practices in quality management are fundamental and essential for effective management and competitive survival of organizations.

Despite its importance and impact on different companies and organizations' performance, as Brito et al. (2007) indicated, quality management researches done on improvement of fleet maintenance service quality are still rarely mentioned in the field. Construction companies, Transport providing companies, heavy machines, and vehicles manufacturers or dealers, public organizations (i.e. telecom companies, schools, hospitals, etc.), and private fleet maintenance service providing companies are from the many companies in which its success and competitiveness are affected by the quality, reliability, and performance of its fleet maintenance service facility.

Construction companies are one of the major companies in the industry sector. As Durdyev and Ismail(2012) stated, construction with its large contribution in terms of output and employment can be classified as one of the largest industries in both developed and developing countries. According to Ethiopian Economic Association 2006/2007 report, the construction industry in Ethiopia covers 70% of the capital budget and is ranked second after the agriculture sector for creating job opportunities for millions of people. Furthermore, as it is stated on CEPHEUS research, in Ethiopia's 2020-21 Budget, roads constitute the largest federal government spending item, with Birr 58.8bn being allocated. These construction companies are involved in the construction of shelters, roads, dams, buildings, bridges, and other infrastructures. Thinking of these companies without a fleet cannot be possible. These fleets consist of heavy earthmoving machinery, trucks, buses, cars, pickups, and auxiliary equipment (generator, compressor, mixer, etc.).

Sener and Iseley(2009) said that the construction industry has not kept up the pace in the adoption and use of new technologies in general and for fleetmanagement of construction equipment in particular. Moreover, in contrast to developed countries, a fleet in developing countries like Ethiopia is seen as of secondary importance. Er-Ratby and Mabrouki(2018) indicate that in a Construction Company fleet availability and reliability takes a lot of share in the accomplishment of projects with planned cost, quality level, and within a scheduled period and one way for having ready and reliable fleet is by performing maintenance activities for broken equipment.

Moreover, as Durdyev and Ismail(2012) stated; with its contribution to economic development and economic activities, the construction sector has a significant effect on the development of any nation. This is because the construction sector is large and responsive, as well as it has a strong linkage with other industries, it is a key sector that can affect economic development. Therefore research studies done on this area has a big importance for the overall improvement of the construction company's performance. This in turn has a benefit for achieving the economic goal of any country especially for developing countries like Ethiopia (considering the current strategy of the government about the completion of projects within the planned time and planned cost).

Almost all Construction companies have a maintenance facility for their fleets. It can vary from simple to highly organized systems. But in most companies especially in government corporations the importance and impact of these facilities on the overall project performance aren't counted into consideration. For example, if we consider cost as criteria, fleet maintenance, and fleet capital cost account for a huge sum of investment in construction companies but the cost associated with maintenance of machinery and vehicles fleet is considered alien to the overall project cost. A study done by Adik and Bobade(2018) shows that; the cost of equipment for civil engineering construction projects can range from 25 to 40% of the total project cost. Moreover, Nepal and Park(2004) stated that Downtime (DT) caused by non-availability of equipment and equipment breakdown is among the most common unanticipated factors that have a non-trivial impact on the equipment productivity and project and organizational performance. In addition to this, the impact of having an efficient and effective fleet maintenance facility on fleet availability and reliability hasn't been given much consideration.

The basic objective of a fleet maintenance company is providing the service with high quality, reasonable price, timely delivery, and considerate service. As many studies indicate maintenance is normally perceived, especially in developing countries like in our country, to have a poorer rate of return than any other major budget item. Thus it hasn't been given the appropriate attention to improve and modernize it. Yet as these studies show, by following the proper maintenance strategy most companies can reduce maintenance costs by at least one-third, and can improve the level of service they can give. In addition to this, if the proper maintenance strategy is followed, the maintenance processes can be streamlined to eliminate waste and achieve the company's overall objective in construction project work. As Haider et al. (2015) state, the company maintenance of fleet is critical in terms of assuring the accomplishment of the stated company's goal on cost, availability, customer satisfaction, and quality. Thus, to avoid major market losses and to achieve the intended success, an efficient maintenance model is required.

In an attempt to improve service quality, reduce maintenance costs, decrease fleet downtime and satisfy a customer, there must be a continuous program that can track, address, control, and improve quality issues within a fleet maintenance facility. Furthermore, Er-Ratby and Mabrouki(2018) assert that the servicing and maintenance methods that are to be followed for

creating an efficient and effective maintenance system require continuous modifications and changes. In this regard root cause analysis technique has been widely used by many practitioners. Mohammad et al. (2016) described root cause analysis (RCA) as a range of approaches and tools drawn from fields including human factors and safety science that are used to establish how and why an incident occurred in an attempt to identify how it, and similar problems, might be prevented from happening again. Butas Percarpio et al. (2008) indicated in RCAs the quality of the analysis is affected by the quality of input data and team member biases. In addition, too often RCA results in a simple linear narrative rather than a wider systems view that displaces more complex, and potentially fruitful, accounts of multiple and interacting contributions to how events unfold (Mohammad et al., 2016).

Whereas, as El Kfita and Drissi-Kaitouni (2017) defined multi-criteria decision-making tool as a framework that aims to provide decision-makers with wise recommendations and alternatives, while being evaluated from multiple experts' opinions, called criteria. Moreover, each of the methods uses numeric techniques to help decision-makers choose among a discrete set of alternative decisions (Triantaphyllou, 2000). But these tools are also criticized as they have a general drawback that the various forms of uncertainty (including ambiguity and/or vagueness) which are typically present in decision-making processes are not or not fully taken into account (Dhanisetty et al., 2018). To minimize this risk fuzzy methods have been developed and combined with the above methods to be more effective in the decision-making process (Dhanisetty et al., 2018). According to R. Kumaret al. (2017), Fuzzy set theory is an extension of classical set theory which is primarily aimed at dealing with real-world problems under an uncertain and vague environment.

This research aims to identify the major causes of poor fleet maintenance service quality by using RCA methods then analyze and prioritize them by integrating MCDM tools with fuzzy methods. Finally, it aimed to analyze their relation to customer satisfaction through the application of House of quality function deployment tools (QFD) to improve the service performance, reduce downtime and improve the competitiveness of the case company.

1.2. Problem statement

Many problems may implicate the urgent need for improvement of the quality of fleet maintenance services in the facility. Using four service quality measuring variables, the quality problems that existed in the case company are presented as follows.

i. **Cost:** - it includes all the costs associated with servicing, repairing, or overhauling a fleet. The case company spends in million birrs for maintenance of its fleets annually which is only in its central Maintenance facility. For instance; last budget year, from July 2019 – Jun 2020 the company spend 16,710,467.12 ETB which increases more than 100% in this budget year. In 8 months, from July 2020- March 2021, it spends 38,115,238.95 ETB. From this maintenance cost, the cost associated with maintenance quality problems takes a huge amount. For example, costs associated with lack of effectiveness in the identification of defects, lack of effectiveness in repairing work, poor materials or tools usage, lack of effectiveness in fleet testing method after maintenance, and poor maintenance facility construction. Etc. These problems result in creating even higher damage next time and an increment in the frequency of equipment failure. The above costs don't even include the market loss by the inefficiency or performance of the equipment and the increment in operating cost because of inefficiency in maintenance activity. Such as; higher fuel and lubricant consumption and more frequency of PM parts change rate from the normal time interval.

ii. **Down Time:** - it is the duration that takes to maintain the equipment after failure. This is the sum of repair time, replacement time, and waiting time. In ECWC's maintenance facility, fleets are taking longer downtime under maintenance compared to the standard maintenance time. For instance; on the monthly maintenance report of the garage from April 01 – May 28/2021 (two months) it is reported that three equipment took more than two years, four equipment more than a year, and many others took more than two months. Based on the standard time for maintenance these maintenances would be completed within 3-4 days if the requirements were fulfilled. This may happen for different reasons but the reasons that show the existence of maintenance quality problems are the major ones. Such as; waiting a long time for a new spare part, ineffectiveness in detecting failure & repairing it and shortage of maintenance material and tool availability, etc. Longer downtime of equipment opens a door for higher-cost

decision-making. This may be renting the equipment from private suppliers or purchasing new equipment. These both are realities in the case company and other government corporations.

iii. **Frequency of Maintenance:** - this is the number of failures that occurred or the number of maintenance done for the equipment. The maintenance service quality provided has a huge impact on the number of equipment failures and maintenance rework done. If the frequency of maintenance increases or the mean time between failures decreases it is one sign that shows a lack of maintenance quality because this might be a result of lack of effectiveness in detecting failures and lack of effectiveness in repair action. This is a case that has been seen in the case company's equipment which is occurring more than the expected/normal number of service per year (4times/year) and also a higher number of maintenances service reworks on a lot of machines. For example within 11 months of this budget year (from July-01/2020 to May-28/2021), for 17 vehicles and machinery maintenance service is provided more than 25 times. This factor is taken as a service quality problem because it is also one of the major sources of customer complaints and dissatisfaction.

iv. **Customer dissatisfaction & compliant**

Based on the different periodic reports of the maintenance department and discussions with some employees, the major customer dissatisfaction and complaints arise from the repair time and reliability of the service. Which is; many customers complain that the maintenance service is taking longer time than it is supposed to take and that they are forced to return for maintenance because they didn't get effective maintenance the first time. Besides these major problems; the difficulty to contact the responsible person for their required service, gaining not enough explanation in terms of what maintenance needs to be done, not getting notification if the vehicle is not going to be ready at the agreed time, the low courtesy shown, etc. are also reasons for the lower customer satisfaction and customers' complaint.

The above discussions indicate the existence of a series of fleet maintenance service quality problems in the case company and the necessity of service quality improvement in the facility. As mentioned in the discussion, these quality problems may be a result of different factors/reasons so identifying and solving all causes might be costly and it might require a long time. Therefore, it requires an effective approach that can consider the importance of each factor on the service

quality, the relation of each factor with quality measuring attributes, and customer service requirement for reliable decision making.

1.3. Research Questions

- What are the causes that decrease the quality of fleet maintenance in the case company?
- What is an efficient and effective methodology to improve fleet maintenance quality in the maintenance facility?
- What is the level of relationship between the quality factors and also the quality factors with quality measuring criteria?
- What are the critical factors for improving the quality of maintenance services?
- What are the main customer service requirements and what is their level of relationship with the major service quality factors?

1.4. Objectives

1.4.1. General objectives

The main objective of this research is

to structurally analyze the maintenance service factors in the fleet maintenance facility of Ethiopian construction Works Corporation for efficient and effective decision-making on fleet maintenance service quality improvement.

1.4.2. Specific objectives

The specific objectives are:

- To examine and evaluate the service providing system and performance of the case company
- To identify the major and minor causes of poor fleet maintenance service quality
- To structurally analyze and then prioritize the major quality factors that contribute to the low level of fleet maintenance service quality
- To analyze the level of relationship between the major quality factors and the service quality measuring criteria for prioritization of the factors.
- To identify the main customer needs and to investigate the relation between the major quality factors with customer service requirements

1.5. Scope of the Study

This research will be done with the general intention of improving fleet maintenance quality in different companies. As it is obvious, one company may differ from other companies by the number and variety of their fleet. As a result, there might be a difference between the level and complexity of their maintenance facility and the effective maintenance methodology that should be followed. Therefore, this research will be done with the specific objective of improving fleet maintenance service quality through decision-making tools and techniques by selecting Ethiopian construction Works Corporation as a case company. The rationale behind selecting this company are: i) Having a large number of fleets; currently, the company owns more than 1, 400 construction machinery & vehicles and provide maintenance service in its own facility ii) having a wide range of variety of fleets; more than 20 types iii) it also provides maintenance service for external customers.

The scope of this research includes an examination of current performance, identification of service quality factors, analysis and prioritization of the factors, and investigating their relationship with the customer service requirements. Finally, currently, the case company is in contract agreement for the construction of more than thirty projects around the country and has a minor to medium maintenance facility on these project locations. This research is mainly focused on the main/central maintenance facility of Ethiopian Construction Works Corporation which is located in Addis Ababa, Kaliti sub-city. Therefore the study will not cover the maintenance done for the equipment other than the main garage because of the time limitation to cover all the projects and the variation in the organization of these facilities.

1.6. Significance of the Study

Most of the written literature in the equipment maintenance area is focused on industrial machinery maintenance. Studies done on improvement of fleet maintenance service will have a significant benefit for companies overall performance especially for those companies which are more dependent on the availability and reliability of their fleet. In this case, construction companies are the best examples and also will have further benefit considering the huge investment in the sector in our country and any other country. Therefore, this study will have the following major benefits.

The managers responsible for enhancing the quality of service in the maintenance facility can use it for decision making to derive policies through the result obtained from the study and help the company for investing finance and resources on the major causes of the problem which can result in efficient service quality improvement. Furthermore, a study done on this case company will have benefit for other companies too for improvement of their fleet maintenance system after customizing to their situation. Furthermore, the research will have a contribution to the literature on fleet maintenance services. It can be used as a reference for further investigation on the area to implement the models on other problems/subjects or as a reference for using other related models and techniques.

1.7. Organization of the research

This research paper is structured into five chapters: the first chapter provides an overall introduction of the thesis; it includes the background and justification of the study and the sector, the problem statement, the research questions, the study objectives, scope of the study, and significance of the study.

The second chapter explains the literature review about the subject matter, key concepts, and approaches help to establish and justify the study's theoretical basis and that would help to understand the study. The third chapter provides details of the research methodology and methods adopted to address the research objectives and to answer the research question was illustrated and reasoned out. In the fourth chapter, findings from the data collection process and results from the data analysis are presented and discussed. Finally, in chapter five conclusions and recommendations are presented concerning the objectives of the thesis.

CHAPTER TWO

LITERATURE REVIEW

This review adopted a systematic literature review methodology which is driven by the research questions that help to establish the search keywords. In identifying sources for this literature review, multiple databases were used. Initially, Google scholar was utilized with broad search terms and used to establish a list of research articles that were primary sources and peer-reviewed. In the beginning, I used a basic search of Fleet maintenance service quality. From the article titles and research data derived from Google Scholar with that search basis, I was able to use a better list of more refined terms when utilizing other databases such as Emerald Insight, Researchgate, Springer, etc.

The search terms selected for this literature review consisted of Quality, service quality, quality management, service quality improvement approaches/tools/techniques/measures, factor prioritization methods, etc. these terms were combined in various ways with “AND” commands in the effort to obtain the most narrowly-defined and appropriate articles. Each of the search terms used was selected due to their appropriateness and relevance in consideration of the purpose of this literature review. In addition to these, I gave greater weight to articles that were focused on fleet maintenance service quality improvement. Finally, I ensured that the journals used had the most recent publication dates, which are from 2000 to onward with few exceptions.

2.1. Concept of Quality

2.1.1. Definitions of Quality

Elshaer (2012) stated that without well-developed conceptual definitions for the research terms, it is impossible to develop a coherent theory, and also it is impossible to develop a valid measure of a concept that is not precisely defined. Unfortunately, although the word quality came into existence many years ago and was quite widely used by practitioners and academics, in the past there was no clear definition established to define the term (M. Kumaret al., 2016 and Elshaer, 2012) and also still as can be seen in a lot of quality-related literature there is no common understanding or generally agreed on definition about the term (Miliauskaite, 2012).

According to M. Kumaret al. (2016) and Elshaer (2012); this variation in the definition of quality resulted because different peoples define the term depending on the time, the context of the Quality examination, and phenomena of the situation. Moreover, Ghobadian et al. (1994) stated that this variation is mainly because the term “quality” means a different thing to different people and for different organizations, and defining “quality” concerning their situation and goal is often the first step in most “quality improvement” journeys.

Ghobadian et al. (1994) stated that a common understanding and vision of what is meant by “quality” will help the organization to focus its “quality improvement” efforts. Thus, defining “quality” is not only important from a semantic point of view but, more importantly, it is required to direct employees’ efforts towards a particularly common cause. Generally speaking the standards of any product, service, or organization can be characterized by the term “quality”. Initially, the quality was observed only from the production process view. It was mainly viewed as the inspection of the product. Then the quality meaning has changed dramatically after the year 1970 which is after a conclusion has been drawn that the quality can also be practiced to the entire organization (M. Kumaret al., 2016).

These various available definitions of “quality” can be categorized under the following five broad categories/approaches as distinguished by the indicated authors and investigated by several other authors.

Table 2.1 Definition of quality

Approach	Definition	Sources
Transcendent/ Metaphysical	Define quality as innate excellence. The product or service will have unequaled properties. a mark of uncompromising standards and high achievement	Ghobadian et al. (1994), Elshaer (2012) and (Miliauskaite, 2012)
Product-based	Defines quality based on quantifiable and measurable characteristics or attributes. It is the units of goodness packed into a product or service	Ghobadian et al. (1994), Elshaer (2012) and (Miliauskaite, 2012)
Manufacturing/Process/ supply based	Define as “conformance to requirements”. It is useful in organizations producing either standard products or services or where the output can be classified	Ghobadian et al. (1994), Elshaer (2012) and (Miliauskaite, 2012)

	as a commodity in which the requirements are stated mostly in technical terms.	
User/Customer based	Define as “satisfying customer’s requirements” or “fitness for purpose”. Relies on the ability of the organization to determine customers’ requirements and then meet these requirements.	Ghobadian et al.(1994), Elshaer (2012) and (Miliauskaite, 2012)
Value-based	Defines quality as the degree of excellence at an acceptable price or as “meeting the customer’s requirements in terms of quality, price, and availability”.	Ghobadian et al.(1994), Elshaer (2012) and (Miliauskaite, 2012)

2.1.2. Service Quality

Chang et al. (2013) define Service as the action or benefit provided by one party. It is essentially intangible and cannot be owned. It cannot render any affection of property transfer. Also, Goldstein et al. (2002) stated that, unlike a product, service components are often not physical entities, but rather are a combination of processes, people skills, and materials that must be appropriately integrated to result in the ‘planned’ or ‘designed’ service. The definition according to the four characteristics (intangibility, heterogeneity, inseparability, and perishability) is the most popular one when dealing with services (Kaczor & Kryvinska, 2013) and these characteristics make the service different from physical goods (Chang et al., 2013)

The first of the four characteristics are described by the intangibility of services is as Kaczor & Kryvinska (2013) stated, service is not a physical object so it generally cannot be easily counted, measured, and inventoried (Chang et al., 2013). The second characteristic is; a service appears to be heterogeneous. This is due to the relative inability of standardizing its output in contrast to goods (Kaczor & Kryvinska, 2013). According to Chang et al. (2013); the performance of a service (especially those with high labor content) often varies from one provider to another, from one customer to another, and from day to day.

Furthermore, service characteristic is represented by inseparability. This arises from the nature of services in which the production and consumption of a service are inseparable (Chang et al., 2013). Finally, a service is typically characterized by its perishable appearance, since it cannot be stored a service in an inventory like a good (Kaczor & Kryvinska, 2013).

When we say service quality Different authors described it in different terms. For instance; Chang et al. (2013) described it as it is a subjective recognition of whether the service is good or bad through the interaction between consumers and providers in the service process. This article also stated that service quality can also be referred to as a measure of the difference between customer expectation of the service and the real affection after being served. According to Honget al.(2020)it is a consumers' judgment of the overall superiority or excellence of perceived service. In more detail,Kang and James(2004)stated service quality definition in terms of physical quality, interactive quality, and corporate (image) quality. According to these authors; Physical quality relates to the tangible aspects of the service whereas Interactive quality involves the interactive nature of services and refers to the two-way flow that occurs between the customer and the service provider. Corporate quality refers to the image attributed to a service provider by its current and potential customers, as well as other public.

Honget al.(2020) classified service quality into four types based on the previous studies done. The first is Human quality: which is composed of categories such as employee knowledge, employee kindness level, and employee image. The second is Material quality: it is composed of items like the latest equipment, facilities, and suitable system. The third is interaction quality: this consists of categories such as response for customers, interest, and problem-solving. Finally,the fourth is System qualities: which constitute items such as speed, process, and time.

According to Ghobadianet al.(1994),the perception of quality is influenced not only by the “service outcome” but is influenced also by the “service process”.As Britoet al.(2007) indicated there is still inconsistency in the literature about how to operationalize and measure service quality.According to Ghobadianet al.(1994); the “perceived quality” lies along a continuum. “Unacceptable quality” lies at one end of this continuum, while “ideal quality” lies at the other end, and the points in between represent different gradations of quality. One such point is the “satisfactory quality”.

2.2. Quality Management

In today’s market, each organization has a competitor which provides the same product or service. As Weckenmannet al.(2015) states this principle is valid independent of the type of offer, including material goods as well as immaterial services or their combination. Therefore as

these authors stated, to assure the fitness of an organization in this competition is by providing service or products of high quality, i.e. a high degree to which a set of inherent characteristics fulfills requirements, which is the core task of quality management. Nair (2006), shows that there is an increased level of interest in quality management irrespective of the sectors of the economy. Such as; manufacturing, service, health care, education, and government. According to this article, it is now widely believed that the underlying practices in quality management are fundamental and essential for effective management and competitive survival of organizations. So as these have been said about the importance of quality management in any organization then looking into how the concept is defined by different authors is important before going to study how its principle can be implemented in a company.

As it is possible to present a lot of references, we can say that Quality management is a philosophy that has received a high degree of attention in numerous literature and is defined using different but related terms. For instance: Barone(2020) defines; Quality management as the act of overseeing all activities and tasks that must be accomplished to maintain a desired level of excellence. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement.

Quality management has been defined as a “philosophy or an approach to management” made up of a “set of mutually reinforcing principles, each of which is supported by a set of practices and techniques (Sousa & Voss, 2002 and Hamid et.al, 2019). According to Hamid et.al (2019), quality management is about all aspects of the overall management function that determine the quality policy objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance, and quality improvement within the quality system. Consistent with this (Sousa & Voss, 2002) also indicated that quality management is a managerial philosophy or an approach made up of a set of mutually reinforcing principles, each of which is supported by a set of practices, tools, and techniques for enduring effectiveness and efficiency concerning the systems and its performance.

Based on the review they have done Hamid et.al. (2019) identify nine items which are; Continuous quality improvement, Conformance to standard, Management understanding, Customer orientation, Quality leadership, Involvement, Quality supplier relationship, Process

management, and System Management as quality management principles. According to Weckenmann et al. (2015), to develop methods and tools to support quality under long-term perspectives and enable innovation by identifying future needs, historic analysis of paradigm shift in quality management should be performed. As this article states the underlying idea and the overall aim remain the same although the paradigms established for the development and implementation of tools and methods in quality management have changed several times. This happens mainly to meet the requirements of the triangle quality, cost, and time.

2.2.1. Evolution of Quality management system principles

As Sousa & Voss (2002) indicated Quality management (QM) was born almost two decades ago with the core ideas of W. Edwards Deming, Joseph Juran, Philip Crosby, and Kaoru Ishikawa. Since then Quality concepts have passed through the different stages of development in history and it has become an all-pervasive management philosophy finding its way into most sectors of today's business society.

As it is stated by Hamid et al. (2019) at early times, quality was associated with inspection with the focus on products and it is checking of the degree to which a set of inherent characteristics fulfills requirements. The central aim was to assure a merely sufficient quality of delivered products and thus avoid complaints and recourse claims from customers (Weckenmann et al., 2015). This same article stated that the necessity to combine ever-increasing requirements on delivery time, production costs, and expected quality widens the focus from product quality to process quality and the main idea of this development was: by controlling and optimizing the manufacturing processes, quality, time and costs could be positively affected at the same time.

Quality control and Quality assurance are the two main quality management principles that are found under process quality. According to Hamid et al. (2019) in the case of quality control, the product was still the key focus and quality improvement was limited to finding the source of the errors and removing that (i.e. finding and fixing problems) without the customers' involvement. Several tools and techniques such as the seven tools of quality management (Q7), the PDCA-cycle by Deming, the "Five-times-Why", sampling Acceptable Quality Levels (AQL), and Average Outgoing Quality Limit (AOQL) strategies emerged and made an impact and supported the identification and correction of errors during this era. It was at the time of Quality assurance,

as Hamid et al. (2019) indicated that the focus of quality management has shifted from product to process. According to Dale (2003), the idea is based on a prevention-based system that assures quality by identifying possible risks and problems and preventing them before they came up. Weckenmann et al. (2015) stated that activities of quality assurance started to consider the whole road of a product through the enterprise instead of only the production and the principle of customer orientation had evolved to understanding customers' requirements through capturing, documenting, and reviewing them as part of the quality process. The Failure Mode and Effects Analysis (FMEA), Fault or Event Tree Analysis (FTA, ETA), Plan-Do-Study-Act (PDSA), Reliability Engineering, Statistical Process Control (SPC), Kaizen, Kanban, Jidoka, and Just-In-Time (JIT) were among the tools and techniques that emerged at this era (Weckenmann et al., 2015 & Hamid et al., 2019).

Then after these developments, as Weckenmann et al. (2015) mentioned, the perspective on quality-related issues has been continuously widened from manufacturing processes and material products to the more and more becoming important service processes and immaterial products and therefore the focus of quality management shifted from process to systems. This quality management stage was referred to as "Total Quality Control (TQC) Era" in Hamid et al. (2019) and it is described as: "total quality control is an effective system for integrating the quality development, quality maintenance and quality improvement efforts of the various groups in an organization to enable marketing, engineering, production and service at the most economical levels which allow for full customer satisfaction". According to these two papers, Quality Loss Function, Quality Functional Deployment (QFD), Poka Yoke, Quality Control Circle (QCC), 7 Quality Tools (i.e. Pareto Analysis; Fish Bone Diagram; Stratification; Check sheet; Histogram; Scatter Diagram and Control Chart), Benchmarking, Lean tools and techniques, and Single Minute Exchange of Die (SMED) were the major tools and techniques that made the headlines during this time.

According to Weckenmann et al. (2015), the need for commitment of all employees in an organization to high quality leads to the paradigm of Total Quality Management after recognizing the relationships between leadership, employee, processes, customer satisfaction, and business results. These authors stated this quality management principle as the fourth and currently last paradigm shift which is fully visible only in the last ten years. As Dale (2003)

stated the principle is about the cooperation of everyone in an organization and associated business processes to produce value-for-money products and services, which meet and exceed the needs and expectations of customers. Thus as briefed in the article by Weckenmann et al.(2015)the concepts of quality management nowadays are used also in areas with no direct competition but an urge for own improvements, such as education, health care, or public administration. To incorporate this new field of application, many existing tools and methods of quality management have been adapted to the needs of service quality, especially considering the difficulty of reproducible data.

2.3. Fleet maintenance service quality

Researches done on fleet maintenance service quality area are still low as Brito et al.(2007) state “even though the automotive industry is a popular investigation setting in operations management, the related automotive services industry is rarely mentioned in the field”.

Maintenance is unavoidable in the life cycle of fleets and hence customers are highly concerned with the extent of maintenance services provided(A.T. James &J. James, 2020).“Maintenance is the combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it in or restore it to, a state in which it can perform the required function. Maintenance also includes engineering decisions and associated actions that are necessary for the optimization of specified equipment capability, where capability is the ability to perform a specified function within a range of performance levels that may relate to capacity, rate, quality, safety and responsiveness” (Er-Ratby and Mabrouki, 2018). Liuet al.(2012)also said that equipment maintenance management is an activation process, which is to keep and restore the performance of the equipment.

Specifically to the fleet maintenance service, A.T. James &J. James(2020)stated that the automotive service industry usually undertakes activities such as vehicle cleaning, servicing, repair of mechanical, hydraulic, and electrical systems, the body works, and the breakdown and recovery services. Although all equipment maintenances have common characteristics, as Vujanovic et al. (2012) indicated, vehicle operation and maintenance processes differ from those related to industrial machines, For example, Purpose of the machines (service vs production), fleet variety range, frequency in technological change, etc. in addition to these differences

Vujanovic et al. (2012) stated that; the fact that vehicles are mobile assets, further affected by a large number of external environmental factors imposes the need for a different approach in their maintenance management, compared to other static machines. In consistence with this statement, Haider et al. (2015) say that fleet maintenance is a complex phenomenon. Various factors such as the number of vehicles, types of vehicles, and maintenance personnel experience are dependent on it. Integration of information flow from different maintenance operations needs to be analyzed systematically.

The study, done by Brito et al. (2007) used an analytical approach to identify the critical service attributes associated with customer choice based on a comprehensive list that encompassed typical service quality characteristics as well as items of particular relevance to the car maintenance industry and identified the following as they stated “the ten most important service attributes”. Keeping to original forecasted price, Value for money service, getting it right the first time, Mechanics’ trustworthiness, Keeping promises, Employees’ knowledge and experience, Willingness to solve customer’s problems, keeping to the agreed schedule, Attention to modifications demanded by the customer and General equipment condition.

According to Bajramovic et al. (2012), authorized motor vehicle services, need to create their own quality philosophies, through the analysis of the development and creation of the superior characteristics for successful service management. The basic notion of this philosophy is that the improvement of the motor vehicle service quality and customer satisfaction has to be the final objective of every manager’s work. Therefore, like Liu et al. (2012) indicated for an established goal and responsibility is related to the effective integration of resources including the planning, organization, coordination, and management behaviors and activities to effectively integrate human, material, time, information and the other equipment maintenance management elements.

Vujanovic et al. (2012) stated that efficient maintenance management facilitates vehicles to be ready for operation during the required periods and certainly influences the reduction of maintenance costs. Specifically for the equipment maintenance management Liu et al. (2012) stated that the basic task of the maintenance organization is to meet the needs of the customer, providing the equipment with high quality, reasonable price, timely delivery, and considerate service. The article also assures that effective quality management methods can effectively

enhance the quality and efficiency of equipment maintenance systems, reasonably complete the maintenance task, timely provide technical service, and meet the needs of the customer from many comprehensive aspects. Related to these statements Vujanovic et al. (2012) specifically indicated that the downtime of equipment during the maintenance period is critical and the moments and durations of those periods depend mainly on fleet maintenance management effectiveness and efficiency.

Based on the above statements and also as James (2020) indicated fleet maintenance falls in the category of the service industry, where assurance of quality and reliability is essential for profit-making and earning goodwill for the maintenance service providers. As this article pointed out in contrast to other service providers the automobile maintenance service is highly labor-intensive with limited space of interaction between customer and service provider.

As mentioned above in general equipment maintenance involves many subjective factors such as the personal qualities of technicians and managers, the work environment, resources, and capacity, etc. Therefore, there should be a method for evaluation of equipment maintenance quality which is identified as an important part of equipment management. According to Zhanget al.(2019), scientific maintenance quality evaluation is helpful for decision-makers to master equipment maintenance status in time and to provide theoretical support for further improvement of maintenance alternatives. In addition to this, the paper stated that it is essential to establish a reasonable multi-standard system to evaluate the quality level of maintenance activities and there is no doubt that multi-criteria decision-making (MCDM) provides a feasible way for the evaluation of maintenance quality.

2.4. Main causes of poor maintenance service quality

According to A.T. James & J. James (2020) Organizations are adopting strategies for enhancing the maintenance quality of their products and processes to sustain in the competitive environment. In consideration to fleet maintenance; it is performed to meet the objectives of increase in operational life, achievement of safety, pollution control, reduction in operating cost, high resale value, and reduction in breakdowns and emergencies (James, 2020). Therefore, the existence of factors that contributes to poor maintenance quality is an obstacle to achieving these objectives. Poor maintenance quality is described as Maintenance errors in James et al.(2017) and

according to the paper in fleet maintenance; it can result in a breakdown, performance degradation, high noise, leakage, high pollution, accidents, a requirement of frequent maintenance, etc.

For measuring and evaluating fleet maintenance service quality, a modified version of the service quality determinants described by Ghobadian et al.(1994) can be very helpful. These are; Reliability, Responsiveness, Customization, Credibility, Competence, Ease of access, Courtesy, Security, Communication to the customers, Tangibles, and Understanding/knowing the customer. With the inclusion of these factors and referring to other different literature the major criteria for measuring fleet maintenance quality are discussed below.

i. Cost: - it includes all the costs associated with servicing, repairing, or overhauling a fleet. It consists; spare part cost, labor/manpower cost, material and tool cost, and overhead cost. From this maintenance cost, the cost associated with maintenance quality problems takes a huge amount. For example, costs associated with lack of effectiveness in the identification of defects, lack of effectiveness in repairing work, poor materials or tools usage, lack of effectiveness in fleet testing method after maintenance, and poor maintenance facility construction. Etc. These problems result in creating even higher damage next time and an increment in the frequency of equipment failure. The above costs don't even include the market loss by the inefficiency or performance of the equipment and the increment in operating cost because of inefficiency in maintenance activity. Such as; higher fuel and lubricant consumption and more frequency of PM parts change rate from the normal time interval.

ii. Down Time: - it is the duration that takes to maintain the equipment after failure. This is the sum of repair time, replacement time, and waiting time. Nepal and Park(2004) stated that Downtime (DT) caused by non-availability of equipment and equipment breakdown is among the most common unanticipated factors that have a non-trivial impact on the equipment productivity and project and organizational performance. This may happen for different reasons but the reasons that show the existence of maintenance quality problems are the major ones Such as; waiting a long time for a new spare part, ineffectiveness in detecting failure & repairing it, and shortage of maintenance material and tool availability, etc. Longer downtime of equipment

opens a door for higher-cost decision-making. This may be renting the equipment from private suppliers or purchasing new equipment.

iii. Frequency of Maintenance: - this is the number of failures that occurred or the number of maintenance done for the equipment. According to A.T. James & J. James (2020) quality in general, means zero defects and for automobile service garages, this implies zero customer handling problems and zero comebacks. Besides other factors such as; operator skill, working condition, and age of the equipment, etc., maintenance quality done for the equipment has a huge impact on the number of failures. If the frequency of maintenance increases or the mean time between failures decreases it is one sign that shows a lack of maintenance quality because this might be a result of lack of effectiveness in detecting failures and lack of effectiveness in repair action. This is one of the major sources of customer complaints about the service. Related to this A.T. James & J. James (2020) stated that a comeback situation occurs, when a customer feels that his/her vehicle was not fixed on the first visit and it necessitated multiple visits to accomplish the repair and according to the author this happens due to improper understanding of the maintenance problem, maintenance errors and spare parts unavailability. Hence, the occurrences of maintenance errors lead to premature failures.

iv. Customer satisfaction: - the positive and negative result of this criterion is the combined result of different causes and it has a strong relationship with the above criteria. For example, James (2020) stated that the maintenance time has a direct influence or bearing on the revenue of service providers since delays restrict their accommodating capacity for maintenance. It also influences customers because of unavailability of automobiles due to delayed maintenance critically affects fleet service providers. According to Ghobadian et al. (1994); it also depends on the interaction between the provider and recipient of service and is often perceived subjectively. As this article stated it is concerned with: the courtesy shown to the customer; physical circumstances of the reception area; the amount of explanation provided in terms of what needs to be done; contacting the customer if the car is not going to be ready at the agreed time, or if additional expensive work is required, etc.

As A.T. James & J. James (2020) indicated fleet maintenance is influenced by a variety of contextual and environmental factors that necessitate a different approach in their maintenance

management. Besides these James et al. (2017) said that in undertaking maintenance services, there are possibilities of maintenance errors that may lead to failures or even accidents. Hence, it is imperative to find those factors influencing service quality in the domain of fleet maintenance. Moreover, James (2020) stated that the proliferation of technology, financial capacity, modern service management concepts, and advanced production management enabled a competitive environment in the automobile service market. Therefore, it becomes important to know the causes for low fleet maintenance service quality in garages to evaluate them according to their severity.

A survey of automobile maintenance garages conducted by James et al. (2017) for identifying the potential maintenance errors and their causes and activities performed by maintenance personnel shows automobile maintenance error causes and sub-causes using the Fishbone diagram. According to this paper, the major maintenance error causes which can also be considered as causes for low fleet maintenance service quality are Inspection and Diagnostics, Maintenance Procedures, System and maintenance tools, Garage ambiance, Parts, fasteners and consumables, and Personnel elements. Based on its intense gathering of information from different garages and supporting literature, James (2020) also has identified the different points as challenges for garages but to stick with this study objective only the challenges those might also be considered as a cause for low maintenance service are; Proliferation of new models and variants, Technological advancements in automobile systems, Space and ambiance requirements, Labor requirements, Requirement of modern support equipment, tools and spares and Proper documentation requirements.

In their paper which attempts to develop models that evaluate the service quality of automobile garages quantitatively based on the factors that influence them, A.T. James & J. James (2020) have segregated these factors under six major headings such as Garage Management, Garage technician capabilities, Support system facilities, Garage ambiance, Sustainable garage practices, Spares supply chain management and Repair process quality and reliability. They have based on a detailed literature review and different garage interactions to classify the factors under these categories. According to this research, each of these service quality influencing factors also comprises several sub factors, which are elaborated in the paper.

Based on the above-mentioned literature the major factors that contribute to low fleet maintenance qualities are briefed as follows:

Table 2.2 Major factors of poor fleet maintenance service quality

Major factors	Discussion	Authors
The proliferation of new models and variants	Includes a wide range of vehicle varieties, the introduction of new technologies, complexity, and fluctuation with design.	James (2020)
Technological advancements in automobile systems	It is due to the fast proliferation of technology, lack of corresponding training, incapable traditional methods, equipment, and other resources for diagnosis and repair to meet the maintenance demands of modern automobiles.	James (2020), James et al. (2017)
Garage management	Decisions in recruitment/selection, training, and deployment/allocation of the garage technicians for maintenance tasks.	A.T. James & J. James (2020)
Support system facilities	This includes exclusive tools, material handling equipment, fixtures, service booklets, instructions, and drawings that guide maintenance technicians.	A.T. James & J. James (2020), James (2020), James et al. (2017)
Garage technician capabilities	Proficiency in the methodologies, techniques, tools, and materials including hands-on experience in the repair of various automobile systems and components. In addition to these, it includes the availability of an adequate number of skillful & well-trained garage staff.	A.T. James & J. James (2020), James (2020), James et al. (2017)
Garage ambiance	This includes sufficient space for repair, proper lighting facilities, a clean & junk-free space, good conditions of temperature and humidity.	A.T. James & J. James (2020), James (2020), James et al. (2017)
Spares and supply chain management	This consists of raw material suppliers, spare parts manufacturers, wholesale distributors, and retailers.	A.T. James & J. James (2020), James (2020), James et al. (2017)

Repair process quality and reliability	includes the workshop preparedness, human resource, maintenance time, ethical practices, etc.	A.T. James &J. James (2020), James (2020), James et al.(2017)
Proper documentation/Information technology implementation	It includes information technology tools (IT),the technical documentation of maintenance, including maintenance management information system	A.T. James &J. James (2020), James (2020)

2.5. Decision making approaches for fleet maintenance quality improvement

Makhanya et al.(2018) stated that quality management and quality improvement continue to play a central role in the success of a business. Moreover, Jagtap et al.(2017) stated that the competitive pressures facing firms in today’s environment have led to increasing reliance on quality-oriented, results-based improvements. Thus many noted quality experts have extolled the need to focus on and improve quality and customer satisfaction as a way of meeting the challenges facing today’s global organizations. As the article stated organizations throughout the world have made quality a priority in the form of Total Quality Management (TQM), Continuous Improvement (CI), and similar initiatives.

2.5.1. Cost of Quality concept

Any serious attempt to improve quality must take into account the costs associated with achieving quality since the objective of continuous improvement programs is not only to meet customer requirements but also to do it at the lowest cost. This can only happen by reducing the costs needed to achieve quality, and the reduction of these costs is only possible if they are identified and measured (Schiffauerova & Thomson, 2006). As Weinstein et al.(2009) define these costs represent the difference between the actual cost of a product or service and what the reduced cost would be if there were no possibilities of substandard service, product failure, or defects in their manufacture.

Quality cost measurement and analysis should cover all functions of the company. As Weinstein et al.(2009) indicated; to be successful in the process and also to be more effective in current tough competition firms better understand the consequences of poor quality in all aspects of their business. Because as it is been said in different works of literature, the primary value of a

COQ approach is that it enables organizations to identify opportunities for improvement and to measure that improvement over time. Moreover concerning poor quality service/product; Weinstein et al.(2009) stated that any company's customers will only no longer tolerate inferior quality in their products and services but firms can no longer afford the financial losses attributable to poor quality.

There are a lot of works done on the modeling of cost of quality. A review of research on the cost of quality models and best practices done by Schiffauerova & Thomson (2006) classifies CoQ models into four groups of generic models. These are P-A-F or Crosby's model, opportunity cost models, process cost models, and ABC models. As this article states quality cost categorization of prevention, appraisal, and failure (internal and external) costs proposed by Feigenbaum in 1956 is the now widely accepted model. The basic suppositions of the P-A-F model are that investment in prevention and appraisal activities will reduce failure costs and that further investment in prevention activities will reduce appraisal costs. The objective of a CoQ system is to find the level of quality that minimizes total CoQ (Schiffauerova & Thomson, 2006).

In another widely accepted view by many authors, CoQ is understood as the sum of conformance plus non-conformance costs, Moreover, Arenas (2014) has mentioned a new additional category of cost called "the cost of lost opportunity" which as the article has stated the approach was more used as a management tool that as an accounting technique.

After service/product cost of quality data are gathered, it should be measured and analyzed based on some measurement criteria. Weinstein et al.(2009) stated that since the volume of business varies over time, real differences in quality costs can best be measured as a percentage of overall operating costs, total or direct labor costs, or the average cost of a delivered product or service.

2.5.1.1 Cost of Quality in the service industry

There are limited researches done on the cost of quality in the service industry as Arenas (2014) stated, although within practitioners it is possible to hear new examples of applying COQ in the service industry, within academics the only well-known model is the Carr Model. According to the article, Lawrence Carr introduced the COQ model for the service industry and in his practical

exercise, Carr proved that COQ in service is applicable under the concept of service processes, and offers benefits for the company.

In their study which investigates a way to integrate the concepts of cost of quality and cost of maintenance to create a more effective approach to establish an appropriate maintenance policy for an organization, Weinstein et al.(2009) stated that; the inclusion of maintenance-related costs in an organization's financial reports, through the analysis of the costs of maintenance, helps management evaluate the relative impact of its maintenance problems on the organization's profitability. The article also mentioned that if a cost of quality/cost of maintenance system once implemented, it provides an invaluable foundation for the efforts to improve the effectiveness of the maintenance function. This approach provides a common language for communication between top management and the maintenance function to draw attention to where management should provide resources to correct quality problems and make improvements.

Despite its benefits and advantage, the cost of quality has many challenges, limitations, and drawbacks to implement it successfully. Jagtap et al.(2017)asserted that it should also be understood that the cost of quality is a comprehensive system, not a piecemeal tool. Thus there is a danger in responding to a customer problem only with added internal operations, such as inspection or tests, and ignoring other consequences of poor quality. Getting all required data related to quality cost is one of the main challenges mentioned by many researchers for effective implementation. According to Lutfi (2014), the main reason behind this is that accounting reports such as the balance sheet and income statement were never designed to report on quality-related costs and the reports were primarily designed to provide the shareholders with the financial position of the organization.

In their study which is assessing the factors that prevent the successful implementation of CoQ, Makhanya et al.(2018) identified that the requirement of the program for adequate resources for implementation and participation of employees which allows ownership and sustainability of the program as the main obstacle. Moreover, the article indicates that the lack of awareness of CoQ as an improvement methodology is a challenge facing both scholars and practitioners in the implementation of a CoQ program. Furthermore, researchers found that measurement and monitoring, and a lack of training, are sources of demotivation during CoQ implementation.

2.5.2. Root cause analysis approach

Incident investigation in the aftermath of an adverse event is intended to identify the latent and active factors contributing to the genesis of a particular adverse event (Mohammad et al., 2016). According to Serrat (2017) for every effect, there is a cause. But the results chain between the two is fairly long and becomes finer as one move from inputs to activities, outputs, outcome, and impact. When looking to solve a problem, it helps to begin at the result, reflect on what caused that. Root cause analysis (RCA) is an event analysis tool used to retrospectively analyze adverse and sentinel events. A multidisciplinary team uses the tool to determine the primary systemic causes of the event without placing blame on the individuals involved and to develop actions to prevent a similar event from occurring in the future (Percarpio et al., 2008).

According to Mohammad et al., (2016) root cause analysis (RCA) is not a single technique and it is broadly understood as a method of structured risk identification and management in the aftermath of adverse events. Rather, it describes a range of approaches and tools drawn from fields including human factors and safety science that are used to establish how and why an incident occurred in an attempt to identify how it, and similar problems, might be prevented from happening again.

Different authors use different techniques, methodologies, and tools to identify factors that contribute to the result of poor fleet maintenance quality. According to different works of literature the most common methodologies used are literature surveys and discussion with experts. Besides these methods, there are a lot of tools that help for identification. James et al.(2017) stated that the literature review revealed the application of several tools such as Fishbone diagram or Ishikawa or cause-effect diagram to show causes of a specific event, which are usually grouped into major categories to identify sources of failures. An event tree diagram is also a well-practiced graphical method in safety analysis to identify accident sequences for an initiating event.

According to James et al.(2017), the event tree diagram helps in understanding the propagation of an initiating event and its culmination into failure effect. Whereas the Fishbone diagram is also variedly known as Cause and Effect Diagram, Ishikawa Diagram, Herringbone Diagram, and Fishkawa Diagram show root causes of a specific event or condition. A major advantage of using

the Fishbone diagram is that it is a convenient and easy-to-understand method, which helps one to visually see potential failure causes and sub-causes of the problem to identify its root causes. Structurally, it is a better and proven approach for a team in a brainstorming session to investigate the causes of a problem.

In addition to the above tools as Huanget al.(2017) indicated Failure mode and effect analysis (FMEA) is a powerful tool applied for system safety and reliability analysis of products, processes, systems, and services. As a proactive risk management instrument, failure mode and effect analysis (FMEA) has been broadly utilized to recognize, evaluate and eliminate failure modes of products, processes, systems, and services. Moreover as this paper states; It also employs risk priority number (RPN) to obtain the priority orders of the identified failure modes although as the paper states, the conventional RPN method suffers from many flaws when used in the real world. Therefore, the determination of the priority order of failure modes in FMEA is a multi-criteria decision-making (MCDM) problem that requires MCDM methods for effective problem-solving.

Despite its importance in the identification of root causes of a problem, RCAs get many criticisms such as; Percarpioet al.(2008) indicated that RCA participants report the difficulty in forming causal statements and in developing/implementing corrective actions. Besides as Mohammad et al., (2016) stated, too often RCA results in a simple linear narrative rather than a wider systems view that displaces more complex and potentially fruitful, accounts of multiple and interacting contributions to how events really unfold.

In addition to these as Percarpioet al.(2008) indicated, by design, RCAs are uncontrolled case studies in which the quality of the analysis is affected by the quality of input data and team members' biases. This is because as these authors stated; the participants already know the outcome so they can experience hindsight bias and assume a higher probability of the event occurring, assign the event greater relevance, and are more critical of those involved. In addition, team members' knowledge, interpersonal relationships, hierarchical tensions, biased perspectives, and preexisting agendas can all influence their actions and outcomes. Not understanding the complexity of error, teams may end their analyses when they have found the most convenient root cause or one that fits their biases rather than the correct root cause.

2.5.3. Multi-criteria decision making MCDM approach

According to Marttunen et al. (2017) making and taking decisions, solving problems, designing and re-designing systems nowadays all have to take place in conditions of unprecedented complexity and uncertainty. An important component of complexity is the differing perspectives, values, and preferences of those responsible for and impacted by decisions taken. Stojcic et al., (2019) also stated that the decision-making theory approach has become an important means of providing real-time solutions to uncertainty problems, especially in engineering processes, which is a key focus of multi-criteria decision analysis (MCDA) (Marttunen et al., 2017).

Multiple criteria decision making (MCDM) is a discipline to support decision-makers to make an optimal choice from alternatives based on multiple criteria (Qin et al., 2017). As Marttunen et al. (2017) stated it is based on different principles and applies different procedures for scoring, weighting, and aggregation. In addition, as these authors stated many recent MCDA applications, do not simply focus on choosing between alternatives but more broadly on exploring alternatives, facilitating communication, improving learning, and supporting joint-solution findings.

MCDM approaches are widely used for selecting the best alternative in presence of several attributes, quantification of elements, determination of weights of elements, development of a structural model, etc. (Attri, 2017). According to El Kfita and Drissi-Kaitouni (2017), MCDM is a framework that aims to provide decision-makers with wise recommendations and alternatives, while being evaluated from multiple experts' opinions, called criteria. Triantaphyllou (2000) stated that each of the methods uses numeric techniques to help decision-makers choose among a discrete set of alternative decisions. This is achieved based on the impact of the alternatives on certain criteria and thereby on the overall utility of the decision-maker(s). Besides these Ishizaka & Siraj (2017) reasoned that it is often the case that a single criterion is insufficient to assess a set of available alternatives so there should be multiple criteria for effective decision making. In that case, MCDM methods are very helpful. Moreover, they stated that Multi-criteria decision making (MCDM) is in the field of operational research wherein the decision alternatives are analyzed with respect to a set of multiple (and often conflicting) criteria.

The multi-criteria decision-making method guides the decision and policymakers in understanding the mutual relationship between the identified criteria and identifying the most significant criteria. It is useful in modifying the existing policies/strategies or formulating new effective selection strategies Gardaset al.(2019). A.T. James &J. James (2020) stated that automobile maintenance can be considered as a service industry and to sustain in the competitive business environment, the service providers must ensure quality in their services. As this article stated, service quality modeling of automobile systems necessitates the consideration factors that influence service quality and their mutual interrelationships. Hence the method will enable them to identify the weak links in the garage and initiate improvement measures.

According to Attri (2017), these methodologies help to impose order and direction on the complexity of relationships among the elements of a system, and also they are an interactive learning method in which a set of different and directly related elements are arranged into a widespread organized model. Generally, as these papers indicated multi-criteria decision-making tools are important in most kinds of fields such as engineering, economics, and management.

Similar to RCAs these techniques have their challenges and limitations. According to Stojcic et al. (2019), the selection between existing MCDM methods is also a multi-criteria problem because each of the methods has its advantages and disadvantages, and it is not possible to claim that any method is more suitable than others. Triantaphyllou (2000) said that the difficulty that always occurs when trying to compare decision methods and choose the best one is that a paradox is reached, i.e., what decision-making method should be used to choose the best decision-making method? Furthermore, Ishizaka & Siraj(2017) also indicated that there is no single “best” method. In addition to this as Dhanisettyet al.(2018) stated, a general drawback of each of these methods is that the various forms of uncertainty (including ambiguity and/or vagueness) are typically present in decision-making processes are not or not fully taken into account.

Studies on equipment maintenance service using MCDM

According to Triantaphyllou (2000), there are three steps in utilizing any decision-making technique involving numerical analysis of alternatives: Determine the relevant criteria and alternatives, Attach numerical measures to the relative importance of the criteria and the impacts

of the alternatives on these criteria and Process the numerical values to determine a ranking of each alternative.

Many multi-criteria decision-making tools are implemented in different researches from these methods the most known are; the weighted sum model (WSM) which is the earliest and probably the most widely used method as Triantaphyllou (2000) mentioned. The analytic hierarchy process (AHP) is a later development and it has recently become increasingly popular. Some other widely used methods are ELECTRE, TOPSIS, TODIM, ISM, ANP, etc. In addition to these El Kfita and Drissi-Kaitouni(2017) mentioned PROMETHEE, VIKOR, SMART, and DEMATEL as classical MCDM techniques and tools those have been employed in problem-solving processes.

In the paper by A.T. James & J. James (2020) a structural methodology of graph theory and matrix approach is applied for developing the service quality index by evaluating the service quality of automobile garages through the development of a service quality index based on the factors influencing service quality. The major objectives of the paper by James et al.(2017) were to identify the maintenance error causes that could lead to the development of maintenance-induced failures and assess the failure severity due to these. The paper tries to mathematically model the failures arising out of various maintenance error causes attributed to the design and contextual factors exclusively in automobile maintenance. So the authors used a fuzzy cognitive map (FCM) modeling tool for this work to establish the relationship between various maintenance error causes and simulate its cumulative effect.

Reviewing the work by Nazeri and Naderikia (2017); the authors aim to develop a risk-based method for selecting a proper maintenance strategy to have available and reliable tamping equipment. In this paper, a fuzzy hybrid approach, including failure mode and effect analysis (FMEA), decision-making trial and evaluation laboratory technique (DEMATEL), and analytic network process (ANP), is presented to select an appropriate maintenance policy through identifying the risk of failures. At first, the authors used a fuzzy FMEA to identify the main risk and sub risk of failure modes. Then, the fuzzy DEMATEL and ANP approach method is used to put forward the interrelationship among the main risks and calculate the weights of the sub-risks.

Finally, the weights of sub-risks are determined. The multi-criteria decision-making tools that are going to be implemented in this research are reviewed as follows.

Interpretive structural modeling (ISM)

According to Attri (2017), the ISM approach was proposed by Warfield in 1973. The approach basically involves the methodical use of the graph-theoretic approach (GTA) in such a way that speculative and intangible aspects are exploited to develop a digraph based on contextual relationships among considered elements. James (2020) stated that interpretive structural modeling is one of the interactive management methods which assist research groups in dealing with complex issues. These methods combine quantitative techniques with qualitative experience and knowledge, yielding the best possible outcome strategically. It is flexible enough to accept a change of parameters without much labor. The model also produces a pictorial representation of the importance of the selected parameters, making the result easily comprehensible for all those involved.

According to Gardaset al.(2019), the ISM approach is a robust methodology that helps: to present a complex structure in a simplified manner; to transform less comprehensible mental models of a structure into explicit, visible models; to identify structure within the system; to interpret the embedded object, and to answer “what” and “how” in theory building. An ISM approach is an MCDM tool that helps in analyzing the interrelationships between the factors/variables. Also, it identifies the order and direction of the relationship. In addition to this as James (2020) stated it is a methodology for identifying and summarizing relationships among specific elements, which define an issue or problem.

The interpretive structural modeling (ISM) approach is one of the widely used MCDM approaches and as James (2020) indicated the methodology had been successfully used by several researchers. According to Attri (2017), it is used as a method for structuring complex issues by using modeling languages such as words, digraphs, and discrete mathematics. The developed ISM model depicts the organization of a complex issue or problem under consideration in a carefully designed structure consisting of graphics as well as words. Moreover, as these authors stated ISM approach can be integrated with other MCDM approaches. This concept will result in a better MCDM tool for solving practical problems.

In his comprehensive literature review,Attri (2017)shows that the applications of the ISM approach have tremendously increased in different application areas. the research showed that from 1974 (the approach's inception) To 2017 there are 406 research papers published on the applications of the ISM approach and from these papers, there are 80 papers concerning maintenance but from these papers, 78 of them are on Total Productive maintenance and two of them are on maintenance system framework development. From this, it can be seen that the approach does not have been used to improve the quality of fleet maintenance service.

TODIM method

TODIM method (an acronym in Portuguese "TOMada de Decis~ao Iterativa Multicrit 'erio"), proposed by Gomes and Lima (Gomes & Lima, 1992), is a valuable and well-known multi-criteria decision making (MCDM) method based on prospect theory that considers human's psychological behavior under risk and uncertainty, which has been widely used to solve different decision-making problems Wanget al.(2019). According to Hanine et al. (2016),the TODIM method is an effective behavioral decision-making method derived from the prospect theory. The main advantage of the TODIM is that the decision maker's psychological character is taken into account and one of the strong characteristics is its capacity to treat risk in MCDM problems.

According to Huang et al. (2019), one common characteristic of the current MCDM methods is that decision-makers are assumed as completely rational. In the real-life world, however, human thought is not absolutely rational presenting strong prejudice in vague and uncertain environments. Relating to theseWanget al.(2019) stated that the TODIM method is different from other MCDM methods (such as AHP, TOPSIS, and so on), it ranks different alternatives based on overall dominance degree rather than the final rating or score of each alternative. One of its outstanding advantages is to capture humans' psychological behavior. TODIM method was defined for dealing with the MCDM problems in which the criteria representatives are in the format of crisp values.

The TODIM not only takes each decision maker's bounded rationality into account to make a comprehensive comparison of alternatives but also technically uses simple resources to remove occasional discrepancies generated from the pair comparisons between decision criteria (Huang et al., 2019).

2.5.4. Fuzzy logic approach

To resolve the issues with RCA and MCDM techniques, different solutions are suggested by authors such as Percarpioet al.(2008) asserted that future research should focus on validation of the RCA framework in improving quality and on comparison of RCA with other analysis tools. Moreover, Gardaset al.(2019)stated that traditionally, it has been assumed that all the information about accessing the alternatives is taken in the form of crisp numbers.Ina real-life situation, it is very important to handle the impreciseness and uncertainties in the data.

To cope with such a situationthe fuzzy set theory is used to handle and describe the uncertainties in the data in terms of defining their membership and non-membership grades. R. Kumaret al.(2017) defined Fuzzy set theory as it is an extension of classical set theory which primarily aimed at dealing with real-world problems under an uncertain and vague environment. The merit of fuzzy set theory is to handle imprecise data and allow the inclusion of vague human judgment in computational problems. The fuzzy set theory effectively handles the conflict resolutions of multiple criteria efficiently and provides a better assessment of options.

Hanine et.al (2016) also mentioned that fuzzy set theory has been widely used for modeling decision-making processes based on vague and imprecise information such as preferences of decision-makers. In addition to this, the paper stated that fuzzy set theory is among the most preferred theories in decision making, which is an extension of ordinary set theory that was introduced for dealing with uncertainty and vagueness associated with information. Moreover, about the importance of the logicZhanget al.(2019) argued that; as can be seen, it is obvious that many studies are associated with AHP although the AHP method is based on the independence of the criteria. Hence as these authors argued the interaction among criteria must be taken into consideration when making decisions for many maintenance alternatives.

To address interaction among criteria, fuzzy measures and fuzzy integral are introduced.Gardaset al.(2019)indicated that the inputs are taken from the experts and these judgments could be biased influencing the final results of the model. To overcome this limitation and to improve the reliability and accuracy of the structure, integrated approaches may be employed. Fuzzy set theory integrated with multi-criteria decision making (MCDM) methods has been widely used to deal with uncertainty in the decision process, since it provides an appropriate language to

manage imprecise criteria, being able to integrate the analysis of qualitative and quantitative factors Peerally et.al (2016). Garg (2017) mentioned that many MCDM approaches have been proposed to handle MCDM problems such as Elimination and Choice Expressing Reality (ELECTRE), Weighted Aggregated Sum Product Assessment (WASPAS), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), TODIM, and VIKOR. According to the paper, all the above-defined decision-making and aggregation operators are under the fuzzy set theories. In addition, Dhanisetty et al. (2018) indicated that fuzzy methods have been developed and combined with MCDM methods to be more effective in the decision-making process. In this research, the MCDM tool i.e. TODIM, integrated with the fuzzy set theory is implemented and reviewed as follows.

Fuzzy TODIM method

As Hanine et al. (2016) stated to avoid the effects of prejudice of decision-makers and bias in the ranking of alternatives, the fuzzy set theory has been integrated with the traditional TODIM. In complement to this Wanget al. (2019) said that to tackle real-world complex decision problems under uncertainty, the TODIM method has been extended to a fuzzy environment, in which extant fuzzy TODIM methods can manage various types of information to model the uncertainty

For expressing the linguistic variables for the attribute values, triangular fuzzy numbers (TFNs) are used. With the use of these fuzzy numbers and according to the concept of the TODIM method, the gain and loss of each one of the alternatives relative to others are evaluated. Then, by computing the dominance degree of each alternative over the others, the global value of each alternative is obtained and alternatives are ranked (Hanine et al., 2016).

According to Wanget al. (2019) Fuzzy TODIM method has been widely and successfully used to solve different decision-making problems and consider decision makers' (DM's) psychological behavior during the decision process under uncertain environment. To assert this Hanine et al. (2016) stated that by fuzzy TODIM, uncertainty and imprecision from subjective and the experiences of experts may be effectively represented and reached to a more efficient decision.

2.5.5. Quality Function Deployment (QFD) Approach

QFD is appeared formally as the TQM technique through the works of Yoji Akao in the year 1972 (R. Thirumanas and Joseph, 2013). According to Jamali and Elahi (2015), Quality function

deployment is a system through which the customers' needs are converted to a decent product or service. The goal of converting customer's requirements into product or service quality characteristics is to guarantee customer's key demands and company's core technologies are systematically put into quality characteristics, such as any functional components, process variables, and service factors, to meet the product or service quality required by the customer (Xing & Min, 2017).

As Jain & Verma(2019) stated; to translate the voice of the customer into technical requirements, QFD utilizes a composite matrix known as House of quality (HOQ) to compare the voice of customers with technical requirements and to determine their respective relationships which provide important information on identifying areas that need an improvement. According to R. Thirumanas and Joseph (2013), the HOQ is the basis for all matrices needed for the QFD method and the number of these matrices is depends on the scope of the project.

2.6. Literature gap

Written literature in the equipment maintenance area is focused more on industrial machinery maintenance which means researches on the improvement of fleet maintenance service is still not adequate. Considering the existence of a difference between these two types of industries as briefed previously, there should be more quality improvement research studies done on fleet maintenance facilities. These researches may have significant importance in fleet maintenance management especially for companies with a huge quantity and variety of fleets like construction companies. In those cases, it makes it even more important considering the investment in the sector in our country and any other country.

In addition to the above general literature gap, most of the works done on improvements of fleet maintenance service quality are limited in using root cause analysis (RCA) techniques. But as being discussed in previous sections, the technique has a limitation that makes it less effective in the identification and prioritization of the causes. Therefore, the implementation of these techniques with the integration of MCDM and fuzzy methods would be more effective in the decision-making process. In practice, published literature on the improvement of fleet maintenance service quality using MCDM methods is very few. Specifically considering the methods implemented in this research study (i.e. ISM and fuzzy TODIM) makes it even much

less. In conclusion, to the best of my findings, I couldn't find articles written on the application of ISM and fuzzy TODIM approach in the improvement of fleet maintenance service quality. Therefore this research study will have a significant contribution to the literature of fleet maintenance services in addition to its practical importance.

CHAPTER THREE

RESEARCH METHODOLOGY

This research has aim to identify and analyze the causes of low service quality in fleet maintenance facility and their relation with the customer requirements that will help for decision making in order to improve the maintenance quality of fleets in a construction company which is very poor as described in the problem statement section of this paper. The methodologies that are employed in the study to accomplish this objective are presented in this chapter. The main topics included in this chapter are; description of the study area, research approach and design, research sampling, types and sources of data used and data analysis & presentation methods.

3.1. Description of the Study Area

The study focused on the improvement of fleet maintenance quality in a construction sub-sector, particularly the research will be done by taking Ethiopian Construction Works Corporation (ECWC) as a case company. The company is selected for this research by considering its construction level (level one contractor), capacity, and experience in the sector. For instance, currently, the company is working on more than sixty major projects and owns a total of more than one thousand vehicles and machinery without including the equipment rented from external suppliers. The company provides maintenance services for its machinery which are more than 20 different kinds and for external customers in its large maintenance facility which is located in Addis Ababa.

3.2. Research Approach and Design

The research followed the concept of an applied research type that will benefit the case company and other fleet maintenance service facilities in the process of improving the service quality of fleet maintenance. Hence, considering the research is focused on identifying the major causes of the quality problem based on the information gathered and then the development of a hierarchy of the causes, it follows an empirical study design methodology. As shown in Figure 3.1, to deal with the key research objectives and answer the research questions, this research utilized both qualitative and quantitative i.e. mixed approaches and a combination of primary and secondary data sources. The qualitative data support the quantitative data analysis and

results. Furthermore, the research adopted a cross-sectional survey method also to provide a conclusion and recommendation a descriptive and explanatory research study is used.

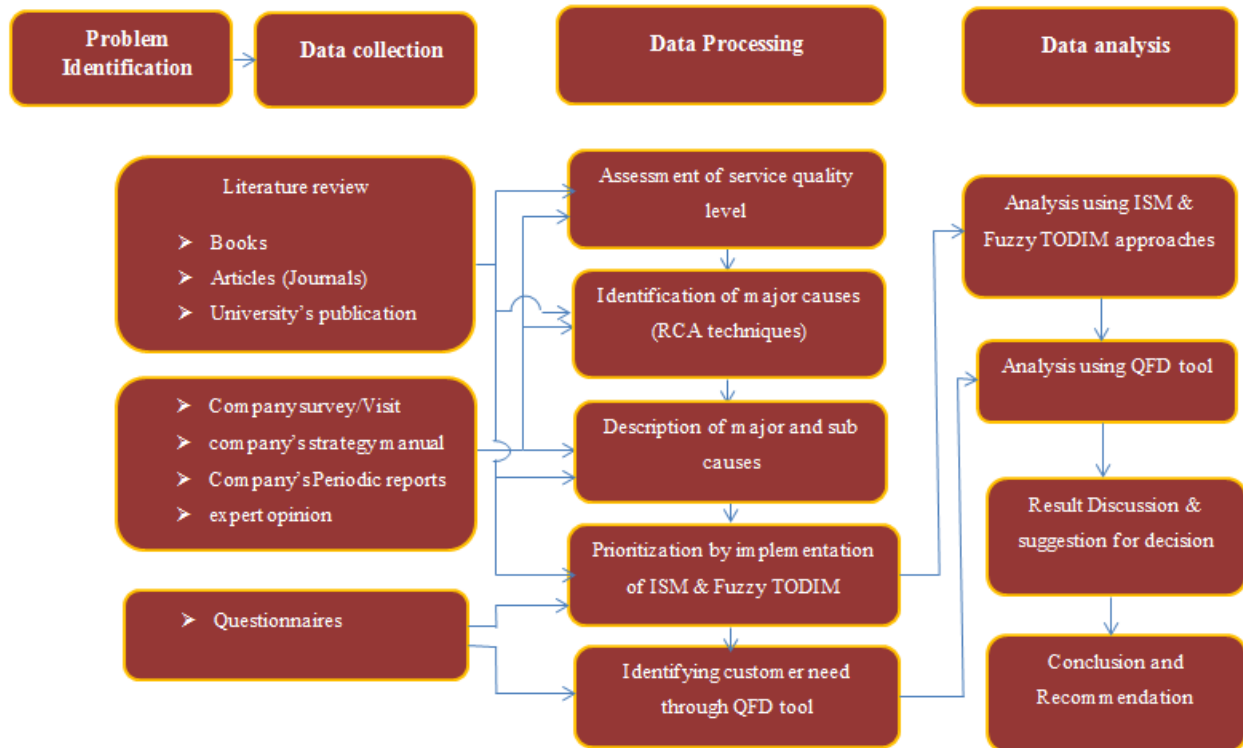


Figure 3.1 Research framework(Source: Own)

The study has continued by assessing and examining in detail of the current fleet maintenance service quality level of the case company. It is accomplished by personal observation of each maintenance related activities done in each shop/section/department of the facility, by referring the company’s maintenance strategy/manual& periodic activity reports and by interviewing selected management personals and employees in the company. After that identification of causes for the poor fleet maintenance service quality in the facility has identified through company survey,interviewing the maintenance personnel including team leader, engineers and technicians for gathering information regarding the causes of poor quality service from their perspective or experience and through detail reviewing and referring of literatures and related books written on this topic.In the process of identifying potential causes and sub-causes of the service quality problem a 6M/6P approach in assistance with the RCA is used.

After identification of the various causes associated with the result of poor fleet maintenance service quality specific to the case company, the methods discussed in the previous chapter, (i.e. ISM and fuzzy TODIM) are utilized for ranking/prioritizing of the causes. For determining of the weights of each low service quality causes and their relation to the identified criteria, experts' opinion is used through a questioner. Then customer service requirements are identified through a questionnaire survey method. After that House of quality function deployment (QFD) tool is used to analyze the relationship that existed between the customer service requirements and the service quality problem causes. Finally, detailed interpretation and discussion from the results of the analysis have been drawn including conclusions and recommendations which provide significant help in the decision-making process.

By using different published literature especially related to multi-criteria decision making and problem identifying methods as a reference, a research conceptual model planned to follow to accomplish this research's key objective is shown in Figure 3.2.

3.3. Research Sampling

3.3.1. Sampling Methods

Sampling is a definite plan for obtaining a sample from a given population. It refers to the technique or the procedure the researcher would adopt in selecting items for the sample (Kothari, 2011) whereas a sample is a representative collection of units from a population used to determine truths about that population. In this research due to resources including time, materials, money, and workload limitation, a random sampling technique is employed for customer requirement assessment in which each sample has an equal probability of being chosen.

3.3.2. Sample Size

To get a representative and reasonable sample size that supports the study, a common formula elaborated by Etikan & Babatope (2019), for calculating sample size in survey studies from a finite population (countable population) is used. Equation (1) is applied to compute the initial sample size. Since the population is finite (less than 50,000), Equation (2) is used to compute the target sample size.

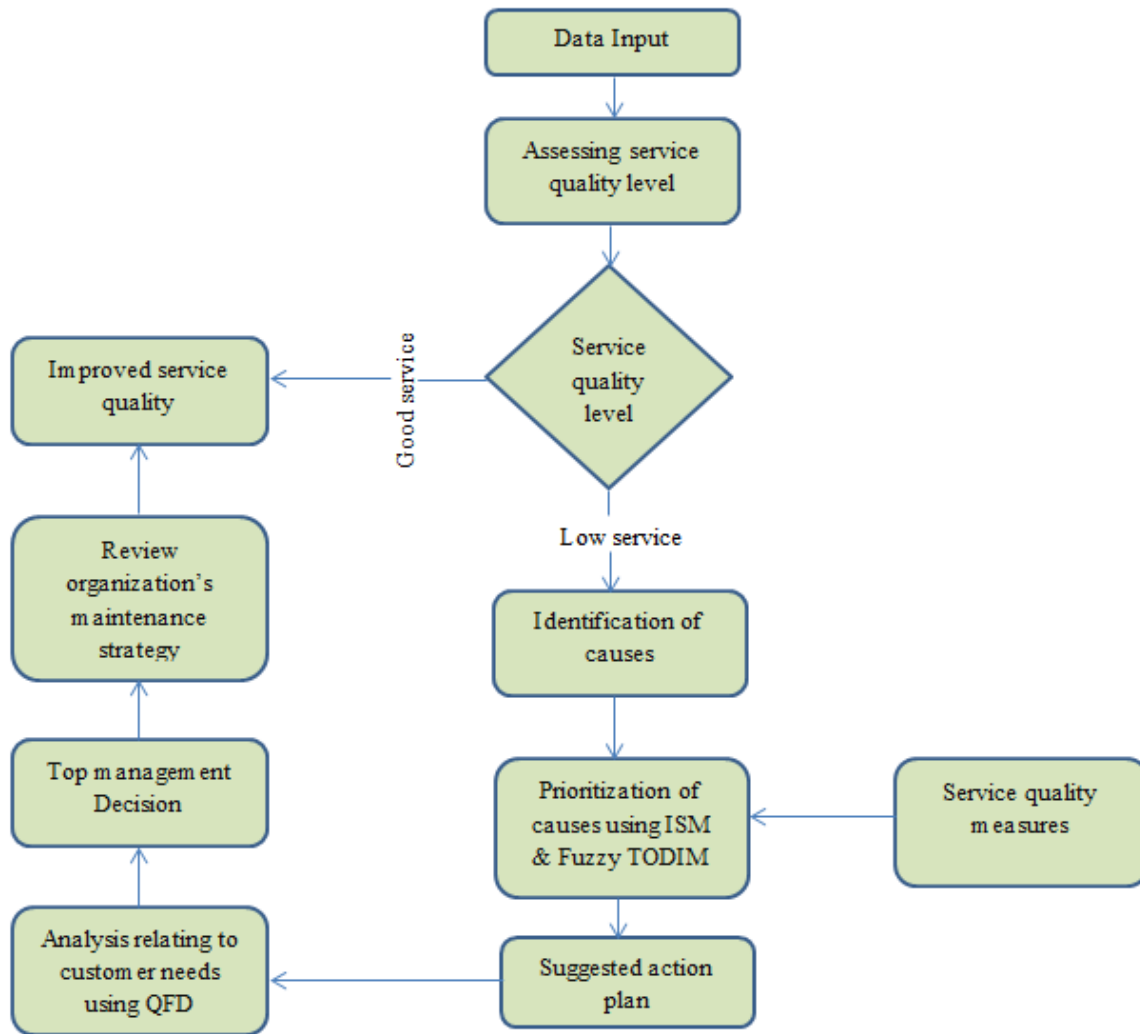


Figure 3.2 Research conceptual model (Source: Own)

$$X = \frac{Z^2 * p(1-p)}{MOE^2} \tag{1}$$

$$n_f = \frac{N * X}{X + N - 1} \tag{2}$$

Where:

X = initial sample size

n_f = target sample size

Z = the critical value of the normal distribution for confidence levels. Which are; 1.645 for 90% confidence level, 1.96 for 95% confidence level and 2.576 for 99% confidence level. In this study, a 95% confidence level is used which has the critical value of 1.96.

p = Proportion of sample

MOE = Margin of error/confidence interval.

Referring to different researches on fleet maintenance service which have implemented customer need survey, for this study 50% (0.50) of proportion value and 8% margin of error is used.

N = Population size; for customer population it is determined as

Number of project equipment administration & maintenance team leaders/representatives = 63

Number of top managers with personal vehicles/ drivers work under different departments in the head office = 160

Number of external customers (external company representatives) = 8

$$\Rightarrow N = 63 + 160 + 8 = 231$$

$$X = \frac{Z^2 * p(1-p)}{MOE^2} = \frac{1.96^2 * 0.5(1-0.5)}{0.08^2} = 150.06, n_f = \frac{N * X}{X + N - 1} = \frac{231 * 150.06}{150.06 + 231 - 1} = 91.2$$

Table 3.1 Target respondents

Customer	Total number	Sample size
Project equipment administration & maintenance team leaders/representatives	63	$\frac{63 * n_f}{N} = \frac{63 * 91.2}{231} \approx 25$
Top managers with personal vehicles/ drivers work under different departments in the head office	160	$\frac{160 * n_f}{N} = \frac{160 * 91.2}{231} \approx 63$
External customers (companies)	8	$\frac{8 * n_f}{N} = \frac{8 * 91.2}{231} \approx 3$

3.4. Types and Sources of data

Vassilakis and Besseris (2009) states that; “Being able to decipher a root cause relies on teamwork that involves maintenance technicians and foremen as well as middle-level managers”. Hence, the research for the improvement of fleet maintenance service quality in the facility had accomplished through expert opinion, company survey, and literature review. The data was gathered from the case company and secondary sources. Both primary and secondary sources of data/information are used to conduct this particular research.

3.4.1. Primary sources of data

The primary data was collected by personal observation of each maintenance-related activity done in each shop/section/department of the facility, through questioners, and by interviewing selected management personals and employees in the company.

An interview is conducted with the maintenance personnel of ECWC including a maintenance manager, 4 team leaders, 3 engineers, and 3 senior technicians for gathering information regarding the causes of poor quality service from their perspective or experience and the possible consequence/result of that cause. To allow the interviewee to share their experience in-depth and give them the freedom to express their thoughts open-ended questions are used with semi-structured type. Furthermore probing questions are used to get more information about the answer and also to identify sub-causes of the major causes.

For determining the weights of each poor service quality cause, their interrelation, and their relation to the identified measuring criteria to prepare for the analysis, a questioner has been developed and given to ten top managements who are considered as decision-makers. The research also used a second questioner to identify customers’ service requirements, importance rating, and weighs. Both questionnaires were developed after conducting an extensive review of literature on fleet maintenance service and the questions are kept as concise as possible with care taken to the actual wording and phrasing of the questions.

3.4.2. Secondary sources of data

Relevant secondary data were collected from the company’s maintenance strategy/manual & periodic company reports, books, manuals, journals internet, government reports, as well as any

other concerned bodies are used to extract any sort of essential information to strengthen the study findings.

3.5. Data analysis and presentation

The research has continued to the analysis stage after assessing and examining the current fleet maintenance system followed by the case company to the problem identification process. The process has assisted by using quality management tools and techniques well espoused in TQM philosophy. Haider et al. (2015), state that the Five Why Analysis gives us the root cause for the problem. According to James et al. (2017), a cause and effect diagram shows the root causes of a specific event or condition. Hence, in the process of identifying potential causes and sub-causes of the service quality problem a 6M/6P approach in assistance with the five why analysis is used.

After that, MCDM tools; interpretive structural modeling (ISM), and Fuzzy TODIM are implemented for the development of a hierarchy of the main identified poor service quality causes. These two methods combine the quantitative techniques with qualitative experience and knowledge, yielding the best possible outcome strategically as briefed in the literature review section. ISM helps in establishing interrelationships among the system variables to yield a hierarchy of importance according to the managerial perspective. The contextual relationship among the identified quality factors is identified based on a pairwise comparison of variables and constructed the structured self-interaction matrix (SSIM) with the help of experts based on a questionnaire survey method.

Whereas, in the fuzzy TODIM method, the fuzzy set theory is integrated into the traditional TODIM approach. The general approach is that, for expressing the linguistic variables for the attribute values provided by the experts (using a questionnaire), triangular fuzzy numbers (TFNs) are used. By using these fuzzy numbers and according to the concept of the TODIM method, the gain and loss of each one of the factors relative to others are evaluated. Then, by computing the dominance degree of each factor over the others, the global value of each factor is obtained and factors are ranked. In both methods the data was analyzed by taking the information from primary and secondary sources. During analysis of the data MS Office 2013, Excel was used to manipulate the raw data collected and the responses of the questionnaire.

Then House of quality function deployment (QFD) tool is used to analyze the relationship that existed between the customer service requirements and the prioritized major service quality factor to propose an effective service quality improvement suggestion that considers customer needs. To administer the QFD a sample was taken from the current customers of the case company as briefed in sample size calculation section. Then these customers defined the importance level of fleet maintenance service attributes using a questionnaire. After that, using the QFD tool analysis the most critical quality factors are identified based on the level of relationship between the quality factors and the customer service requirements. A second QFD is also employed to relate the prioritized quality problem causes against the recommendations that have proposed for eliminating the highest-ranked problem cause. Finally, detailed interpretation and discussion from the results of the statistical analysis have been drawn which provide significant help in the decision-making process.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Assessment of current performance of the case company

4.1.1. Overview of the case company

The Ethiopian Construction Works Corporation (ECWC) is a public enterprise established on 18 Dec. 2015 based on Council of Ministers Regulation No. 366/2015. The corporation is a result of the amalgamation of three formerly independent public enterprises, namely the Ethiopian Road Construction Corporation, the Ethiopian Water Works Construction Enterprise, and the Ethiopian Prefabricated Building Parts Production Enterprise. While the establishment of the corporation is a recent phenomenon, the history of the above-mentioned three former enterprises traced back to the late 1940s and early 1950s.

According to the company's first half of the 2020/2021 Ethiopian fiscal year report, the corporation is currently working on 30 construction projects within the transportation sector, 15 dam and irrigation construction projects within the water infrastructure construction sector and dams and irrigation management center, and 20 construction and renovation projects within the building and housing construction sector. A total of 63 projects with a contract amount of Birr 42, 113,815,669.28 are being carried out by the corporation. Currently, the corporation owns 1, 476 construction equipment and machinery and has over 20,000 permanent and contract employees who are working at the head office and its various projects. Besides construction and investment works domestically and oversees the corporation has set the mission; to assemble construction equipment and vehicles; as well as to manufacture spare parts; deliver maintenance service by using skilled manpower and modern technology. The corporation is organized into six sectors, three centers, and six departments.

Construction Equipment and Machineries Management Sector

The construction Equipment and Machineries Management Sector is accountable directly to the CEO of the corporation and it prepares its policies, guidelines, manuals, procedures, and standards to efficiently discharge its duties and responsibilities given by the CEO and put them

in place after approval. The sector monitors and controls the administration and maintenance of the construction equipment and machinery, plants, and vehicles as per the laws and regulations of the sector and has the following general organizational structure.

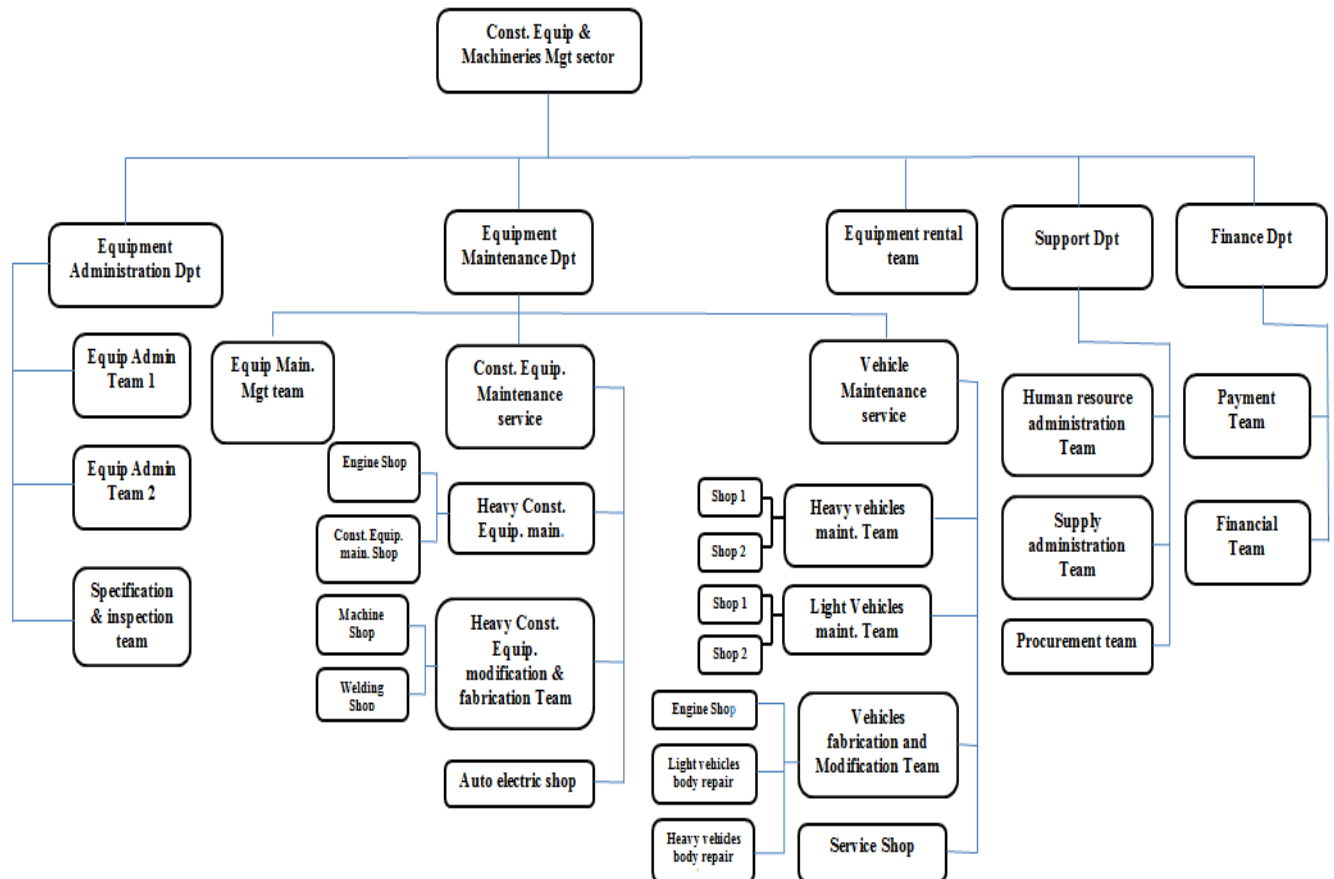


Figure 4.1 Construction Equipment & Machineries management sector organizational structure (Source: Own)

i. Equipment Administration Management

The major duties and responsibilities of this management are:

- Ensures and controls the proper and timely supply of construction equipment and machinery to the projects of the construction sectors as per the request filed by the respective sectors and collects revenues from them as per the internal renting and leasing work system. It also generates income by renting excess equipment and machinery for external customers if there is any.

- Prepares and submits specifications for the procurement of plants, machinery, equipment, and vehicles for the corporation, and ensures the acquisition of the procured plants, machinery, equipment, and vehicles as the procurement specification.
- Prepares or reviews the guideline, code, and criteria for the eradication of obsolete construction equipment and machinery submits the criteria to the CEO & avails the obsolete materials to pertinent bodies for eradication.

ii. Equipment Maintenance Management

The major duty and responsibilities of this management are to provide maintenance service for construction equipment and machinery, plants, and vehicles for internal and external customers and to collect the revenue obtained from the service. The internal customers are the corporation's construction sector projects, other management departments, and centers. Currently, the major external customers of the maintenance service are other government organizations and corporations. Such as; Human Rights Commission, Ethiopian Sugar Corporation, FIDCA, Federal Supreme court, Transport minister, National Bank, Federal judicial administration, and others.

4.1.2. Maintenance Service Performance of the facility

Based on the information found from the company's maintenance data history and personal observation, currently, the company is providing maintenance services for more than 20 different kinds of machinery without brand and model specialization. Such as:

- Construction machinery: Dozer, Grader, Excavator, Loader, Roller, Paver, etc.
- Trucks: Dump Truck, Cargo Truck, Fuel Truck, Water Truck, etc.
- Light vehicle & Bus: Station wagon, Pickup, automobile, etc.
- Plants & Crushers: Asphalt plant, concrete batch plant, sand maker
- Auxiliary Equipment: Generator, Compressor, Welding machine, Water pump

To help the company to give effective and efficient maintenance service for all kinds of the above-mentioned machinery and others, the maintenance department is organized based on the machine kinds and activity types as shown in Figure 4.1 of the organizational structure of the sector. It is organized under two services heads, six teams, and a total of thirteen shops. At this time there are 250 employees in the department.

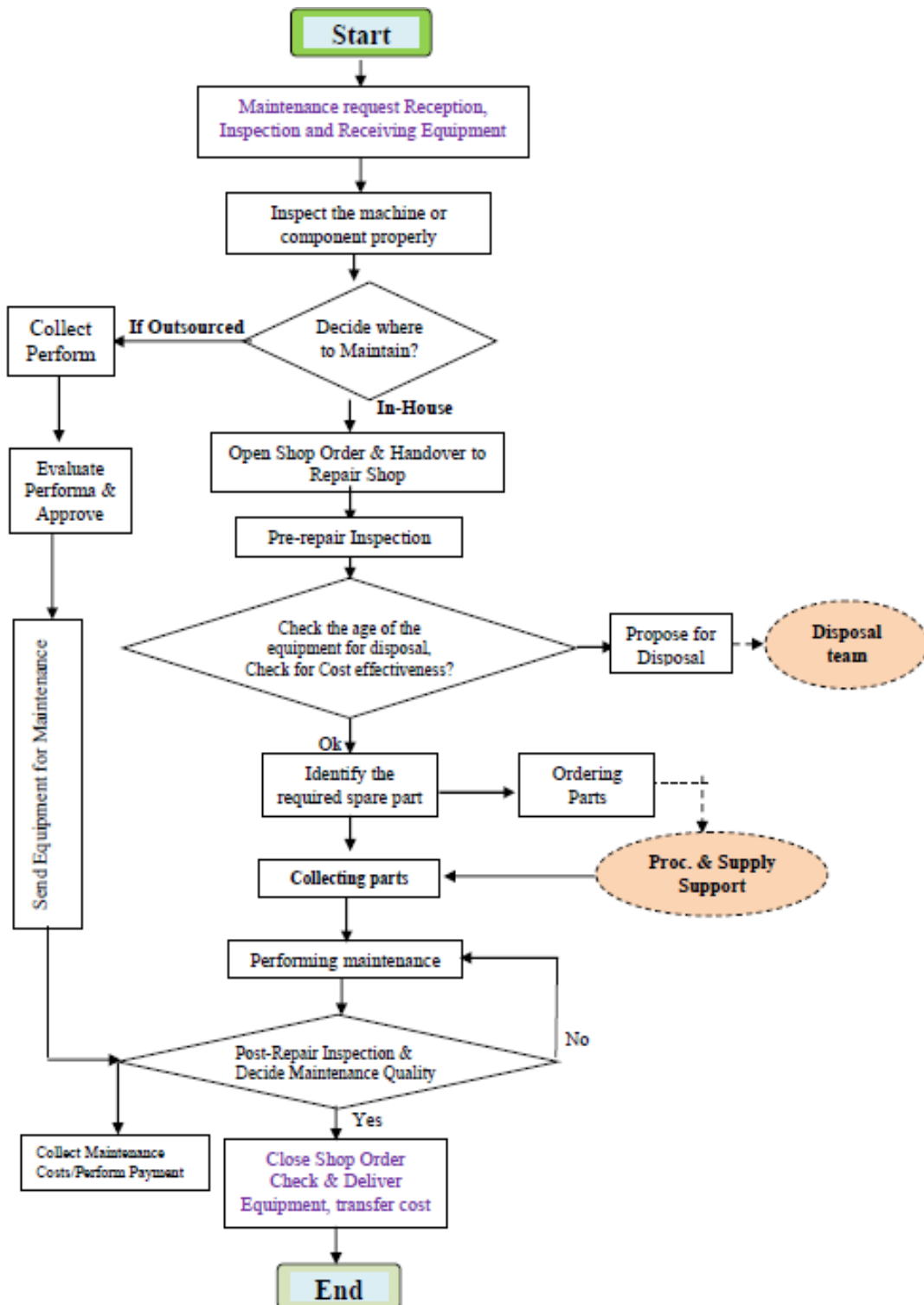


Figure 4.2 Maintenance service process flow chart (Source: ECWC’s Equipment Maintenance Management System Manual, July 2016)

Figure 4.2 shows the general maintenance process flow chart followed by the company starting from maintenance service request to the final delivery. According to the department’s nine months (from July/2020 to March/2021) performance report, the company provided the following maintenance services and collected the indicated revenue from them.

Table 4.1 Service provided and Revenue collected in nine-month (Source: ECWC Equipment maintenance department nine months report)

I/No.	From	No. of service Provided	Total Revenue collected (in ETB)
1	Internal Customers	3,345	38,115,238.95
2	External Customers	74	694,897.84
Total		3,419	38,810,137

4.1.3. Identified maintenance service quality problems

Based on the information gathered from the periodic performance reports of the maintenance department and the collected nine-month vehicles and machinery maintenance service data, the major service quality problems are briefed as follows.

i. Longer Down Time

Downtime is the duration that takes to maintain the equipment after failure. This is the sum of repair time, replacement time, and waiting time. As stated on FASTTRAK (2021), Auto Shop Management Blog, on-time vehicle deliveries have a significant impact on customer retention, and also it is very important in customers' minds as time is so valuable these days. Hence, understanding this significance, the maintenance department set “Minimize downtime and increase equipment availability for users by supporting maintenance activity towards delivery of fast, quality & cost-effective service” as the main objective.

Even though the company stated this as a major objective, in reality, most of the maintenance services requests are taking longer time than they are supposed to and many are taking much longer time which has been the main source of customer complaints and dissatisfaction. To show the existence of this problem twelve months of recent maintenance service data is taken as a

sample from the company’s maintenance service report. The duration that the sample taken is starts from June 01/2020 – May 28/2021 and in this period major and minor service requests are completed and delivered to the customer. From these services, the service that took the longest days in each month are selected and presented in table 4.2. The table proves that much longer time is taking for completing maintenance services and from this information, guessing that there are many numbers of services that lag by two or three days is not difficult.

Standard times are used as a guide to efficiency in many companies and the case company also stated them as a reference even though there is a question and a limitation on their implementation. According to the definition stated on the reference document of the case company, time standards are flat-rate man-hour assessments for specific maintenance and repair tasks. These times have been developed through time and motion studies and grouped in machine types and activities. They are generally determined by manufacturers and used by their dealer workshop networks to regularize customer billing. These times are usually quite generous, i.e. the average mechanic can complete tasks comfortably within the allotted time. However, this assumes that the workshop is properly tooled and the mechanics fully trained.

The standard times are stated in a range, therefore, for this analysis, the maximum time is used in each breakdown activity, and also activity description listed on the table is assumed and taken as the most time-consuming from the available option. For example, if the activity description says “Engine repair” then it is taken as “engine overhaul” to know the maximum standard time.

Table 4.2 Downtime observed from June/2020 to May 2021 (Source: ECWC equipment maintenance department monthly report)

I/No	Equipment Type	Activity description	Down Time (in days)	Standard time (in days)	Difference (in days)
1	Cargo Truck	Engine overhaul	1515	9	1506
2	Loader	Repair radiator and starting system	1369	6	1363
3	Roller	Engine repair	1345	9	1336
4	Dozer	Chain repair	1236	6	1230
5	Dozer	Engine overhaul	1236	9	1227
6	Dump Truck	Body and brake system repair	947	6	941

7	Cargo Truck	PM, starting system and brake system repair	847	4	843
8	Pickup	Engine repair	793	9	784
9	Grader	Cooling system and engine repair	732	4	728
10	Fuel Truck	Body repair	721	7	714
11	Pickup	Changing damage body by accident	703	3	700
13	Pickup	Engine repair	670	9	661
14	Pickup	Body repair	558	7	551
15	bus	Brake system repair	546	3	543
16	Pickup	Engine overhaul	542	9	533
17	Pickup	PM and Cooling system repair	524	4	520
18	Roller	Repair rear fiber glass, left door glass, door lock and accelerator leakage	443	8	435
19	Station wagon	Steering system repair	425	3	422
20	Generator	Starting system and Engine repair	422	12	410
21	Station wagon	PM and Cooling system repair	409	4	405
22	Grader	Starter motor repair and PM service	377	4	373
23	Pickup	PM and body repair	374	4	370
24	Station wagon	Engine and brake system repair	380	12	368
25	bus	Steering system repair	360	3	357
26	bus	Suspension and electrical system repair	360	6	354
27	Station wagon	Gear box repair	353	3	350
28	Station wagon	Suspension and steering system repair	353	6	347
29	Pickup	Body repair	346	7	339
30	Roller	Pump Repair	340	5	335
31	Roller	Engine repair	333	9	324
32	Pickup	Power system repair	315	5	310
33	Station wagon	PM and Brake system repair	302	4	298
34	Station wagon	Suspension system repair	284	3	281
35	Cargo Truck	body repair	270	7	263
36	Pickup	Check door regulator and door lock	258	2	256
37	Pickup	Brake system repair	257	3	254
38	Station wagon	Head light and bumper repair	229	3	226
39	Pickup	Starting system and Engine repair	238	12	226

ii. Higher frequency of maintenance & rework

The frequency of maintenance is the number of failures that occurred or the number of maintenance done for the equipment. The maintenance service quality provided has a huge impact on the number of equipment failures and maintenance rework done. This is a case that has been seen in the case company. Equipment failures have occurred more than the expected/normal number of failures per year and also a higher number of maintenances service reworks on a lot of machines. This factor is taken as a service quality problem because it is also one of the major sources of customer complaints and dissatisfaction. Table 4.3 listed some of the equipment with a higher frequency of maintenance in 11 month period (from July-01/2020 to May-28/2021).

Table 4.3 Equipment with a higher frequency of maintenance (Source: ECWC equipment maintenance department monthly report)

I/No	Equipment Type	Equipment Plate No/Serial No	Frequency of Maintenance
1	Bebien Dump Truck	3-64946	46
2	Nissan m/bus	4-12393	45
3	Bishoftu bus	3-61175	41
4	Faw dump truck	3-62992	38
5	Eurotrackker Fuel Truck	3-04047	35
6	Eurotrackker Fuel Truck	3-04051	34
7	Mercedes bus	3-33146	29
8	Scania Fuel Truck	3-14056	28
9	Mitsubishi d/cab	3-37619	27
10	Volvo loader	5475	26
11	Sino Fuel Truck	3-62560	26
12	Toyota double cab	4-03369	26
13	Eurotrackker f/truck	3-04041	25
14	Toyota station wagon	4-00213	25
15	Toyota double cab	4-08489	25
16	Nissan m/bus	4-12386	25
17	Nissan f/truck	4-12807	25

iii. Higher Cost

Cost includes all the spending associated with servicing, repairing, or overhauling a fleet. It consists; spare part cost, labor/manpower cost, material and tool cost, and overhead cost. Besides the cost increment and market loss due to poor maintenance service quality on the customer side, which is mentioned in the problem statement section of this paper, the case company was also forced to use outsourced maintenance service option because of incapability to give service in its facility which is a result of many reasons. According to ECWC’s maintenance manual, it is stated that the garages considered as well established and skilled compared to other garages so any repair requirement should be resolved in own garage except for a few special cases. In addition to capacity limitation, in my observation, the option has been used as a shortcut and a simple strategy to be free from responsibility and it is much more costly compared to own service. Table 4.4 shows the number of maintenance provided during the period from July/2020-April/2021 to internal customers in its garage and in outsource facility. The table also shows that the total cost spend in each maintenance facility and the ratio per equipment to visualize the cost difference.

Table 4.4 Cost comparison between own maintenance and outsourced maintenance (Source: ECWC equipment maintenance department monthly report)

I/No	Maintenance Place	Total No of machines and vehicles maintained	Total cost	Ratio (cost per equipment)
1	Own garage	2,979	18,267,472.57	6,132.08
2	Outsourced	113	5,776,632.38	51,120.64

iv. Lower Customer satisfaction&high complaints

The positive and negative results of customer satisfaction might be a combined result of different causes. Based on my study through different reports of the maintenance department and discussion with some employees, the major customer dissatisfaction and complaints come from the repair time and reliability of the service. That is: many customers complain that the maintenance service is taking longer time than it is supposed to take and that they are forced to return for maintenance because they didn’t get effective maintenance the first time. Besides these

major problems, the following problems are also related to lower customer satisfaction and customer complaints:

- the difficulty to contact the responsible person for their required service
- gaining not enough explanation in terms of what maintenance needs to be done
- getting notification if the vehicle is not going to be ready at the agreed time,
- low courtesy shown

From the performance indicators listed on FASTTRAK (2021), Auto Shop Management Blog, which can be used to identify repair shop strengths and weaknesses, Customer Acquisition Rate and Customer Retention are used to show the existence of customer-related problems.

- Customer Acquisition Rate is the rate at which new customers are added and it is an important measure of business growth. In ECWC's case, this is related to the external customers and these customers are known and constant throughout the year. This means the probability of the addition of a new customer is very rare.
- Customer Retention: is the percentage of existing customers that purchased service during a period and it is a measurement of how well the shop is doing at keeping customers. In this regard the available ECWC's external customer doesn't even come frequently for the service as indicated on the performance of the company section (i.e. only 74 services in 9 months) and services are requested only for light vehicles.

4.2. Major causes of poor maintenance service quality

For identification of causes for the above-mentioned major fleet maintenance service quality problems in the company, mainly three methodologies had been followed.

The first method used is: visiting the facility's shop organization and observing while the maintenance service activities are performed in each shop. To support the problem cause identification, the visit and observation are oriented based on the reviewed reference literature on the fleet maintenance service area. The second method used is studying monthly and annual reports of the maintenance department for higher managers which briefs the achievements and problems encountered during the period.

The third method is interviewing selected employees that include team leaders, engineers, and technicians regarding the causes of poor quality service from their perspective and experience. To allow the interviewee to share their experience in-depth and give them the freedom to express their thoughts, open-ended questions are used with semi-structured type. Furthermore probing questions are used to get more information about the answer and also to identify sub-causes of the major causes.

By using mainly these methodologies' various detail and specific root causes and sub-causes for poor maintenance service quality in the case company were identified. Since these identified root causes and sub-causes were many in number and various in type, categorization under some categories is needed to make it simple for visualization and the analysis and then to identify a potential area for quality improvement. Therefore, 6M (Man, Method, Machine, Mother Nature, Material and Measurement) and 6P (People, Process, Policy, Plant, Program, and Product) classification approach is employed in combination. In the process of categorization, literature; Lynch (2021), A.T. James & J. James (2020), James et al. (2017) and Vela (2019) (continuous improvement) and experts' opinions are used as input. Finally these typical 6M/6P categories' are generic terms in manufacturing/service sectors so it is customized for this study through the literature review, garage observation, and discussion on the interview. The major poor service quality factors with their sub-clauses are discussed as follows.

4.2.1. Technicians' knowledge, skills, and performance

This considers the quality of maintenance service activities which are mainly dependent on the maintenance personals' knowledge, skill, physical and mental health, and adherence to rules. Based on the information gathered, the main sources of longer maintenance service time (downtime) which are related to technicians are; low manpower, not having adequate knowledge and skill, and low work motivation. During garage observation, I have observed that there is a scarcity of technicians compared to the large number of vehicles waiting for service and also garage foremen indicated that there is a scarcity of well-trained technicians, with good skills and familiar for providing service for the incoming various vehicle types and models with unique design and features which requires a passion for continuous learning and self-updating.

Besides the problem of longer downtime, ineffectiveness in inspection and diagnosis on activities like problem detection, fault isolation, and localization during vehicle reception are the causes for the higher frequency of maintenance identified. In addition to these, the interviewees mentioned that inefficiency in repairing, incorrect assessment of the condition of the considered unit, and faults and failures that are not detected during the first repair activity contribute to the observed frequent failures and reworks. Workload, time pressure (especially for highly needed machinery and vehicles), lack of experience, lack of knowledge and skill, negligence, and poor professionalism to follow the proper maintenance procedures are the sub-clauses that are mentioned by the expertise.

Furthermore, some shop foremen and team leaders mentioned that poor garage staff professionalism and unethical practices followed by some technicians that include part-swapping and theft, manipulation of procedures, and mishandling of automobiles are sources for customer complaints and comebacks. Poor customer handling, not enough maintenance service advice given to customers, and poor communication are the other causes mentioned for customer dissatisfaction.

4.2.2. Maintenance method and strategies

The quality problem causes in this category are related to the general maintenance policies and strategies and also with the methods and work process followed by the garage. Based on the information gathered, the main causes for poor maintenance quality results are complex and lengthy spare part purchasing process, weak cannibalization policy, weak integration between shops, and poor scheduled or planned maintenance policy.

According to the interviewees, the spare part purchasing process is very slow and the reasons they have mentioned for this are slow Performa collection, the bureaucracy that takes a very long time in the process of payment approval, check preparation, and releasing process. Due to this maintenance will be delayed thus there will be longer downtime. Furthermore, when the part purchasing procedure becomes complex and lengthy, to beat the time, technicians take shortcuts such as, short-circuiting sensitive electrical and electronic circuits and removing a pre-failure warning component which results in equipment failure and comebacks after a while.

The other major problem cause mentioned is Cannibalization; which istaking of unit or parts from one down equipment and fixing it to another down equipment.As observed in the garage and based on the interview response, currently manynumbers of equipment that are down for a very long time are exposed to high cannibalization and because ofthisit even becomesvery difficult to make them operational.The sub-causes identified for this inefficient maintenance strategy are weak cannibalization policies and guidelines, part supply problem, carelessness for consequences, andconsidering as easy solution than trying to purchase or finding another way.

As per the participants' opinion a weak scheduled or planned maintenance service policy results ina frequent breakdown, high downtime due to workload, and higher cost for the customer.The factors that contribute to this are low top management commitment, not enough spare part availability, low users and manager's awareness, etc. the influence of the top managers on the service process also affect the downtime and technicians' work schedule. I.e. sometimes top managers forced foremen to give priority to some customers who come later based on their favorite which crates customers' complaints and work schedule disruption.

Based on the information gathered, the weak integration between shops is also cause for the identified poor service quality result. For example, if the requested service is for repairing a brake system then the inspector only inspect the brake system of the vehicle and issue an order for maintenance to the concerned shop. Therefore, if there was any problemwiththe engine/on the cooling system/electrical system or other systems the probability of detecting itwould be high and hence the vehicle won't be repaired effectively. This will be a reason for the high frequency of failure and the long downtime.

4.2.3. Machines and maintenance tools

This service quality problem arises from the unavailability or shortage of machines, support equipment, and tools that are essential for amaintenance garage.Itincludesvehicle component testing machines, diagnosis tools, and material handling equipment, fixtures, protective gears, and safety devices. According to the interviewed employees, there is a shortage of scanning, diagnosing, and repairing tools.Hence this affects the efficiency and effectiveness of the service. Asan example, it is mentioned that inspectors don't have any scanning tools therefore they use driver's word, simple visual and sound inspection for failure identification, and then issuing

maintenance orders. Apart from this, shortage of the proper repair tools and equipment has affected the performance of the technicians and most of the time forced them to use tools other than the recommended ones. Thus this decreased the quality of repair and increased the repair time and also it sometimes damages other parts.

Not functioning or unavailability of special testing machines in the garage is another cause for poor service quality results. Unavailability of machines such as; dynamometer, injection pump & nozzle tester, radiator repairing machine, component cleaning machine, etc. decreased the efficiency and effectiveness of the service and it is one of the main reasons for referring the service to the costly outsource maintenance option.

Moreover, it is indicated that the shortage of material handling equipment like a forklift in the garage has a significant contribution to the observed service delay. Usually, shops wait for their turn to get the forklift and to bring parts from the warehouse or to transport vehicle components to other shops to repair in their specific shops like engine shop, electric shop, machine shop, etc. Also, the unavailability of other material handling equipment like shop cranes and fixtures in some shops made the service difficult for technicians that affected the performance and quality of the service.

4.2.4. Spare part and materials availability

Here the poor service quality performances are initiated from the unavailability of spare parts and consumable materials that are needed for the proper maintenance at the required time. Unavailability of spare parts, lubricants, cleaning agents, and chemicals, which are critical for the repair, replacements, and service is the major reason given to most of the equipment listed in the problem identification section that took the highest repair time. The main factors which are identified during the data collection, for unavailability of the required parts and materials in the company store or for supplying at the required time are Financial problems, Lengthy and complex part purchasing process, and unavailability of parts on the market or in the vehicle suppliers stock.

The large number and variety of the vehicles and machinery the company owns made the capital investment high for having all the required spare parts under its store. In addition to this, the frequent financial shortage the company encountered made it difficult to supply the required

parts by purchasing at the needed time. Apart from the financial limitation, the lengthy and complex purchasing process is the other main cause for not having the required parts at the required time. Therefore, besides providing a significant contribution to the observed longer repairing time, these factors forced the shop foremen to follow ineffective maintenance options such as; short-circuiting of sensitive electrical and electronic circuits and removing a pre-failure warning component. For example, during an interview, a technician mentioned that the customer would come for the brake service after hearing an alarming sound. Then if there is no brake pad kit in the store and of course considering the slow purchasing process, the technicians will provide the service by simply removing the metal that makes the sound. But ignoring this warning and shortcutting the maintenance would result in a brake disc failure which is much costlier.

Usually, major vehicle components such as Engine, Gearbox, differential, and others does not available on the market or at dealers' stock considering the high budget requirement and ordering and importing the part takes a longer time. Hence this leads to the long downtime witnessed in the company or other inefficient maintenance alternatives like cannibalization and outsourced maintenance.

4.2.5. Technological advancements in vehicles systems and wide variation in models

The other main cause identified during the information gathering for the performance of poor service quality delivery is the coming of a wide range of vehicles that also come up with new technologies introduced every year and with varieties of models and variants to the garage. Knowing that this might create difficulty in the maintenance service, the garage doesn't restrict itself to the maintenance of a specific vehicle or machinery types or models like other known maintenance facilities in the city because of the possession of a wide variety of equipment types and models by the company itself. The problem arises from the reality that nowadays; vehicle and machinery manufacturers employ intelligent systems, computers, and electronic systems for efficient vehicle control, performance, safety, reliability, economy, and a comfort function that has enormously increased the system complexity and these technologies are being updated continuously.

The sub causes identified for not providing good quality of maintenance service under this factor are; lack of technicians' skill & knowledge, not having of a repair manual for all vehicle types & models, unavailability of specialized scanning & diagnosing tools, and unavailability of written maintenance procedure for all vehicle types. There is a shortage of technicians who are skillful and who are continuously updating themselves to deal with the maintenance of these wide ranges of vehicles that also come up with new technologies. In addition to that, there is the inadequacy of a corresponding training given to the technicians. The unavailability of specialized diagnosing and repairing tools that are compatible with each machine type is also the other sub-clause identified. Furthermore, unavailability of service manuals for every coming vehicle type and model to the garage, the requirement of modern machines for e-maintenance and a more sophisticated maintenance approach, which is a limitation seen in the garage, and also the reluctance of the garage to accept and adapt to the changes required are the other identified sub causes.

These factors increase the repair time, promote the recurrence of the problem because of the inefficient maintenance tools and procedures as well as it is one of the main reason for the referring of the service to outsource maintenance which is to a much costlier maintenance facility.

4.2.6. Maintenance facility layout and Ambiance

Based on the findings of the information gathering, all the causes of poor maintenance service quality which are related to the layout of the garage as a whole and each shop in particular and which are related to the ambiance of the garage are assigned under this major cause. The first sub-cause identified is the poor construction of the garage layout. It includes the distance between each shop and between the shops and other facilities. For example, it is mentioned during the interview that the distance between the light vehicle shop and the spare part warehouse is long and also some section of the way between them is difficult for even walking. Therefore to bring required spare parts, which are heavy by hand, they have to wait for the busy forklift or use vehicles that are under maintenance and that increase the repair time.

As observed and mentioned by some interviewees most of the shops are poorly constructed, some are under construction and also some shops don't even have a shade. The poorly constructed

shops are very crowded with vehicles and have inadequate space for the maintenance technician to perform the necessary task and have no benches to place the tools and parts that have been designed considering human ergonomics. Furthermore, some maintenance activities such as tire changing activity break system repairing, and body repair are seen when performed outside of the shade because of the space limit. For those shops that don't have a shade like heavy construction machinery maintenance shops, maintenance activities are performed out in the field which is very difficult for the technicians considering the dusty and hot environment. Besides, the reaction of the dust with the wastage like lubricants, acid from the battery, benzene, degreasers, car exhausts, and detergents make the area very stinky and very bad for their health in long-term exposure. Apart from that it physically harms the machine's systems, especially in rainy seasons.

The other cause which is identified during information gathering is poor shop ambiance. That is in some shops there is insufficient lighting and ventilation, some shops have eroded floors, some shops don't clean regularly despite the garages get dirty easily because of the deals with substances and chemicals which are contaminating, etc. as mentioned by some mechanics there is also a shortage of locker rooms, shower, and restrooms in their shop area.

These all causes contributed especially to the long downtime observed. Besides that because of these factors which create difficulties in performing the tasks, the motivation of the technicians becomes very low and also made a significant contribution to the high frequency of vehicle comebacks because the quality of repair work is affected.

4.2.7. Shop technology & Documentation

Here the identified causes of poor fleet maintenance service quality performances which come from the lack of current technologies in the garage and also an inefficient way of documentation are included.

Based on some interviewees, usage of technology is mentioned mainly focusing on the shops and warehouses. According to these interviewees, the warehouse work system is outdated and mostly follows manual work methods. This has its own contribution for the longer part waiting time in the maintenance service. It is also mentioned that this warehouse working system, creates difficulty in frequent and regular stock balance checking. Hence, it occurs a lot of times that available parts are reported as out of stock. Besides these gaps, because of the unavailability of

information technology systems between warehouses, parts that are available and no more needed in other warehouses (including projects) do not know on time when they are needed in the garage. Concerning the shops, the participants mentioned that lack of the latest technology and access to the internet made their work hard and inefficient. For instance, they mentioned that if there was any technology that allows communication with the original equipment manufacturer that would have helped them to correctly diagnose and solve common vehicle issues much easier and also omit any cause that can damage expensive machine systems. Apart from this, lack of internet access created difficulty for technicians to learn and update themselves with the current vehicles system and tools technology.

Moreover, the garage uses a manual work management system with a lot of job cards and does not implement management software such as Shop Management System (SMS) and computer-managed maintenance systems (CMMS) which makes it time-consuming and less efficient. Maintenance activities done for each vehicle are then recorded on a job card and filed in a history jacket which is in a hard copy and opened for each vehicle during its life cycle. The data fed and kept in the computer is only for the finance and report for the top management purpose which does not give much help for facilitation of maintenance service for the next maintenance request.

Unavailability or missing of vehicle manufacturers' maintenance manuals is the other cause mentioned by the participants and the available service manuals are old and not updated. These factors increased the failure identification and repair time. It is also a factor for ineffective service provided and a result for vehicle comeback.

Table 4.5 summarizes the identified poor quality root causes and sub causes, the 6M/6P major factor to which the sub causes are assigned to and the major cause categories.

Table 4.5 Poor fleet maintenance service causes and sub-cause category

Identified poor quality root causes and sub causes	6M/6P major factor in which the sub cause assigned to	Cause categories
Shortage of manpower, Poor professionalism, Lack of skill, Lack of	Manpower/ People	Technicians' knowledge, skills, and performance

knowledge, Unethical practices, Physical and mental unfitness, Lack of motivation, lack of experience

Complex & lengthy spare part purchasing process, Cannibalization easiness, Poor pre-maintenance inspection, Weak shop integration, Poor PM policy, Complex & lengthy maintenance procedure, Top management influence

Methods/ Process/Policy

Maintenance method and strategies

Shortage of maintenance tools, Lack of essential shop machines, lack of special diagnosing tools, Inadequate material handling equipment, Inadequate safety devices & gears

Machinery/Equipment, Measurements

Machines and maintenance tools

Unavailability on the market, Financial limitation, Low top management commitment, part, and material damage, Having large quantity & variety of fleet, lengthy & complex purchasing process, Poor part & material requirement planning

Materials/Product

Spare part and materials availability

Continuous technological advancement, Lack of continuous garage modernization, Having old machines & tools, Lack of service manual, Lack of maintenance procedure, Unspecialized vehicle service

Technology

Technological advancements in vehicles systems and wide variation in models

Poor ambiance, Inadequate space, Mother nature/Plant	Maintenance facility layout and Ambiance
Poor shop layout, Untidiness, Poor garage layout construction, Shortage of essential facilities	
Inefficient file documentation, Lack of shop management software, missing of service manuals, Lack of IT system, Outdated service manuals, Manual working system	Program/Information Shop technology & Documentation

4.3. Implementation of MCDM tools for prioritization of the factors

This section utilized the techniques proposed for ranking/prioritizing the main factors associated with the poor fleet maintenance service quality specific to the ECWC context which is identified through extensive literature review and a brief interview with experts and which are discussed in detail in the previous section. The multi-criteria decision-making methods; Interpretive structural modeling (ISM) and fuzzy TODIM are selected for this purpose and their brief procedural steps and factor analysis with these methods are provided in the following sections.

4.3.1. Interpretive structural modeling (ISM)

As James (2020) stated, ISM helps in establishing interrelationships among the system variables to yield a hierarchy of importance according to the managerial perspective. Referring articles by; Gardaset al.(2019), G.Kavilalet al.(2018), James (2020), Nandalet al.(2019), Verma and Singh(2018),and Attri(2017) the following steps are followed while developing the basic framework of the ISM model.

Step 1: Identification of elements/Variables related to an issue or problem.As briefed in detail in the previous section of this chapter, seven main fleet maintenance quality factors are identified through a primary and secondary source of data and listed in tableTable 4.6.

Table 4.6 Main factors for fleet maintenance service quality

I.No	Factors	Notation
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1	Technicians’ knowledge, skills and performance	F ₁
2	Maintenance method and strategies	F ₂
3	Machines and maintenance tools	F ₃
4	Spare part and materials availability	F ₄
5	Technological advancements in vehicles systems and wide variation in models	F ₅
6	Maintenance facility layout and Ambiance	F ₆
7	Shop technology & Documentation	F ₇

Step 2: Development of contextual relationship. In this step, a contextual relationship among the identified quality factors (in step 1) is identified based on a pairwise comparison of variables and constructed the structured self-interaction matrix (SSIM) with the help of experts based on a questionnaire survey. Here, four symbols as mentioned in Table 4.7 are used for determining the contextual relationship.


As many scholars on the area indicated, there is nothing in the literature that specifies exactly how many experts' opinions as a minimum or maximum need to be considered in Interpretive Structural Modeling. For instance, the papers referred in this study used 5-14 experts’ opinions for their study (Gardaset al., 2019; G.Kavilalet al., 2018; James,2020; Nandalet al., 2019; Verma and Singh, 2018 and Attri, 2017). They also indicated that the most important issue is to identify who is an expert on the problem area under study. Hence in this paper opinions are collected from ten experts from the case company through a questionnaire-based survey. The experts are chosen based on their subject knowledge, experience, and company position. The team includes; one maintenance general manager, two service managers, six team leaders, and one lead mechanical engineer. As mentioned in the prepared questionnaire, Appendix II, The experts have requested to state the relationship between the quality factors using the four symbols mentioned in Table 4.7. The response provided by one participant is shown in Table 4.8 of the structural self-interaction matrix (SSIM).

Table 4.7 Symbols for development of a contextual relationship

Symbols	Meaning	Description
FR	Forward relation	Factor “i” affects factor j

BR	Backward relation	Factor j affects factor i
CR	Cross relation	Factor i and j affect each other
NR	No relation	Factor i and j do not affect each other

Table 4.8 Structural self-interaction matrix (SSIM)

		Factors for fleet maintenance service quality						
		F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
 F ₁ F ₂ F ₃ F ₄ F ₅ F ₆ F ₇	F ₁		CR	BR	FR	BR	BR	CR
	F ₂			BR	CR	CR	BR	BR
	F ₃				NR	FR	CR	NR
	F ₄					FR	FR	BR
	F ₅						BR	BR
	F ₆							NR
	F ₇							

Step 3:Development of initial reachability matrix (IRM). At this stage, the developed SSIM is converted into a binary matrix, called the Initial ReachabilityMatrix (IRM)by substituting the symbols FR, BR, CR,and NR with “0” and “1” depending upon their meanings.The rules/guidelines mentioned in Table 4.9 are employed for the creation of an initial reachability matrix.The initial reachability matrix for the above respondent is depicted in Table 4.10.

Table 4.9 Guidelines for development of IRM from SSIM

A symbol in (i, j) element in SSIM	Value of (i, j) element in IRM	Value of (j, i) element in IRM
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FR	1	0
BR	0	1
CR	1	1
NR	0	0

Table 4.10 Initial reachability matrix (IRM)

Quality Factors	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
F ₁	1	1	0	1	0	0	1
F ₂	1	1	0	1	1	0	0
F ₃	1	1	1	0	1	1	0
F ₄	0	1	0	1	1	1	0
F ₅	1	1	0	0	1	0	0
F ₆	1	1	1	0	1	1	0
F ₇	1	1	0	1	1	0	1

Step 4: Development of final reachability matrix (FRM). In this step, IRM is then modified to the final reachability matrix (FRM). Before that, some variation observed in the responses from one expert to another owing to their differing experiences needs to be cumulated. Thus a technique used by Sari et al. (2018) is employed to develop the cumulative relationship between the factors. That is the ten IRMs are summed up to form the total IRM using MS Excel software. Then the threshold of 5 is set so that the total IRM would be transformed into cumulative IRM, which is a binary matrix (only consists of 0 and 1) as shown in table 4.11. It means that if there is an element in the total RM which is greater than or equal to 5, then that element will be 1 in the cumulative IRM; vice versa.

After that, the FRM is developed by adding transitive links. The transitivity rule states that if element 'A' affects element 'B' and element 'B' affects element 'C', then element 'A' also affects element 'C'. Following this rule, the developed final reachability matrix is shown in Table 4.12. The entries marked * show the transitivity.

Table 4.11 Cumulative IRM

Quality Factors	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
F ₁	1	1	0	0	0	0	1
F ₂	1	1	0	1	1	0	0
F ₃	1	1	1	0	0	0	0
F ₄	0	1	0	1	0	0	0
F ₅	1	1	1	1	1	1	1
F ₆	1	0	1	0	1	1	1
F ₇	1	1	0	0	1	0	1

Table 4.12 Final reachability matrix (FRM)

Quality Factors	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
F ₁	1	1	0	1*	1*	0	1
F ₂	1	1	1*	1	1	1*	1*
F ₃	1	1	1	1*	1*	0	1*
F ₄	0	1	0	1	1*	0	0
F ₅	1	1	1	1	1	1	1
F ₆	1	1*	1	1*	1	1	1
F ₇	1	1	0	1*	1	1*	1

Step 5: Partitioning of Final Reachability Matrix (FRM). At this stage, the level separations are done from the acquired FRM. It is accomplished through the following sub-steps:

- i. Identify reachability set for each factor: this set is also known as the Driver set and it consists of the factor itself and other factors which it may affect.
- ii. Identify antecedent set for each factor: antecedent set also known as Dependent set and it consists of the factor itself and other factors on which it is dependent.
- iii. Identify intersection set for each factor: Here, the intersection of the above two sets is determined for each factor.

- iv. Identification of top-level factor (s): Here, iteration is carried out. The first iteration is carried out by identifying the factor(s) having their intersection set the same as that of the reachability set. These factors attain the highest rank or occupy the top-level in the ISM model. Top-level factors in the ISM model do not affect all. A level partition matrix is obtained following these processes.
- v. Elimination of top-level factors(s): The top-level factors identified in the previous step are eliminated from further ISM analysis to identify the level of other factors.
- vi. Repetition of the procedure: here the same process is repeated to find the next factors of the next level. This process is continued until the levels of all the factors have been identified. A final level partitioning matrix for the maintenance quality factors for the case company is formulated and shown in Table 4.13.

Table 4.13 Level partitioning matrix

Factors	Reachability set	Antecedent set	Intersection set	Level
F ₁	F ₁ ,F ₂ ,F ₄ ,F ₅ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₅ ,F ₇	II
F ₂	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	I
F ₃	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₇	F ₂ ,F ₃ ,F ₅ ,F ₆	F ₂ ,F ₃ ,F ₅	III
F ₄	F ₂ ,F ₄ ,F ₅	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₂ ,F ₄ ,F ₅	I
F ₅	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	I
F ₆	F ₁ ,F ₂ ,F ₃ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₂ ,F ₅ ,F ₆ ,F ₇	F ₂ ,F ₅ ,F ₆ ,F ₇	IV
F ₇	F ₁ ,F ₂ ,F ₄ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₃ ,F ₅ ,F ₆ ,F ₇	F ₁ ,F ₂ ,F ₅ ,F ₆ ,F ₇	II

Step 6: Development of conical matrix (CM). In this step, CM is developed from FRM. It is developed by clubbing the elements of the same level (identified in the partitioning step), across the rows and columns of FRM to easily evaluate the factors at different levels and the interrelationships among them. This conical form of the final reachability matrix (Table 4.14) also depicts the dependence and driving power for each factor.

Table 4.14 Conical form of final reachability matrix

Factors	F ₂	F ₄	F ₅	F ₁	F ₇	F ₃	F ₆	Driving power

F ₂	1	1	1	1	1	1	1	7
F ₄	1	1	1	0	0	0	0	3
F ₅	1	1	1	1	1	1	1	7
F ₁	1	1	1	1	1	0	0	5
F ₇	1	1	1	1	1	0	1	6
F ₃	1	1	1	1	1	1	0	6
F ₆	1	1	1	1	1	1	1	7
Dependence power	7	7	7	6	6	4	4	41

Step 7: Development of digraph. At this step, a graphical model known as a directed graph is developed after the removal of transitive links. It is a graphical representation of the factors, their directed relationships, and hierarchical levels. It is developed based on the relationship established in the reachability matrix and partitioning levels.

Step 8: Development of ISM model. Lastly, the hierarchical structure or ISM model is developed from the digraph by substituting statements in element nodes. The developed ISM hierarchical model (Figure 4.4) provides a better graphical vision of the levels of factors obtained in the Level Partition Matrix along with their relationships.

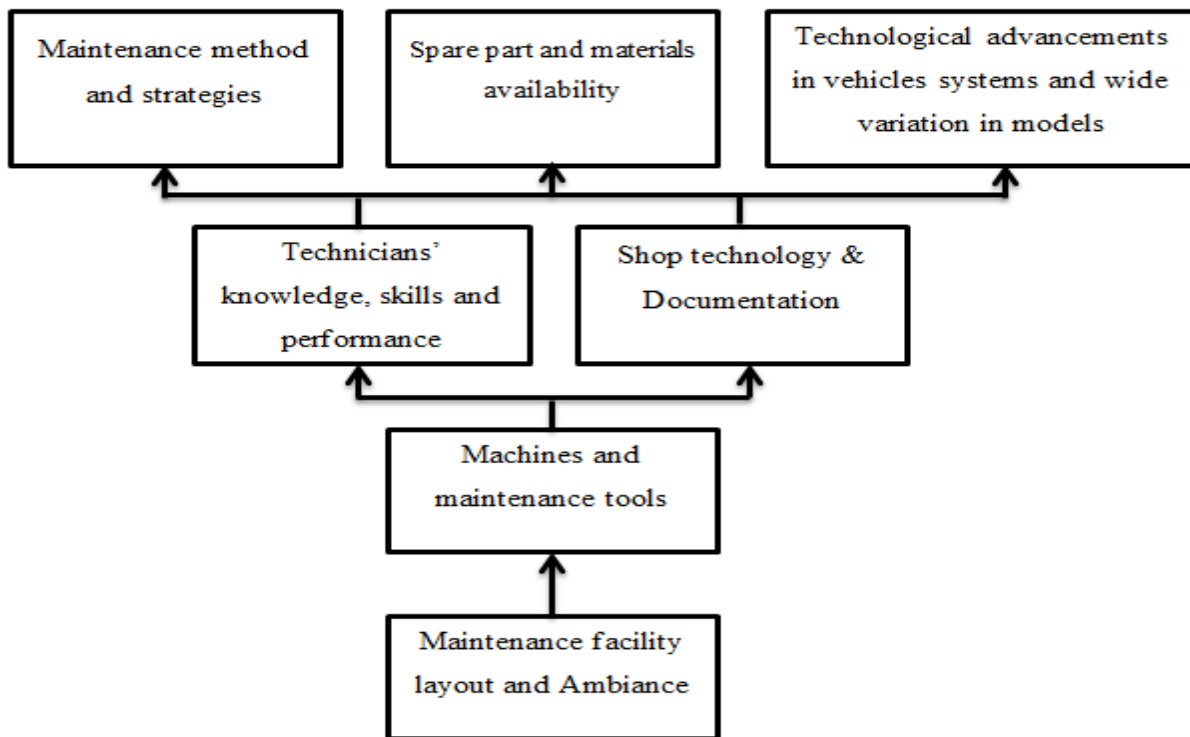


Figure 4.4 Hierarchical or ISM model of maintenance quality factors

The model, Figure 4.4, shows that the two factors; F_6 (Maintenance facility layout and Ambiance) followed by F_3 (Machine and maintenance tools), hold the highest level in the rank. Since ISM is a decision making tool and according to the developed model, these are the driving factors that have the potential to influence the factors above them in the hierarchy. That means if any quality enhancement activity done on the company's maintenance facility layout and ambiance and on the company's machines and maintenance tools, then it will also have an effect on improvement of quality on the other factors (i.e. "Technicians' knowledge, skills, and performance", "Shop technology & Documentation", etc.). As briefed in previous section since these factors are the major factors in increasing maintenance downtime, frequency of maintenance, maintenance cost and customer dissatisfaction, quality improvement made on these factors will lead to overall service quality improvement.

F_1 (Technicians' knowledge, skills, and performance) and F_7 (Shop technology & Documentation) hold the middle rank. That means these factors are affected by the high-level factors and have the capability to drive the least level factors situated above them in the

hierarchy. Finally, the model has shown that F_2 (Maintenance method and strategies), F_4 (Spare part and materials availability) and F_5 (Technological advancements in vehicles systems and wide variation in models) are the least ranked factors. That means, these factors are dependent on high and middle-level factors and hold no driving power over the other factors.

As it is briefed in the literature review section, the ISM method develops the overall prioritization/ranking of the factors based on the interrelationship that existed between the quality factors. It doesn't consider their relation with the maintenance quality measuring criteria (i.e., Cost, Downtime, Frequency of maintenance & Customer satisfaction). Therefore, the MCDM tool that can analyze the relationship and then rank each one of the factors relative to the other based on each quality measuring criterion should also be used for reaching a better conclusion.

4.3.2. Fuzzy TODIM

In this section, the proposed fuzzy TODIM is used for ranking the major maintenance quality factors that are identified for the case company. In this method as Hanine et.al (2016) indicated, to avoid the effects of prejudice of decision-makers and bias in the ranking of alternatives, the fuzzy set theory is integrated into the traditional TODIM and also to reduce the subjectivity, many decision-makers (experts) have participated. Unfortunately, as briefed in the ISM method, there is nothing in the literature that specifies exactly how many experts' opinions as a minimum or maximum need to be considered in the MCDM methods. Therefore a group of ten decision-makers/experts are selected from the case company for the study. The experts are chosen based on their subject knowledge, experience, and company position. The team involves one maintenance general manager, two service managers, six Team leaders, and one lead mechanical engineer.

As Hanine et.al (2016) stated the general approach is that, for expressing the linguistic variables for the attribute values provided by the experts, triangular fuzzy numbers (TFNs) are used. By using these fuzzy numbers and according to the concept of the TODIM method, the gain and loss of each one of the factors relative to others are evaluated. Then, by computing the dominance degree of each factor over the others, the global value of each factor is obtained and factors are ranked.

The major factors which are briefed in the previous section as F_1, F_2, \dots, F_7 are considered as maintenance quality factors in the case company and also four evaluation criteria are selected. These criteria are selected with the help of the experts' experiences and literature surveys: C1- Cost, C2-Downtime, C3-Frequency of maintenance, and C4-Customer dissatisfaction & Complaint. In this paper, the fuzzy TODIM method, which was proposed in Tosun and Akyuz (2015) and Hanine et al. (2016), and the TODIM method by Gomes and Rangel (2009) is considered to prepare the analysis steps. The process steps followed while developing the rankings are described as follows.

Step 1: Evaluation of the criteria and factors. At first, questionnaires, Appendix II, are developed and given to the decision-makers/experts for the evaluation process. In the questionnaires, the decision-makers evaluated the importance weight of the maintenance service quality measuring criteria, and also they evaluated the quality factors according to each criterion. The assessment was based on five-point scales using linguistic variables.

Step 2: Conversion of linguistic variables into fuzzy numbers. At this step decision makers' linguistic evaluation of the criteria and the quality factors relative to each criterion are transformed to triangular fuzzy numbers following the rules listed in Table 4.15. That means each linguistic variable response from the experts has transformed into lower (l), medium (m), and upper (u) fuzzy numbers.

Table 4.15 Linguistic variables and fuzzy numbers

Linguistic variables	Fuzzy numbers		
	l	m	u
Very Low (VL)	0.00	0.00	0.25
Low (L)	0.00	0.25	0.50
Medium (M)	0.25	0.50	0.75
High (H)	0.50	0.75	1.00
Very High (VH)	0.75	1.00	1.00

Step 3: Integration of scores. Here, after decision-makers evaluate the criteria and the factors with each criterion which are also transformed to triangular fuzzy numbers, their scores are integrated. The integrated fuzzy weights of each criterion and integrated fuzzy assessment of each factor with each criterion are calculated using equations (3) and (4). In the formulas, d is the number of decision-makers. The computed integrated scores are shown in Table 4.16 and Table 4.17.

$$cw_j = \frac{1}{d} [\sum_{e=1}^d cw_j^e] \quad j = 1, 2, \dots, n \quad (3)$$

\tilde{x}_{ij} = Integrated fuzzy evaluation of i . alternative according to j . criteria

$$\tilde{x}_{ij} = \frac{1}{d} [\sum_{e=1}^d \tilde{x}_{ij}^e] \quad i = 1, 2, \dots, m \quad (4)$$

Table 4.16 Aggregated fuzzy weights of the criteria

Criteria	Fuzzy weights (cw_j)		
	l	m	u
C ₁	0.25	0.25	0.275
C ₂	0.625	0.65	0.675
C ₃	0.425	0.45	0.475
C ₄	0.2	0.225	0.25

Table 4.17 Fuzzy decision matrix of the factors

	F ₁			F ₂			F ₃			F ₄			F ₅			F ₆			F ₇		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
C ₁	0.38	0.6	0.78	0.55	0.8	0.95	0.6	0.85	0.98	0.725	0.98	1	0.350	0.6	0.78	0.58	0.83	0.95	0.33	0.58	0.78
C ₂	0.48	0.7	0.85	0.33	0.53	0.75	0.48	0.73	0.90	0.55	0.8	0.95	0.38	0.63	0.8	0.48	0.73	0.9	0.28	0.53	0.75
C ₃	0.2	0.43	0.65	0.35	0.6	0.78	0.4	0.65	0.83	0.475	0.7	0.88	0.35	0.6	0.78	0.4	0.63	0.83	0.25	0.5	0.7
C ₄	0.33	0.55	0.78	0.35	0.6	0.8	0.28	0.5	0.68	0.575	0.83	0.95	0.3	0.55	0.73	0.48	0.73	0.9	0.15	0.38	0.63

Step 4: Defuzzification of fuzzy criteria weights (cw_j). At this stage, fuzzy weights of the criteria are defuzzificated. As Tosun and Akyuz(2015)and Hanine et.al (2016) indicated, there are different normalization methods so in this study the technique of Abdel-Kader and Dugdale

(2001) is used. In this technique, the three parameters of triangular fuzzy numbers (l, m, and u) for the fuzzy estimates are used. Furthermore, an index of optimism (α) is used to reflect the decision makers' characteristics, risk-taking attitudes, and different environmental conditions. High values in α represent an optimistic decision-maker, while smaller values represent a pessimistic decision-maker. In this paper index of optimism (α) is used as 0.5 as a neutral point of view to balance between optimism and pessimism (Hanine et.al, 2016).

Criteria weights (w_j) given in Table 4.15 are defuzzificated using Equations (5) - (9) and standardized.

Let $V(\tilde{A}_j)$ will be the value of \tilde{A}_j . In this situation, ordering is calculated as;

$$V(\tilde{A}_j) = m_j \left\{ \alpha \left[\frac{u_j - x_{min}}{x_{max} - x_{min} + u_j - m_j} \right] + (1 - \alpha) \left[1 - \frac{x_{max} - l_j}{x_{max} - x_{min} + m_j - l_j} \right] \right\} \quad (5)$$

Where;

$$x_{min} = \inf S \quad (6)$$

$$x_{max} = \sup S$$

$$S = \bigcup_{j=1}^n S_j \quad (7)$$

$$S_j = (l_1, m_1, u_1, \dots, l_n, m_n, u_n) \quad j = 1, 2, \dots, n \quad (8)$$

Calculated weights with the ordering method are standardized (normalized) with the given equation:

$$w_j = \frac{V(\tilde{A}_j)}{\sum_{j=1}^n V(\tilde{A}_j)} \quad (9)$$

Step 5: Calculation of relative weights (w_{jr}).As Tosun and Akyuz(2015)stated, the TODIM method is based on a projection of the differences between the consequences of any two alternatives to a reference attribute. Attribute with the highest weight value is selected as the reference attribute to translate all pairs of differences between performance measurements into the same dimension. Hence, here each criterion's (C_j) relative weights (w_{jr}) is calculated based

on the reference criterion (C_r). Table 4.18 presents the relative weight of criteria (w_{jr}) that are determined by Eq. (10) in which C_2 is selected as the reference criterion.

Let C_r denote the reference criterion, then the relative weight w_{jr} of criterion C_j to the reference criterion C_r is given as:

$$w_{jr} = \frac{w_j}{w_r}, j \in N \text{ where } w_r = \max_{j \in N} \left\{ \frac{w_j}{w_r} \right\} \quad (10)$$

Table 4.18 Relative weights of the criteria

Criteria	A_j	w_j	w_{jr}
C_1	0.06	0.04	0.07
C_2	0.84	0.66	1.00
C_3	0.34	0.27	0.41
C_4	0.03	0.03	0.04
Sum	1.27		

Step 6: Determination of Gains and Loses values. This step is focused on calculating the gain and loss of each factor relative to the others, first, the values of factors are compared by pair. Using the fuzzy values in Table 4.17, gain and loss matrices for each criterion are calculated with Eq. 11-15.

Let \tilde{x}_{kj} and \tilde{x}_{ij} be the value of factor F_i and F_k concerning criterion C_j , $i, k \in M$, $j \in N$. Then, gain and loss of factors F_i relative to F_k according to criterion C_j is given as:

$$d(\hat{x}_{ij}, \hat{x}_{kj}) = \sqrt{\frac{1}{3} \left[(x_{ij}^l - x_{kj}^l)^2 + (x_{ij}^m - x_{kj}^m)^2 + (x_{ij}^u - x_{kj}^u)^2 \right]} \quad (11)$$

Then for benefit attribute:

$$G_{ik}^j = \begin{cases} d(\hat{x}_{ij}, \hat{x}_{kj}), & \tilde{x}_{ij} \geq \tilde{x}_{kj} \\ 0, & \tilde{x}_{ij} < \tilde{x}_{kj} \end{cases} \quad (12)$$

$$L_{ik}^j = \begin{cases} 0, & \tilde{x}_{ij} \geq \tilde{x}_{kj} \\ -d(\hat{x}_{ij}, \hat{x}_{kj}), & \tilde{x}_{ij} < \tilde{x}_{kj} \end{cases} \quad (13)$$

For cost attribute:

$$G_{ik}^j = \begin{cases} 0, & \tilde{x}_{ij} \geq \tilde{x}_{kj} \\ d(\hat{x}_{ij}, \hat{x}_{kj}), & \tilde{x}_{ij} < \tilde{x}_{kj} \end{cases} \quad (14)$$

$$L_{ik}^j = \begin{cases} -d(\hat{x}_{ij}, \hat{x}_{kj}), & \tilde{x}_{ij} \geq \tilde{x}_{kj} \\ 0, & \tilde{x}_{ij} < \tilde{x}_{kj} \end{cases} \quad (15)$$

Through these equations gain matrix $G_j = [G_{ik}^j]_{m \times m}$ and loss matrix $L_j = [L_{ik}^j]_{m \times m}$ for each criterion C_j are;

G1	0.00	0.18	0.23	0.32	0.00	0.20	0.00	G2	0.00	0.00	0.03	0.09	0.00	0.03	0.00
	0.00	0.00	0.043	0.15	0.00	0.02	0.00		0.15	0.00	0.17	0.24	0.07	0.17	0.00
	0.00	0.00	0.00	0.10	0.00	0.00	0.00		0.00	0.00	0.00	0.07	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.01	0.19	0.23	0.33	0.00	0.21	0.00		0.08	0.00	0.10	0.17	0.00	0.10	0.00
	0.00	0.00	0.03	0.13	0.00	0.00	0.00		0.00	0.00	0.00	0.07	0.00	0.00	0.00
	0.03	0.21	0.25	0.35	0.02	0.23	0.00		0.16	0.03	0.18	0.25	0.09	0.18	0.00

G3	0.00	0.15	0.20	0.26	0.15	0.19	0.06	G4	0.00	0.04	0.00	0.24	0.00	0.15	0.00
	0.00	0.00	0.05	0.11	0.00	0.04	0.00		0.00	0.00	0.00	0.20	0.00	0.12	0.00
	0.00	0.00	0.00	0.06	0.00	0.00	0.00		0.07	0.10	0.00	0.30	0.04	0.22	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.05	0.11	0.00	0.04	0.00		0.03	0.06	0.00	0.26	0.00	0.18	0.00
	0.00	0.00	0.00	0.07	0.00	0.00	0.00		0.00	0.00	0.00	0.09	0.00	0.00	0.00
	0.00	0.09	0.14	0.20	0.09	0.13	0.00		0.17	0.20	0.11	0.40	0.15	0.32	0.00

L1	0.00	0.00	0.00	0.00	-0.01	0.00	-0.03	L2	0.00	-0.15	0.00	0.00	-0.08	0.00	-0.16
	-0.18	0.00	0.00	0.00	-0.19	0.00	-0.21		0.00	0.00	0.00	0.00	0.00	0.00	-0.03
	-0.23	-0.04	0.00	0.00	-0.23	-0.03	-0.25		-0.03	-0.17	0.00	0.00	-0.10	0.00	-0.18
	-0.32	-0.15	-0.10	0.00	-0.33	-0.13	-0.35		-0.09	-0.24	-0.07	0.00	-0.17	-0.07	-0.25
	0.00	0.00	0.00	0.00	0.00	0.00	-0.02		0.00	-0.07	0.00	0.00	0.00	0.00	-0.09
	-0.20	-0.02	0.00	0.00	-0.21	0.00	-0.23		-0.03	-0.17	0.00	0.00	-0.10	0.00	-0.18
	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00

L3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	L4	0.00	0.00	-0.07	0.00	-0.03	0.00	-0.17
	-0.15	0.00	0.00	0.00	0.00	0.00	-0.09			-0.04	0.00	-0.10	0.00	-0.06	0.00	-0.20
	-0.20	-0.05	0.00	0.00	-0.05	-0.01	-0.14			0.00	0.00	0.00	0.00	0.00	0.00	-0.11
	-0.26	-0.11	-0.06	0.00	-0.11	-0.07	-0.20			-0.24	-0.20	-0.30	0.00	-0.26	-0.09	-0.40
	-0.15	0.00	0.00	0.00	0.00	0.00	-0.09			0.00	0.00	-0.04	0.00	0.00	0.00	-0.15
	-0.19	-0.04	-0.01	0.00	-0.04	0.00	-0.13			-0.15	-0.12	-0.22	0.00	-0.18	0.00	-0.32
	-0.06	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00

Step 7: Construction of dominance degree matrix for each criterion(C_j). Here, the dominance degree for gain and dominance degree for loss of factor F_i over factor F_k for criterion C_j is calculated. Then by using it the dominance degree matrix for each criterion C_j will be constructed.

The dominance degree for gain $\Phi_{ik}^{j(+)}$ and dominance degree for the loss $\Phi_{ik}^{j(-)}$ is calculated by:

$$\Phi_{ik}^{j(+)} = \sqrt{G_{ik}^j w_{jr} / (\sum_{j=1}^n w_{jr})} \tag{16}$$

$$\Phi_{ik}^{j(-)} = -\frac{1}{\theta} \sqrt{-L_{ik}^j (\sum_{j=1}^n w_{jr}) / w_{jr}} \tag{17}$$

Where θ is the attenuation factor of the loss and in this study, the value of θ is given 1 which means as Hanine et.al, (2016) stated the losses will contribute with their real values to the overall value. Then the dominance degree for the gain and loss Φ_{ik}^j is found using:

$$\Phi_{ik}^j = \Phi_{ik}^{j(+)} + \Phi_{ik}^{j(-)} \tag{18}$$

By using Equation (16), (17) & (18), the dominance degree matrix for each criterion C_j, $\Phi_j = [\Phi_{ik}^j]_{m \times m}$, is calculated as follows.

$\phi 1$	0	0.1	0.11	0.132	-0.52	0.1	-0.78	$\phi 2$	0	-0.43	0.16	0.27	-0.31	0.16	-0.5
	-1.85	0	0.05	0.088	-1.89	0.03	-1.98		0.34	0	0.36	0.43	0.24	0.36	-0.2
	-2.05	-0.9	0	0.074	-2.09	-0.68	-2.17		-0.2	-0.46	0	0.23	-0.36	0	-0.5
	-2.45	-1.65	-1.39	0	-2.49	-1.53	-2.56		-0.34	-0.55	-0.29	0	-0.46	-0.29	-0.6
	0.03	0.1	0.11	0.134	0	0.11	-0.62		0.25	-0.3	0.28	0.36	0	0.28	-0.3
	-1.94	-0.62	0.04	0.082	-1.98	0	-2.06		-0.2	-0.46	0	0.23	-0.36	0	-0.5
	0.04	0.11	0.12	0.137	0.03	0.11	0		0.36	0.15	0.38	0.45	0.26	0.38	0

$\phi 3$	0	0.22	0.25	0.29	0.22	0.25	0.14	$\phi 4$	0	0.03	-1.5	0.09	-1	0.07	-2.3
	-0.7	0	0.13	0.19	0	0.12	-0.5		-1	0	-1.8	0.08	-1.4	0.06	-2.5
	-0.8	-0.4	0	0.14	-0.4	-0.2	-0.7		0.05	0.06	0	0.1	0.04	0.08	-1.8
	-0.9	-0.6	-0.4	0	-0.6	-0.5	-0.8		-2.7	-2.5	-3	0	-2.8	-1.6	-3.5
	-0.7	0	0.13	0.19	0	0.12	-0.5		0.03	0.04	-1.2	0.09	0	0.08	-2.1
	-0.8	-0.4	-0.2	0.15	-0.4	0	-0.6		-2.2	-1.9	-2.6	0.05	-2.3	0	-3.1
	-0.4	0.17	0.21	0.25	0.17	0.21	0		0.07	0.08	0.06	0.11	0.07	0.1	0

Step 8: Determination of overall dominance degree ($\Delta = [\delta_{ik}]_{m \times m}$). In this step, the overall dominance degree matrix is calculated from the dominance degree matrix of each criterion using Equation (19).

$$\delta_{ik} = \sum_{j=1}^n \Phi_{ik}^j \quad (19)$$

Using this equation the overall dominance matrix can be found as:

δ_{ik}	0	-0.08	-0.95	0.777	-1.61	0.58	-3.37
	-3.25	0	-1.24	0.787	-3.01	0.58	-5.2
	-3	-1.7	0	0.542	-2.8	-0.81	-5.13
	-6.4	-5.28	-5.16	0	-6.36	-3.92	-7.45
	-0.38	-0.15	-0.64	0.775	0	0.58	-3.6
	-5.08	-3.35	-2.77	0.513	-5.03	0	-6.33
	0.04	0.51	0.77	0.952	0.53	0.8	0

Step 9: Calculation of overall value of each factor and ranking of the factors. In this final step, the overall value of each factor will be computed from the overall dominance degree matrix (Δ) found in the previous step. Then their ranking will be determined from the result.

Based on matrix Δ , the overall value of factor F_i , $\delta(F_i)$, is calculated by:

$$\delta(F_i) = \frac{\sum_{k=1}^m \delta_{ik} - \min_{i \in M} \{\sum_{k=1}^m \delta_{ik}\}}{\max_{i \in M} \{\sum_{k=1}^m \delta_{ik}\} - \min_{i \in M} \{\sum_{k=1}^m \delta_{ik}\}} \quad (20)$$

As Tosun and Akyuz(2015)stated it is obvious that $0 \leq (F_i) \leq 1$, and the grater (F_i) is, the better factor(F_i). Consequently, according to descending order of the overall values of all the factors, the ranking of all factors is determined. Finally, by using Equation (20) the global value of each factor is obtained as shown in Table 4.19. Concerning these values of the seven factors, the ranking is determined as $F_7 > F_5 > F_1 > F_2 > F_3 > F_6 > F_4$

Table 4.19 Overall values and ranking of each factor

F_i	$\sum_{j=1}^m \delta_{ik}$	$\delta(F_i)$	Rank
F_1	-4.65	0.7839	3
F_2	-11.3	0.6091	4
F_3	-12.9	0.5679	5
F_4	-34.6	0.0005	7
F_5	-3.42	0.8160	2
F_6	-22	0.3290	6
F_7	3.61	1.0000	1

Since all the service quality measuring criteria are cost attributes, the found result implies that:if the factor is ranked higherits contribution for increasing the measuring criteria will be lesser.Inthis analysis, the objective is to identify and prioritize the factors according to their contribution to lowering the service quality which means increasing the measuring criteria. Therefore, based on the above ranking, F_4 (Spare part and materials availability) has a higher contribution for the low maintenance service quality. Then it followed by: F_6 (Maintenance facility layout and Ambiance), F_3 (Machines and maintenance tools), F_2 (Maintenance method and strategies), F_1 (Technicians’ knowledge, skills, and performance), F_5 (Technological advancements in vehicles systems and wide variation in models) and finally F_7 (Shop technology & Documentation).

4.3.3. Results and discussion

As it is shown in the result both ISM and fuzzy TODIM methods are appropriate for the prioritization of quality factors. However, due to the way of their problem analysis technique, the results obtained from the two methods have shown some differences. As it is briefed in the previous sections, in the ISM method the overall prioritization is developed based onthe relationship among the quality factors. Whereas, fuzzy TODIM method ranks the factors by evaluating the gain and loss of each one of the factors relative to the other according to each quality measuring criterion. To summarize the results obtained from the two MCDM tools analysis, the major maintenance service quality factors are classified under three categories namely high priority, moderate priority, and leastpriority factors. The results of the ranking of factors based on both methodologies, i.e. I.S.M and fuzzy TODIM, and their respective category are shown in Table 4.20.

Table 4.20 Results of ISM and fuzzy TODIM analysis

Priority Level	ISM Method	Fuzzy TODIM	Common factors
High Priority	F_6, F_3	F_4, F_6, F_3	F_6, F_3
Moderate Priority	F_1, F_7	F_2, F_1	F_1
Least Priority	F_2, F_4, F_5	F_5, F_7	F_5

Based on the ISM method ranking, the two factors; F_6 (Maintenance facility layout and Ambiance) and F_3 (Machine and maintenance tools) hold the highest priority in the process of service quality improvement. According to ISM, these are the driving factors that have the potential to influence the factors above them in the hierarchy (Fig 4.4). So, any quality enhancement activity done on these two factors also helps to improve the service quality under the other factors which leads to overall quality improvement. The fuzzy TODIM analysis suggests that besides the two factors (F_6 and F_3), F_4 (Spare part and material availability) should get the highest priority. In fuzzy TODIM these factors get the highest priority because of their high relation with the service quality measuring criteria (cost, downtime, frequency of maintenance, and customer dissatisfaction & complaints). This means any quality improvement activities done on these factors will have a high outcome on decreasing; service cost, downtime, frequency of maintenance, and customer dissatisfaction. Therefore, concluding from the results of the methods, the decision and policymakers should give their maximum attention to these factors for effective and efficient service quality improvement.

F_1 (Technicians' knowledge, skills, and performance) and F_7 (Shop technology & Documentation) ranked under the second category, "moderate priority factors" according to the ISM method. These factors are affected by the high priority factors and have the capability to drive the least priority factors situated above them in the hierarchy. Based on the fuzzy TODIM analysis, instead of F_7 , F_2 (Maintenance method and strategies) is placed under this category with F_1 . This implies that F_1 and F_2 has a moderate contribution in increasing service cost, down time-frequency of maintenance, and customer dissatisfaction.

Under least priority factors, the ISM method placed the factors: F_2 (Maintenance method and strategies), F_4 (Spare part and materials availability) and F_5 (Technological advancements in vehicles

systems and wide variation in models). These factors are dependent on high and moderate priority factors and hold no driving power over the other factors. Whereas to the fuzzy TODIM method, F_5 and F_7 are the least priority factors. These factors have minimum significance on increasing or decreasing the quality measurement criterion. Hence, as per the methods, these factors demand less attention from the policy/decision-makers in quality improvement planning.

4.4. Impact of service quality factors on the customer service requirement

In this section, the level of relationship that existed between the customer service requirements and the prioritized major service quality factor is analyzed to propose an effective service quality improvement suggestion that considers customer needs. As R. Thirumanas and Joseph (2013) asserted, it is not effective for companies to set quality standards without consideration of customer service requirements or with misguided assumptions of customers' expectations. Besides that, as many scholars agreed, for most businesses, it is a small number of things that will ensure its competitiveness, and everything else is more or less equal. So, considering also the time and resource constraint it is most efficient to focus on the few things that make a competitive difference. This analysis is also made to evaluate the impact of the higher-ranked quality factors which are identified through the MCDM tools on the customer service demands. To accomplish this objective House of quality function deployment (QFD) tool is used to analyze the relationship between the customer service requirements and the prioritized major service quality factors.

4.4.1. Implementation of QFD

In this study two QFD matrices are developed, the first relates the customer service requirements with the major service quality factors. Then based on the result found on the first QFD, action plans to improve the service quality are developed and these action plans are evaluated based on the customer demands through a second QFD matrix.

To administer the QFD a sample was taken from the current customers of the case company. The sample size was determined as 91 to represent the total population of 231 customers, with a 95% confidence level as briefed in the research methodology section. The survey was conducted using a face-to-face method with a random sampling selection of the target respondents. Referring to

papers by; R. Thirumanas and Joseph (2013), Jamali & Elahi (2015), Xing & Min (2017), and Jain & Verma(2019), the general steps followed to develop the matrices are briefed as follows.

Step 1: Defining customer needs and priority level. This is the first step of QFD which analyzes the demands of the customer. To do that, 19 fleet maintenance service quality attributes are first identified through literature review and discussion with some customers. Then for the process of defining their importance level, a questionnaire method is employed. The questionnaire is designed around the service elements to obtain the score of the customer on the importance of these service elements. Using this questionnaire, Appendix III, the 91 participants were requested to indicate the importance level of the listed service quality attributes based on their experience as a customer. The questionnaire was prepared based on five points Likert scale with the left extreme of the scale marked as “much less importance” and the right extreme as “very high importance”. Then an overall weightage or priority value for every service attribute was calculated by summing all the importance level values given by the participant for the attribute. The results implied that the most important service quality attribute in the category is the Maintenance personnel with friendly & good behavior, followed by Willingness of the staff to give enough explanation & advice, then a reliable and error-free maintenance service, Reasonable and fair maintenance service pricing. Table 4.21 shows all customer service demand attributes with their calculated priority value.

Table 4.21 Customer maintenance service needs and their priority value

I.No	Customers' service needs	Priority Value
1	Maintenance personnel with friendly & good behavior	365
2	The willingness of the staff to give enough explanation & advise	356
3	A reliable and error-free maintenance service	349
4	Reasonable and fair maintenance service pricing	342
5	The willingness of the staff to listen & fix any request or after service dissatisfaction	342
6	Availability of high protection for the property from theft, swapping & damage	342
7	Availability of enough parking & maintenance space in the garage	341

8	The motivation of the staff to further examine and also consult the customer if other service demands	338
9	Using of high quality spare part & material for maintenance	336
10	The capacity to deliver maintenance services with minimum downtime	333
11	Clean deliverance of vehicle/machine after maintenance	332
12	Access for the customer to watch the maintenance process if he required	329
13	The capability of the garage to deliver the service on the promised time	325
14	Easy availability for service booking/ minimum time for an appointment	325
15	Maintenance personnel with a proper and neat uniform	319
16	Clean appearance of maintenance shops	317
17	Availability of a comfortable reception/waiting area	313
18	Capability to provide field/roadside service when required	310
19	Availability of access for the customer to get any consultation/explanation on phone/online	304

Step 2: Defining technical requirements. At this stage based on the defined customer needs and their priority level, technical requirements would be prepared. But as presented in the results and discussion section, the MCDM tools employed in this study have given the priority order for the quality factors based on the level of relationship between the factors and the dominance degree of the factors relative to the quality measuring criteria. So, they did not consider their priority level with respect to meeting customer demands. Therefore, to analyze the level of relationship that existed between the customer needs and the prioritized service quality factors by using the MCDM tools, the quality factors are used as a technical requirement for the first QFD matrix developed. As briefly discussed in the previous sections, these major service quality factors are; Technicians’ knowledge, skills, and performance (F_1), Maintenance method and strategies (F_2), Machines and maintenance tools (F_3), Spare part and materials availability (F_4), Technological advancements in vehicles systems and wide variation in models (F_5), Maintenance facility layout and Ambiance (F_6), and Shop technology & Documentation (F_7).

Step 3: Development of Interrelationships & Correlation-ships Matrix. The developed interrelationship matrix compares the prioritized demands of the customers with the service

quality factors to determine their respective relationships. Whereas the correlation matrix, which is a triangular matrix found at the roof of the House of Quality, identifies the interrelationship found between each of the service quality factors. For the representation of the degree of relationship between the parameters, rating scales are employed.

According to R. Thirumanas and Joseph (2013), researchers used various relationship rating scales in their study but none of them provided an explicit justification for the choice of their rating scale and also there is no scientific basis for any of the choices. As the same author stated a rating scale of 1-3-9 is used by most of the researchers so the same rating method is employed for this study. Where,

- 1 show a weak relationship and is represented by “∇” symbol
- 3 indicates a medium relationship and is represented by “○” symbol
- 9 indicates a strong relationship and is represented by “●” symbol
- An empty cell in the matrix represents no relationship between the customer's need and the technical requirements.

For the correlation-ships matrix, symbols are used to represent the strength of the interrelationships as follows:

- ✚ A strong and weak positive relationship is represented by using a (++) and (+) symbol respectively.
- ✚ A strong and weak negative relationship is represented by using a (--) and (-) symbol respectively.
- ✚ No correlation is represented by a blank box

For deciding the level of relationship between the parameters and also completing the matrix, information found from the MCDM tools analysis questionnaire and discussion with five maintenance team leaders is used. The overall QFD matrix structure or the House of Quality (HoQ) developed after following the above procedures is shown in figure 4.5

Step 4: Determination of Absolute weight (AW) and Relative Weight (RW) of Technical Requirements.

- Absolute weight and Technical importance rating are calculated by using Equation (21) & (22):

$$AW = \sum(IW * CI) \quad (21)$$

$$TIR = \frac{AW}{\sum CI} * 100 \quad (22)$$

Where;

AW = Absolute weight

CI= Customer Importance

IW=Interrelationship Weight, which is a weight assigned to the Interrelationship matrix of Technical requirements

TIR= Technical importance rating

- Relative Weight is calculated using Equation (23):

$$RW \% = \frac{AW}{\sum AW} * 100 \quad (23)$$

The overall result is shown inFigure 4.5

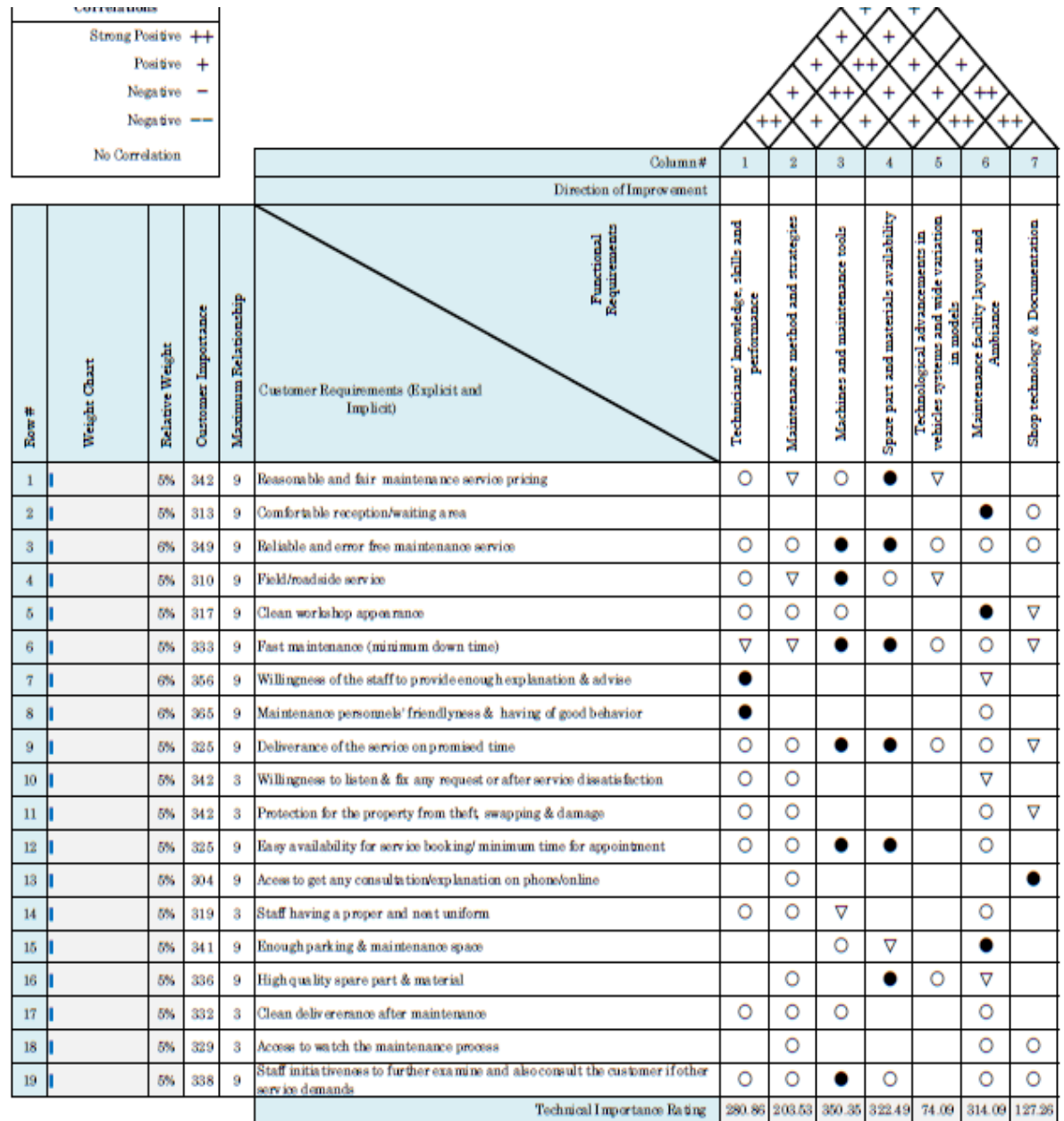


Figure 4.5 House of Quality (HoQ)

Step 5: Technical importance leveling. Here the most critical technical requirements are identified based on the computed technical importance levels. The calculated technical importance rating values indicate the level of relationship between the quality factors and the customer service requirements. Whereas, the relative weight shows the level of relationship using a percentage of each individual factor's importance weight to the total weight.

Hence, the factors with the highest technical requirement rating and relative weight are the most critical ones to satisfy the customer needs. Therefore, as shown in Fig 4.5, the most critical technical requirement is “machines and maintenance tools” with a technical importance rating value of 350.3 and relative weight of 21%. Then it followed by “spare part and materials availability” and “maintenance facility layout and Ambiance”.

4.4.2. Results summary

After a detailed examination and evaluation of the service providing system and performance of the case company and through the primary and secondary source of data, the research has identified seven major fleet maintenance service quality factors from the many root causes that have a high effect on the quality of the service provided in the company. The identified quality factors are; Technicians’ knowledge, skills & performance, Maintenance method & strategies, Machines & maintenance tools, Spare parts & materials availability, Technological advancements in vehicles systems & wide variation in models, Maintenance facility layout & Ambiance, and Shop technology & Documentation.

Then the ISM method has developed the overall prioritization/ranking of the factors based on the interrelationship that existed between the quality factors. Whereas the MCDM tool, fuzzy TODIM, has given the priority order for the quality factors based on the dominance degree of the factors relative to the quality measuring criteria. Finally, the QFD matrix provided the level of importance of the quality factors with respect to meeting customer demands.

The result of the analysis showed that the three factors; Machine & maintenance tools, Spare part & material availability, and Maintenance facility layout & Ambiance are the most critical factor for fleet maintenance service quality improvement and for meeting customer requirements in the case company. Besides that, the analysis results indicated that the most prioritized customer requirements are; maintenance personnel with friendly & good behavior, followed by the willingness of the staff to give enough explanation & advice, then a reliable and error-free maintenance service and reasonable and fair maintenance service pricing. Based on the result found, it can be concluded that to develop an efficient and effective solution plan, the plan should consider both the highly ranked service quality factors and the voice of the customers.

Previous researches' done on the improvement of fleet maintenance service quality considers quality improvement initiating from a limited perspective. For instance, as briefed in the literature review section, root cause analysis (RCA) tries to investigate how and why an incident occurred in an attempt to prevent a similar problem from happening again whereas, the CoQ approach improves quality by optimization of quality-related costs. Similar to these techniques and as explained previously, each individual tool employed in this research provides quality improvement solutions from the analysis of limited quality improvement perspective. Therefore, integration of the three approaches, as employed in this research, helps to consider different perspectives & fill each individual tool's gap for reaching a better and reliable conclusion.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Many organizations and companies' success and competitiveness are highly dependent on the availability, reliability, and performance of their fleets. Construction companies, transport providing companies, heavy machines, and vehicles manufacturers or dealers, public organizations (i.e. telecom companies, schools, hospitals, etc.) are from the major ones. For instance, the availability and reliability of fleets in construction companies take a lot of share in the accomplishment of projects with planned cost, quality level, and within the scheduled period. In this regard, the quality of maintenance service provided for the fleets has a significant role in having highly available and reliable equipment. In addition to that, assurance of quality and reliability in fleet maintenance is essential for the service providers for profit-making and competitiveness in the market. Despite its importance, the maintenance service quality provided in the case company is very poor and it is presented through the high maintenance cost spent, high downtime, high frequency of maintenance, and overall customer dissatisfaction and complaint.

Fleet maintenance service involves many subjective factors such as the personal qualities of technicians and managers, the work environment, resources, and capacity, etc. thus it requires engineering decisions and associated actions that are necessary for the improvement of the service quality. Therefore, this research aimed to structurally analyze the maintenance service quality factors in the fleet maintenance facility of a construction company for efficient and effective decision-making on fleet maintenance service quality improvement.

Using the primary and secondary sources of data, the research has identified seven major service quality factors and nineteen customer service requirements. To achieve the objective, the research has used two multi-criteria decision-making tools (ISM & TODIM) with integration of fuzzy logic theory and Quality function deployment tools. Based on the qualitative and quantitative data analysis through these tools, the research has shown that; "Machine and

maintenance tools”, “Maintenance facility layout and Ambiance” and “Spare part and material availability” are the most critical service quality factors and have high relation with the most prioritized customer requirements which are; “maintenance personnel with friendly & good behavior”, “willingness of the staff to give enough explanation & advise”, “a reliable and error-free maintenance service” and “reasonable and fair maintenance service pricing”. Therefore, these factors need high consideration when developing fleet maintenance service strategies and policies. Further analysis has also shown that “Maintaining shop environment”, “Continuous staff training” and “Modernizing diagnosing and maintenance tools” are very important technical requirements for the service, which have a higher effect on meeting customer needs and service quality improvement.

Since the tools & techniques employed in this research has considered the relationship between each quality factor, the relation between the factors and quality measuring criteria, the human judgment on the uncertain and vague situation, and the relation of each factor with the customer service requirements, it can be concluded that the methodology followed provided a reliable result in developing prioritization of the factors for improvement of fleet maintenance quality in the facility. Finally, considering previous researches done on improvements of fleet maintenance service quality are limited on the use of root cause analysis (RCA) and cost of quality techniques, this research has shown a more reliable approach for the decision-making process and it has significant importance for companies with the huge quantity and variety of fleets like construction companies.

5.2. Recommendation

Based on the result obtained from the analysis and the conclusion drawn from it, eight service technical requirements/solution plans are suggested by relating the highly prioritized customer requirements with the highly ranked service quality factors to the decision-makers of the company for their consideration in the development maintenance policy and strategy. To develop these recommendations for service quality improvement, methods such as; discussion with the case company experts, literature review, and referring from other successful companies’ experience in Ethiopia (such as MOINCO, Ries Engineering, and Nyala motors) is employed. The suggested solutions are discussed as follows.

i. **Continuous staff training:** the company should train the maintenance personnel continuously focusing on personal attitude, customer handling, and fleet maintenance. The training on personal attitude and customer handling will help the workers in understanding how a customer can be handled & satisfied and also how can satisfying a customer will improve the company competitiveness which has a final benefit for them. Whereas, the continuous training on fleet maintenance will help the staff to efficiently and effectively repair modern vehicles which comes with the continuous introduction of new technologies every year. The training also helps in the understanding of how to use the latest maintenance diagnosing & repairing tools and machines.

ii. **Modernizing diagnosing and maintenance tools:** If the company wants to improve the service quality and its place in the market, the service should be provided with modern equipment and tools. Availability of testing and diagnosing tools that stayed up with the technology helps in the effective identification of failures without disassembling any vehicle components. Then an efficient maintenance order and the process can be developed/ issued based on the test result. Furthermore, the availability of modern tools and material handling equipment in the facility improves the productivity of the workers and minimizes the number of outsourced maintenance services. As it is obvious, investing in new tools and equipment might require higher capital but the investment can be offset by factoring these costs into the charging policy. This could be the best option considering the garage is providing the service at a low price compared to its competitors. Through time the additional small fee would be paid off the initial cost and it can be used for purchasing other tools and equipment.

iii. **Standardizing maintenance service:** the other major difference found between the case company and its successful competitors is providing unspecialized maintenance service. For instance; Rais engineering provides services only for caterpillar in machines and Ford in vehicles, MOINCO provides service for Komatsu machines and Toyota vehicles, and the same is true for other similar companies. Providing specialized maintenance service helps to decrease the capital investment required for storing required spare parts and for purchasing special maintenance tools to a minimum and it also it makes easy for having several maintenance experts. Therefore, the company should limit itself to specific machines and vehicles which require revision of maintenance policy.

iv. **Strengthening relations with suppliers:** The company should have a strong relationship with its spare part and consumable maintenance material suppliers which mannered on a partnership basis. This can help to ensure a timely spare part and material availability and also has the benefit of negotiating volume and payment terms. A strong relationship with suppliers can be established by understanding the relationship required first, and then writing a contract based on the need, followed by engaging the market, then by managing the negotiation and proceeding according to the agreed contract. In parallel to creating a strong partnership with suppliers, a company should modify its internal long bureaucracy on the part purchasing process.

v. **Maintaining shop environment:** the maintenance shops should be maintained/reconstructed in a way that leaves adequate space for performing the necessary maintenance activities with proper benches/ places for the tools and parts and also they should be designed considering human ergonomics. Moreover, the shops should have a clean & comfortable floor for movement with a proper level of lightning and ventilation; in general, they should be constructed with good shop ambiance. As asserted by many ergonomics scholars, these factors have a high impact on employees' health, behavior, motivation, productivity, and service quality. Apart from that, it helps to protect the vehicle and machine systems from unintentional damages.

vi. **Continuous recognizing and awarding system:** the other main thing the company should have is a system that gives recognition and value to highly productive and behaved employees. As many research studies indicated, the existence of formal employee recognition and the awarding system helps to increase productivity and work engagement, improve employee satisfaction, improve team culture, improve overall staff attitude, improve loyalty and satisfaction of customers, decrease employee stress, and absenteeism.

vii. **Systematic part & material requirement planning:** Although the company plans part and material requirements for every year, mostly it is only used for estimation of the annual budget needed. This can be expected because of the difficulty to purchase all the required spare parts and materials according to the plan considering the large number and variety of fleets. Therefore, the company should develop a systematic material requirement plan by setting improvement of service quality as an objective and it should aim to have the correct amount of spare parts at the right time. Effective MRP can be developed by selecting the dominant types of machines and vehicles makes and by identification of their preventive maintenance schedule.

viii. **Strengthening interconnection network between warehouses:** As briefed in the quality factor discussion section, the company's outdated and manual warehouse working system has created a difficulty to know which spare parts are available in which warehouse on time. Therefore, to identify the quantity and types of spare parts available in the central and other different warehouses when required, the company should have an efficient networking system that connects these warehouses. Besides increasing spare part availability, the existence of an efficient networking system helps to be cost-effective and it helps to identify and then move parts that are available and no more needed in one construction project in time before damage occurs through time.

These eight technical requirements can be very important for the improvement of service quality and also for customer satisfaction. A second QFD matrix is constructed to analyze their level of relationship with the customer requirements and prioritize them based on the result. The methods and techniques used for the construction of the first HoQ are used to develop the second HoQ, which is presented in Fig 4.6.

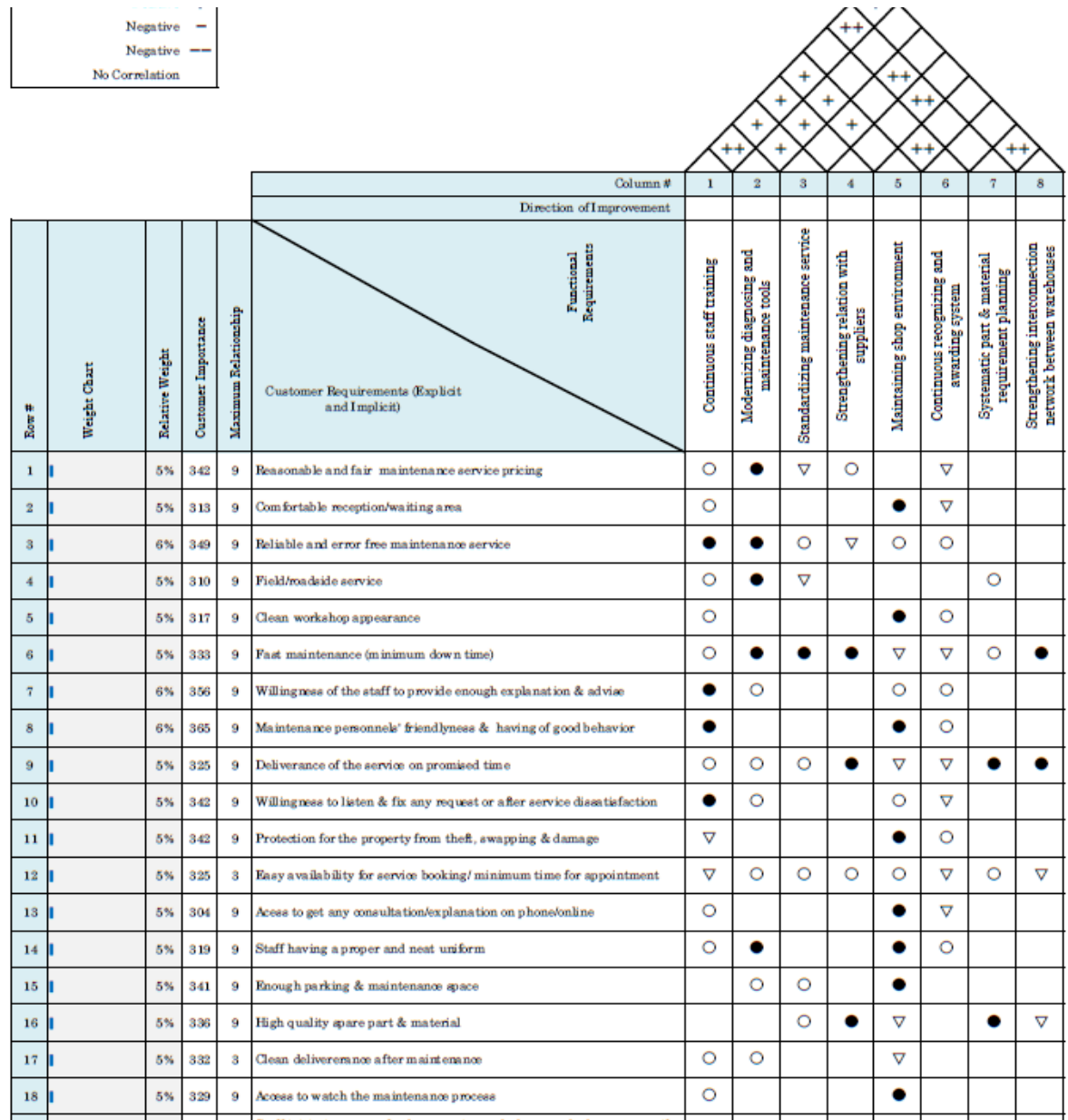


Figure 4.6 House of Quality (HoQ) 2

As mentioned in the first HoQ analysis, the technical requirements with the highest technical requirement rating and relative weight are considered the most critical ones. Therefore, as shown in Figure 4.6, the most critical technical requirement is “Maintaining shop environment” with a technical importance rating value of 476.8 and a relative weight of 24%. Then it is followed by “Continuous staff training” with a technical importance rating value of 412.9 and relative weight of 21% and then “Modernizing diagnosing and maintenance tools” with a technical importance rating value of 379.6 and relative weight of 19%.

5.3. Future research area

Since the research is done by taking specifically ECWC as a case company, based on this research, policy/decision-makers or in general practitioners in other organizations and companies can consider the critical factors and/or the methodology employed in this research to develop effective & efficient maintenance policies and strategies after customizing to their working condition.

This research can also be further continued to the analysis of the root causes of the identified three critical major quality factors using the tools and techniques employed in this research to prioritize the root causes and identify the critical ones for further narrowing it down. Finally, to better expand the application area and benefits of this research future studies should be done using multiple companies as case companies to conclude at a city level which can also help newcomers into the business of vehicle and machinery dealing and fleet maintenance service.

Reference

- Adik, P., & Bobade, S. (2018). Analysis of Losses due to Breakdown of Equipment in Construction. *International Research Journal of Engineering and Technology*, 5(6).
- Aniza, L. A. (2014). Development of Quality Cost Model within a Supply Chain Environment. University of Windsor.
- Arenas, P. D. (2014). Quality costs analysis in the service sector: an empirical study of the Colombian banking system. Concordia Institute for Information Systems Engineering.
- Association, E. E. (2008). Report on the Ethiopian economy: The current state of the construction industry. Addis Ababa.
- Attri, R. (2017). Interpretive structural modeling: a comprehensive literature review on applications. *International Journal of Six Sigma and Competitive Advantage*, 10(Nos. 3/4).
- Ayalew, T., Dakhli, Z., & Lafhaj, Z. (2016). Assessment on Performance and Challenges of Ethiopian Construction Industry. *Journal of Architecture and Civil Engineering*, 2(11), 01-11.
- Bajramovic, E., Islamovic, F., & Gaco, D. (2012). *Acta Technica Corviniensis*. Retrieved 2021
- Barone, A. (2020). Quality Management. Retrieved from Investopedia: <https://www.investopedia.com/terms/q/quality-management.asp>
- Brito, E. P., Aguilar, R. L., & Birto, L. A. (2007). Customer choice of a car maintenance service provider. *International Journal of Operations & Production Management*, 27(5), 464-481.
- Chang, M.-Y., Chen, K., Pang, C., Chen, C.-M., & C.Yen, D. (2013). A study on the effects of service convenience and service quality on maintenance revisit intentions. *Computer Standards & Interfaces*, 187-194.
- Dale, G. B. (2003). *Managing Quality* (Fourth ed.). Oxford, UK: Blackwell Publishing Ltd.

- Dhanisetty, V. V., Verhagen, W., & Curran, R. (2018). Multi-criteria weighted decision making for operational maintenance processes. *Journal of Air Transport Management*, 68(C), 152-164.
- Durdyev, S., & Ismail, S. (2012). Role of the construction industry in the economic development of Turkmenistan. *Energy Education Science and Technology Part A. Energy Science and Research*, 29(2), 883-890.
- El Kfita, A., & Drissi-Kaitouni, O. (2017). A fuzzy revised-DEMATEL method to evaluate vehicles fleet maintenance management in uncertainty. *International Journal of Logistic System and Management*, 28(1), 59-83.
- Elshaer, I. A. (2012). What is the Meaning of Quality? Munich Personal RePEc Archive,.
- Er-Ratby, M., & Mabrouki, M. (2018). Optimization of the Maintenance and Productivity of Industrial Organization. *International Journal of Applied Engineering Research*, 13(8), 6315-6324.
- Etikan, I., & Babatope, O. (2019). A Basic Approach in Sampling Methodology and Sample Size Calculation. *Med Life Clin*.
- G, K. E., Venkatesan, S. P., & Sanket, J. (2018). An integrated interpretive structural modeling and a graph-theoretic approach for measuring the supply chain complexity in the Indian automotive industry journal of Manufacturing Technology Management. *Journal of Manufacturing Technology Management*.
- Gardas, B. B., Raut, R. D., & Narkhede, B. E. (2019). Analyzing the 3PL service provider's evaluation criteria through a sustainable approach. *International Journal of Productivity and Performance Management*.
- Garg, H. (2017). Some Picture Fuzzy Aggregation Operators and Their Applications to Multicriteria Decision-Making. *Arab Journal of Science Engineering*.

- Gh, J., & M., E. (2015). Application of QFD model for automobile after-sales service quality improvement (case study: Bushehr saipa agencies). *Indian Journal of Fundamental and Applied Life Sciences*.
- Ghobadian, A., Speller, S., & Jones, M. (1994). Service Quality: Concepts and Models. *International Journal of Quality & Reliability*, 11(9), 43-66.
- Goldstein, S. M., Johnston, R., Duffy, J., & Raod, J. (2002). The service concept: the missing link in service design research? *Journal of Operations Management*, 20, 121-134.
- Gomes, L. A., & Rangel, L. D. (2009). An application of the TODIM method to the multicriteria rental evaluation of residential properties. *European Journal of Operational Research*, 193, 204-211.
- Haider, R., Kakar, A., Khattak, S. B., Rahman, S., Maqsood, S., Ullah, M., et al. (2015). Development Of Optimized Maintenance System For Vehicle Fleet. *Journal of Engineering and Applied Science*, 34(2).
- Hamid, S. R., Isa, S., Chew, B. C., & Altun, A. (2019). Quality Management Evolution from the Past to Present: Challenges for Tomorrow. *Organizacija*, 52(3).
- Hanine, M., Boutkhoul, O., Tikniouine, A., & Agouti, T. (2016). Comparison of fuzzy AHP and fuzzy TODIM methods for landfill location selection.
- Hong, J.-P., Kim, B.-Y., & Oh, S.-H. (2020). The Perceived-experiential Value and Service Quality of Auto Maintenance and Repair service. *Journal of Distribution Science*, 18(1), 59-69.
- Huang, J., Li, Z., & Liu, H.-C. (2017). A new approach for failure mode and effect analysis using linguistic distribution assessments and TODIM method. *Reliability Engineering and System Safety*.
- Huang, J., Liu, H.-C., Duan, C.-Y., & Song, M.-S. (2019). An improved reliability model for FMEA using probabilistic linguistic term sets and TODIM method. *Annals of Operations Research*.

- Ishizaka, A., & Siraj, S. (2017). Are multi-criteria decision-making tools useful? An experimental comparative study of three methods. *European Journal of Operational Research*.
- Jain, A., & Verma, D. S. (2019). Improvement on Service Quality of Automobile Service Center. *International journal of scientific & technology research*, 8(08).
- James, A. T. (2020). Analysis of challenges for automobile service garages in India: a structural modeling approach. *Journal of Advances in Management Research*.
- James, A. T., & James, J. (2020). Service quality evaluation of automobile garages using a structural approach. *International Journal of Quality & Reliability Management*.
- James, A. T., Gandhi, O. P., & Deshmukh, S. G. (2017). Assessment of failures in automobiles due to maintenance errors. *International Journal of System Assurance Engineering Management*.
- Kaczor, S., & Kryvinska, N. (2013). It is all about Services - Fundamentals, Drivers, and Business Models. *The Society of Service Science Journal of Service Science Research*, 5(2), 125-154.
- Kang, G.-D., & James, J. (2004). Service quality dimensions: an examination of Gronroos's service quality model. *Managing Service Quality*, 14(4), 266-277.
- Kumar, M., Raju, N., & Kumar, M. S. (2016). Quality of Quality Definitions –An Analysis. *International Journal of Scientific Engineering and Technology*, 5(3), 142-148.
- Kumar, R. R., Mishra, S., & Kumar, C. (2017). Prioritizing the solution of cloud service selection using integrated MCDM methods under a Fuzzy environment. *Journal of Supercomputing*.
- Liu, Z., Wang, P., & Zhang, A. (2012). *Research on Equipment Maintenance Management Based on The Total Quality Management Theory*. Tianjin, China: Equipment Support Department Military Transportation University.

- Lynch, A. (2021). Cause & Effect Analysis - 6M. Retrieved from edrawsoft: <https://www.edrawsoft.com/6m-method.html>
- M, L., C, W., L, Z., & L, Y. (2015). An intuitionistic fuzzy-TODIM method to solve distributor evaluation and selection problem. *International journal of simulation modeling*, 14(3), 511-524.
- M. Jagtap, S. M., & Chanewar, N. (2017). Cost of Quality Applications and Challenges: A Review. *International Journal of Scientific & Engineering Research*, 8(3).
- Makhanya, B., Nel, H., & Pretorius, J.-H. C. (2018). A Systematic Literature Review of the Implementation of Cost of Quality. University of Johannesburg, Postgraduate School of Engineering Management. Johannesburg: IEE.
- Marttunen, M., Lienert, J., & Belton, V. (2017). Structuring problems for Multi-Criteria Decision Analysis in Practice: A Literature Review of Method Combinations. *European Journal of Operational Research*.
- Miliauskaite, J. (2012). Quality of Service: Concept Analysis. Čaplinskas, A.; Dzemyda, G.; Lupeikienė, A, 235-240.
- Nair, A. (2006). Meta-analysis of the relationship between quality management practices and firm performance-implication for quality management theory development. *Journal of Operations Management*, 24, 948-975.
- Nandal, V., Kumar, R., & Singh, S. K. (2019). Barriers identification and analysis of solar power implementation in Indian thermal power plants: An Interpretative Structural Modeling approach. *Renewable and Sustainable Energy Reviews*, 114.
- Nazeri, A., & Naderikia, R. (2017). A new fuzzy approach to identify the critical risk factors in maintenance management. *International Journal of Advanced Manufacturing Technology*.
- Nepal, M. P., & Park, M. (2004). Downtime model development for construction equipment management. *Engineering Construction and Architectural Management*, 11(3), 199-210.

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- Peerally, M. F., Carr, S., Waring, J., & Dixon-Woods, M. (2016). The problem with root cause analysis. *BMJ Quality & Safety*.
- Percarpio, K. B., Watts, B. V., & Weeks, W. B. (2008). The Effectiveness of Root Cause Analysis: What Does the Literature Tell Us? *The Joint Commission Journal on Quality and Patient Safety*, 34(7).
- Qin, Q., Liang, F., Li, L., Chen, Y.-W., & Yu, G.-F. (2017). A TODIM-based multi-criteria group decision making with triangular intuitionistic fuzzy numbers. *Applied Soft Computing Journal*.
- R, T. K., & Joseph, K. C. (2013). Service quality analysis and improving customer satisfaction in automobile service industry using QFD. *International journal of industrial engineering research and development (IJIERD)*, 4(1), 41-51.
- Sari, D. P., Ulkhaq, M., Rinawati, D. I., & Rasyida, D. R. (2018). Barriers of Reverse Logistics Implementation: A Case Study in a Car Battery Industry in Indonesia. *International Journal of Supply Chain Management*, 7(5).
- Schiffauerova, A., & Thomson, V. (2006). A review of research on the cost of quality models and best practices. *International Journal of Quality & Reliability Management*, 23(6), 647-669.
- Sener, E., & Iseley, D. (2009). *Construction Equipment Fleet Management Using Telematics Technology: Research And Resultant Educational Perspectives*. American Society for Engineering Education.
- Serrat, O. (2017). *Knowledge Solutions: Tools, Methods, and Approaches to Drive Organizational Performance*. Asian Development Bank, Creative Commons Attribution-NonCommercial.
- Sousa, R., & Voss, C. (2002). Quality management re-visited: a reflective review and agenda for future research. *Journal of Operations Management*, 20, 91-109.

- Stojcic, M., Zavadskas, E. K., Pamucar, D., Stevic, Z., & Mardani, A. (2019). Application of MCDM Methods in Sustainability Engineering: A Literature Review 2008–2018. *Symmetry journal*, 11(350).
- Tosun, O., & Akyuz, G. (2015). A Fuzzy TODIM Approach for the Supplier Selection Problem. *International Journal of Computational Intelligence Systems*, 8(2), 317-329.
- Triantaphyllou, E. (2000). *Multi-criteria Decision Making Methods: A Comparative Study*. Springer Science+Business Media Dordrecht.
- Velaction. (2021). 6P's. Retrieved 2021, from <https://www.velaction.com/6-ps/>
- Verma, H., & Singh, S. (2018). Interpretive Structural modeling for e-impulse buying: an Indian study. *International Journal of Electronics Marketing and Retailing*, 9(3).
- Vujanovic, D., Momc ilovic, V., Bojovic, N., & Papic, V. (2012). Evaluation of vehicle fleet maintenance management indicators by application of DEMATEL and ANP. *Expert System with Applications*, 39, 10552-10563.
- Wang, L., Wang, Y.-M., & Martinez, L. (2019). Fuzzy TODIM method based on alpha-level sets. *Expert Systems with Applications*.
- Weckenmann, A., Akkasoglu, G., & Werner, T. (2015). Quality management- history and trends. *The TQM Journal*, 27(3), 281-293.
- Weinstein, L., Vokurka, R. J., & Graman, G. A. (2009). Costs of quality and maintenance: Improvement approaches. *Total Quality Management & Business Excellence*, 20(5), 497-507.
- Xing, W., & Min, Y. (2017). QFD Analysis and Case Research for After-sales Service Quality of the Automobile 4S Store. *Advances in Social Science, Education and Humanities Research*, 123.
- Zhang, L., Zhang, L., & Shan, H. (2019). Evaluation of equipment maintenance quality: A hybrid multi-criteria decision-making approach. *Advances in Mechanical Engineering*, 11(3), 1-16.

Appendix

Appendix I: Identification of causes of poor maintenance service quality: Interview

Questions

Longer Down Time

- #1. In your experience what are the major factors that contribute to longer maintenance service time (longer downtime)?
- #2. During your work in ECWC, what do you think are the major causes for the observed long maintenance service time?
- #3. What are the minor causes that contribute to the major factors (this depends on the interviewee's answer)

Frequency of Maintenance

- #4. Why do you think that vehicles or machines come back more frequently for maintenance?
- #5. In your experience in the company, what are the reasons for frequent vehicles failure?

Outsource maintenance

- #6. Considering the high cost of outsourcing maintenance options what are the reasons that forced to use this alternative?

Customers compliant

- #7. Why do you think that customers find it difficult for contacting the responsible person and also gain proper explanation on maintenance service done?

Appendix II: Expert/Decision makers' opinion survey questionnaire

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

Research Questionnaire for the fulfillment of Degree of Masters in industrial engineering

In the title of Identification and Analysis of causes of poor service quality in fleet maintenance facility: a structural modeling approach (A case of Ethiopian construction Works Corporation)

Dear Participants, this questionnaire is purely for academic purposes and only for the Partial Fulfillment of the Degree of Masters of Science in Industrial Engineering. Your genuine response will have an important role and the responses will be used as a valuable and primary input for the study. For this reason, you are kindly requested to spare a few minutes of your busy schedule and genuinely fill this questionnaire.

Part I. Demographic or background information of the respondent

1. Please indicate your highest level of education

v Diploma Diplom ree Master D and above

2. Please indicate your designation or working position in the company:

Deputy CEO Manager Maintenance service leader

Team leader Shop foreman Lead/Senior Engineer

Other (please specify):

3. Number of years of experience in ECWC:

than 2 years between 2 years More than 5 years

Part II. Maintenance service quality analysis

The symbol used in the questionnaire represents the following factors for fleet maintenance service quality

F₁:- Technicians' knowledge, skills, and performance

F₂:- Maintenance method and strategies

F₃: - Machines and maintenance tools

F₄: - Spare part and materials availability

F₅: - Technological advancements in vehicles systems and wide variation in models

F₆: - Maintenance facility layout and Ambiance

F₇: - Shop technology & Documentation

1. Based on your experience and knowledge, please state the relationship between the above factors which are causes for poor maintenance service quality performance, on the table below based on the following four symbols.

Symbols	Meaning	Description
FR	Forward relation	Factor “i” affects factor j
BR	Backward relation	Factor j affects factor i
CR	Cross relation	Factor i and j affect each other
NR	No relation	Factor i and j do not affect each other

Factors for fleet maintenance service quality							
	F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇
F ₁							
F ₂							
F ₃							
F ₄							
F ₅							
F ₆							
F ₇							

2. Considering the current situation in the garage please rank the importance weight of the following maintenance service quality measuring criteria based on five-point scales. Put “√” mark in the corresponding cell

Maintenance service measuring criteria	Very Low	Low	Medium	High	Very High
Cost					
Downtime					
Frequency of maintenance					
Customer dissatisfaction & complaint					

3. Considering the garage’s work performance, please rate the impact of the maintenance service factors in increased downtime, frequency of maintenance, maintenance cost, and customers’ complaint and dissatisfaction with the following five-point scale symbols.

Symbol	Meaning
VL	Very Low
L	Low
M	Medium
H	High
VH	Very High

I. No.	Maintenance service quality factors	Maintenance service measuring criteria			
		Down time	Frequency of maintenance	Cost	Customer dissatisfaction & complaint
1	F1: Technicians’ knowledge, skills, and performance				
2	F2: Maintenance method and strategies				
3	F3: Machines and maintenance tools				
4	F4: Spare part and materials availability				
5	F5: Technological advancements in vehicles systems and wide variation in models				
6	F6: Maintenance facility layout and Ambiance				
7	F7: Shop technology & Documentation				

Appendix III: Customer need survey questionnaire

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

Research Questionnaire for the fulfillment of Degree of Masters in industrial engineering

In the title of Identification and Analysis of causes of poor service quality in fleet maintenance facility: a structural modeling approach (A case of Ethiopian construction Works Corporation)

Dear Participants, this questionnaire is purely for academic purposes and only for the Partial Fulfillment of the Degree of Masters of Science in Industrial Engineering. Your genuine response will have an important role and the responses will be used as a valuable and primary input for the study. For this reason, you are kindly requested to spare a few minutes of your busy schedule and genuinely fill this questionnaire.

Part I. Demographic or background information of the respondent

1. What is your age

18-30 years 31-40 years 41-50 years Above 50 years

2. Please indicate your highest level of education

Under High school High school Complete Diploma Bachelor Degree
 Master Degree and above

3. Please indicate which type of customer you are for the garage

Fleet equipment administration and maintenance Team leader External customer
 Manager/ driver in a department under the head office

4. Length of your relationship with the garage as a maintenance customer:

Less than 2 years Between 2 to 5 years More than 5 years

Part II. Customers’ maintenance service requirement questionnaire

Please indicate the level of importance the following maintenance service quality measuring attributes have on a scale of 1-5 **based on your service needs**. Put “√” mark on the corresponding cell.

Where, 1= **Much less importance** 2= **Less importance** 3= **Moderate** 4= **High importance**
5= **Very high importance**

I. No.	Maintenance service requirement	1	2	3	4	5
1	Reasonable and fair maintenance service pricing					
2	Availability of a comfortable reception/waiting area					
3	A reliable and error-free maintenance service					
4	Capability to provide field/roadside service when required					
5	The clean appearance of maintenance shops					
6	The capacity to deliver maintenance services with minimum downtime					
7	The willingness of the staff to give enough explanation & advise					
8	Maintenance personnel with friendly & good behavior					
9	The capability of the garage to deliver the service on the promised time					
10	The willingness of the staff to listen & fix any request or after service dissatisfaction					
11	Availability of high protection for the property from theft, swapping & damage					
12	Easy availability for service booking/ minimum time for appointment					
13	Availability of access for the customer to get any consultation/explanation on phone/online					
14	Maintenance personnel with a proper and neat uniform					
15	Availability of enough parking & maintenance space in the garage					
16	Using high-quality spare parts& material for maintenance					
17	Clean deliverance of vehicle/machine after maintenance					
18	Access for the customer to watch the maintenance process if he required					
19	The motivation of the staff to further examine and also consult the customer if other service demands					