ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING (SMIE)

Enhancing a Vehicle Competency Assurance Service in Case of Addis Ababa City Administration Driver & Vehicle License & Control Authority (DVLCA).

A master's Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for a Degree of Master of Science in Mechanical and Industrial Engineering (Industrial Engineering Stream)

By: Berhe Tesfakiros

Advisor: Gezahegne Tesfaye (PhD)

Co-Adviser: Sharmarke A. candidate (PhD)

Addis Ababa, Ethiopia

June 2024

Declaration

I hereby declare that I am the author of this thesis, "Enhancing a vehicle competency assurance service in case of Addis Ababa city Administration Driver & Vehicle License & Control Authority(DVLCA)," and that I have had assistance from my advisor. I also declare that, unless otherwise indicated in the text, all of the work in this thesis is original to me and has not been submitted in whole or in part for credit toward any other degree or professional qualification.

Addis Ababa Institute of Technology

School Of Mechanical and Industrial Engineering (SMIE)

Industrial Engineering

Enhancing a Vehicle Competency Assurance Service in Case of Addis Ababa City Administration Driver & Vehicle License & Control Authority (DVLCA).

By

Berhe Tesfakiros

Approved by the Board of Examiners

Gezahegne Tesfaye (Ph.D.)	_____	_____
Advisor	Signature	Date
Gulelat Gatew (Ph.D.)	_____	_____
Internal Examiner	Signature	Date
Daniel Ashagrie (Ph.D.)	_____	_____
External Examiner	Signature	Date
Araya Abera (Ph.D.)	_____	_____
School Dean	Signature	Date

Acknowledgements

I want to sincerely thank my advisor Dr. Gezahegne Tesfaye, for all of his help and insightful feedback on this thesis. Dr. Gezahegne has been very helpful in helping me to define my academic goals and has guided me through the entire process in a very nice way. Furthermore, I express my gratitude to God for unwavering and unceasing assistance.

Abstract

The Addis Ababa City Administration Driver & Vehicle License & Control Authority (AA-DVLCA) has a lot of problems and inefficiencies when it comes to providing services for vehicle competency assurance. The efficacy and efficiency of vehicle inspections are significantly impacted by problems including antiquated equipment, a shortage of skilled workers, and ineffective processes. Longer inspection periods and lower service quality are caused by these issues, which increase the risk to public safety and erode customer happiness.

The study uses both qualitative and quantitative research approaches to address these problems. Site visits, semi-structured interviews, and document analysis are some of the techniques used to gather data with the goal of comprehending existing issues and seeing areas for change. In addition, a discrete event simulation model is created to assess the functionality of the current system and suggest improvements. In order to simulate numerous scenarios and evaluate their effects on system performance and service quality, the model includes a variety of factors and variables.

The results of the study show that by modernizing inspection methods and maximizing resource utilization, considerable improvements in inspection times and service standards can be attained. Purchasing state-of-the-art inspection tools, improving staff development initiatives, and putting in place thorough quality control protocols are among the main suggestions. The report also emphasizes how crucial it is to build ongoing feedback systems and include stakeholders in order to guarantee long-lasting advancements in vehicle competency assurance services. It is anticipated that these actions will greatly improve the effectiveness, dependability, and general caliber of services rendered by the AA-DVLCA.

Key Words: Service enhancement, Vehicle competency Assurance, Discrete event simulation

Table of Contents

List of Tables

List of Figures

Acronyms

VCA: vehicle competence assurance

VSC: vehicle spot checking

VAI: vehicle annual inspection

TIS: technical inspection service

DVLCA: driver and vehicle license & control authority

I/M: inspection and maintenance

SDP: Service Delivery Policy

NTSA: National Transport and Safety Authority

DES: Discrete Event Simulation

DVSA: Driver and Vehicle Standards Agency

ADAS: Advanced Driver Assistance Systems

ATF: Authorized Testing Facilities

AA-DVLCA: Addis Ababa Driver and Vehicle License and Control Authority

VCA-TIS: vehicle competency assurance technical inspection service

AWT: Average waiting time

QL: Queue length

IT: Inspection time

INS: Inspector

MC: Machine

LT: Lighting test

ST: Smoke test

CRS: Congressional Research Service (USA)

NHTSA: National Highway Traffic Safety Administration (USA)

Chapter one

1.1 Introduction

The development of vehicle competency assurance service is essential for maintaining and enhancing the safety and efficiency of vehicles on the road. This service plays a crucial role in ensuring that vehicles are well-maintained, compliant with regulations, and operated by skilled drivers.in the '90s, the growing economic role of the service sector in most of the developed economies was in clear contrast to the practice, which still focused on the physical and tangible output of the traditional industrial sectors [1]. Service improvement is often described as the service development. Therefore, the service industry needs to develop, integrate, and appropriate design as a central competence [2].

The vehicle competency assurance service must also guarantee that the vehicles comply with all applicable local, state, and federal regulations. The Department of Transportation (DOT) is a trustworthy source for information about traffic laws. It provides information on license requirements, required inspections, and other compliance needs. The two kinds of vehicle inspection operations that are displayed here are inspection simply and repair & inspection. A reasonably low cost per inspection can be attained via an inspection-only facility [3]. Three different vehicle inspection procedures are recognized by the AADVLCA: vehicle competency authentication, vehicle on spot checking (VSC), and vehicle annual inspection (VAI). While the government operates the remaining portions, among this yearly inspection is outsourced. Thus, the best course of action is to do an inspection alone.

Addis Ababa city is currently busy with vehicle traffic, where many accidents can be seen and a growing number of automobiles on the road. As a result, there is now a greater demand for appropriate vehicle maintenance and inspection services to preserve traffic safety and reduce accidents. To implement this AA-DVLCA, has been in the spotlight due to the implementation of new regulations aimed at improving road safety and traffic management. The authority has been actively enforcing the Council of Ministers Regulation No. 208/2011, which introduces a points-based system for recording traffic offenses that can lead to license suspension or revocation, in charge of licensing, car registration, and traffic law enforcement. In order to do

this, the DVLCA must create technical testing services for vehicle competency assurance that are both efficient and effective[4][5].

A number of problems that have come up recently are the focus of the research into enhancing the vehicle competency assurance service. Among these concerns are the growing intricacy of automobiles, the want for enhanced safety regulations, and the escalating necessity for transportation solutions that are both eco-friendly and efficient. Researchers can pinpoint the most urgent issues and create workable strategies to solve them by assessing the condition of vehicle competence assurance services as they stand today and considering possible upgrades.

A thorough analysis of several factors pertaining to the competence and dependability of automobiles as well as the services offered for their upkeep and assurance is required while studying vehicle competency assurance service issues. This is a broad category that includes Things like performance, safety, legal compliance, and how well vehicle competency assurance services work. Many viewpoints, including engineering, regulatory compliance, customer happiness, and industry best practices, must be taken into account in order to properly research these topics.

The research objective of enhancing vehicle competency assurance service is to improve the overall quality, efficiency, and effectiveness of the services provided to ensure that vehicles meet the required standards of safety, performance, and environmental impact through DES. This objective encompasses various aspects related to the assessment, certification, and ongoing monitoring of vehicle competency, with the ultimate goal of promoting public safety, environmental sustainability, and regulatory compliance within the automotive industry.

1.1.1. Problem Statement

Ensuring the competency of vehicles operating in the city presents substantial issues for the Addis Ababa Driver & Vehicle License & Control Authority bole branch inspection center. There are ongoing problems with the effectiveness, consistency, and correctness of vehicle competency assessments in spite of the inspection procedures and regulatory frameworks that are in place. These difficulties increase the risk to road safety, raise issues with the environment, and aggravate public dissatisfaction with the services received[4].therefore, the key issues identified include;

1. Inadequate inspection processes: The thoroughness and technology support required to properly identify all potential safety and environmental issues may be lacking from current vehicle inspection procedures.
2. Operational Inefficiencies: Processing vehicle inspections and certificates in a timely and effective manner is hampered by delays, administrative obstacles, and resource shortages.
3. Compliance and Enforcement Gaps: Vehicle owners frequently fail to comply with regulations due to inconsistencies in the way that vehicle competency standards are enforced.
4. Technological Limitations: Current car inspection data monitoring, recording, and management systems could not be taking advantage of current technological developments, which could lead to data inaccuracies and management issues.
5. Stakeholder Engagement: Insufficient interaction and correspondence with vehicle owners, service providers, and additional stakeholders impact the general efficacy and approval of competency assurance services.

This may result inaccurate assessments, overlooked safety risks, and a general decrease in the inspection process efficacy, Inconsistent Inspection Standards[20].likewise, A number of research gaps have been found in the vehicle competency assurance technical inspection service in recent studies. These gaps point to areas that require additional study and development in order to improve the effectiveness and dependability of technical inspections for vehicles like, the absence of uniform inspection protocols among various nations or areas represents a major research gap. The overall quality of the inspection process may be impacted by inconsistent inspection results caused by a lack of consistent criteria[19],

1.1.2. Research questions of the study:

1. How effective are the current procedures for vehicle competence assurance services?
2. What are the primary performance enhancement variables in the vehicle competency assurance services?

3. How effective are the vehicle technical performance inspection operation manual and standards of the DVLCA?

4. What are the challenges and drawbacks of the current vehicle competence assurance (VCA) service of DVLCA?

5. How can simulation models be developed to enhance vehicle competence assurance service?

6. What are the most effective vehicle competence assurance service enhancement options, and how can they be validated and implemented?

1.2 Objectives

1.2.1 General Objective

The main objective of this research is to investigate and propose enhancements to the vehicle competency assurance services provided by the Addis Ababa Driver & Vehicle License & Control Authority bole branch inspection center.

1.2.2 Specific Objectives

The specific objectives of this research are to:

- Assess the current vehicle competence assurance service procedures.
- Sort out the primary performance enhancement variables of the vehicle competency assurance service.
- Assess the Vehicle technical performance inspection operation manual and standards of DVLCA.
- Identify the challenges and drawbacks of the current VCA service.
- Develop simulation models for vehicle competence assurance service enhancement.
- Validate and propose major vehicle competence assurance service enhancement options.

1.4.Scope and limitation of the study

1.4.1. Scope

The research covers Driver & Vehicle License & Control Authority Bole Branch office on vehicle competency assurance service. The selection criteria is by its location, transport availability and population size. The thesis focuses on enhancing vehicle competency assurance service.

The research includes the following primary endeavors:

- Vehicle registration renewal
- The registration process involves the transfer of automobiles from different parts of the country.
- Change in service type
- Yearly examination of a vehicle's condition
- Modification of the vehicle's physical structure
- Replacement of the engine in a vehicle
- Chassis substitution
- On-site inspection of a vehicle

1.4.2. Limitation of the study

Since it is a government institution, customers find it difficult to express their opinions without fear, and this brings limitations to the data gathering process.

1.4.3. Significance

The study holds significant importance in various aspects to vehicle competency assurance service the following benefits can be achieved:

- Improved system efficiency
- Enhanced reliability and safety
- Cost-effective testing and validation
- Better decision-making
- Flexibility and adaptability
- Enhanced training and education
- Better collaboration and communication

1.5.Organization of the paper

There are five chapters in this research. Introduction is covered in the first chapter. It includes definitions of essential terminology, an overview of the study's organization, the issue statement,

the study's aim, research questions, limitations, delimitations, and scope. Chapter two reviews pertinent literature, while Chapter Three focuses entirely on the study's methods. The analysis and presentation section are covered in Chapter 4. Chapter 5 highlights the recommendations based on the findings and the closing thoughts.

Chapter two

2. Literature Review

2.1. Introduction

This study touches different research works, and consists of theoretical orientation, concept, and empirical reviews. And the researcher will try to review related literatures in order to assess the current state of VCA service procedures, to identify the shortcomings and to sort the variables of the VCA service.

2.2. Explanation of Important Terminology

2.2.1. Vehicle competency Assurance

Vehicle competency assurance is the term used to describe a methodical process designed to guarantee that automobiles, especially those fitted with cutting-edge technologies like autonomous driving systems, adhere to predetermined performance and safety criteria. This procedure includes assessing the car's capacity to operate safely and effectively in a range of situations. The intention is to instill trust in the vehicle's ability to operate safely and predictably in everyday situations[6].

A comprehensive strategy called "vehicle competence assurance" attempts to guarantee the performance, dependability, and safety of automobiles on the road. The process encompasses multiple phases, such as design, production, testing, and maintenance, with the aim of ensuring that vehicles adhere to the necessary regulations and standards. Reducing the likelihood of vehicle malfunctions, collisions, and related problems is the main goal of vehicle competence assurance[30]. Under this main term the following key term should be defined:

Vehicle Inspection Service (VIS): is a technical vehicle inspection program. It's carried out in compliance with national laws and regulations. For nations to guarantee that the automobiles

operating on their roads adhere to national legislation and any other mandatory national requirements, it is imperative. VIS is also used to monitor the compliance and safety of used import cars[31].

2.2.2. Service Enhancement

The process of raising the standard, effectiveness, and total value of services offered to clients is known as service enhancement. This can include a broad range of activities designed to improve customer pleasure, experience, and add value to services provided. Improving customer service is essential for companies to remain competitive, draw in new clients, and keep existing ones. It entails a number of tactics and initiatives centered on comprehending client requirements, resolving issues, and consistently enhancing service performance. Externally driven strategy development describing change process for service enhancement deals with “improving service performance” and describes improvement strategies for either radical change or more continuous improvement; but both strategies have high failure rates [32].Because, if the service capacity of a firm is enhanced, the accompanying costs will increase. If the service capacity is insufficient, it will increase waiting time and possibly cause customer complications[33].

In the context of vehicle competency assurance, "service enhancement" refers to the methodical changes made to the caliber and efficiency of automobile services offered by repair facilities. By using defined procedures, this method seeks to improve customer happiness, guarantee safety, and preserve vehicle performance[7][8].

2.2.3. The State Of The Art

The state of the art in vehicle competency assurance involves advanced technologies, rigorous testing protocols, and comprehensive quality management systems to ensure that vehicles meet the highest standards of safety and performance, such as diagnostic equipment, computerized testing systems, and sensor-based tools. These technologies enable precise measurement and analysis of critical vehicle components, including engine performance; braking systems, suspension dynamics, and emissions control systems. Furthermore, the integration of artificial intelligence (AI) and machine learning algorithms enhances the predictive capabilities of these inspection services, allowing for early detection of potential issues and proactive maintenance recommendations[12]. The role of technology provides substantial benefits for both firms and users. Even if, the existence of technology can raise customers concerns of privacy, confidentiality and the acceptance of unsolicited communications[19].These aspects of technology cause users to be wary of new technological applications. However, this study focuses on implementation of technology for service enhancement[19].

2.2.3.1. Autonomous Vehicle Testing

Highway safety might significantly improve with the use of autonomous vehicles. The National Highway Traffic Safety Administration (NHTSA) study indicates that 94% of crashes involving motor vehicles involve human error, accounting for an anticipated 36,096 fatalities in 2019(CRS report, 2021).

Autonomous vehicle testing has accelerated in the private and public sectors in recent years, but it's possible that widespread adoption of completely autonomous vehicles, which require no human intervention. However, the pace of autonomous vehicle commercialization was slowed after the 2018 death in Arizona of a pedestrian struck by an autonomous vehicle, which highlighted the challenges of duplicating human decision making by artificial intelligence. Following two fatalities in April 2021 in a Tesla vehicle operating without a driver, the National Transportation Safety Board determined that the fatality was caused by an "inadequate safety culture" at rideshare company Uber, which was testing the vehicle, as well as deficiencies in state and federal regulation. These incidents raised further concerns about driverless technologies (CRS Report, 2021).

Five reports from the NHTSA and the U.S. Department of Transportation since 2016 have influenced the conversation surrounding federal regulations for autonomous vehicles. These

include recommendations for best practices that states should take into account when enforcing driver regulations, a set of voluntary, publicly accessible self-assessments by automakers outlining how they are incorporating safety into their cars, a plan to alter the way that exemptions from federal safety standards are currently granted, and a multimodal approach to get ready for the integration of more automated cars. The first autonomous vehicle exemption from three federal motor vehicle standards was approved by the NHTSA in February 2020, Nuro, a California-based company that plans to deliver packages with a robotic vehicle smaller than a typical car[8].

2.3. General view of the Research Question's to be answered by the study

2.3.1. The procedures of VCA Technical inspection service

Several crucial steps are involved in the VCA Technical Inspection Service to guarantee the compliance and safety of automobiles. The VCA Technical Inspection Service consists of the following primary steps[13][12]:

Application Submission: Through the VCA application form, which is accessible on the VCA website or customer portal, clients must submit their requests for technical inspection services. To create a customer record and obtain financial clearance, new clients must fill out the VCA application form.

Fee Structure: Depending on the service rendered, VCA may impose time charges or set rates in addition to specified fee schedules for its technical inspection services. The fee schedule is decided upon prior to work starting, and clients might get an invoice when the inspection is finished.

Inspection Procedure: The technical inspection is carried out upon the receipt of the application and payment of the associated fees. This entails giving the car a close inspection to make sure it satisfies safety and legal requirements. Numerous topics are covered by the examination, including safety features, emissions, vehicle components, and general regulatory compliance. Reporting and Certification: Following the inspection, a thorough report containing the results is produced. A certification or approval certificate indicating conformity with safety and regulatory standards is given to the vehicle if all requirements are met.

Follow-Up Actions: If a few minor problems are found during the inspection, there may be a need for additional steps. This can entail a follow-up inspection following any repairs or modifications required to bring the car into compliance.

Continuous Compliance: Even after initial certification, car owners must continue to adhere to safety and legal requirements. To guarantee continued compliance with rules, it could be required to conduct audits or inspections on a regular basis.

2.3.2. Performance enhancement variables of VCA Technical inspection service

A number of performance-enhancing factors can be taken into account while providing a Vehicle Competency Assurance Technical Inspection service in order to guarantee the efficacy and efficiency of the inspection procedure. These factors play a critical role in preserving the caliber and dependability of the services rendered. Among the crucial elements for improving performance are[23][7]:

Technological Tools: You may improve the accuracy and speed of inspections by using cutting-edge technological tools including software systems, digital inspection platforms, and diagnostic equipment. These instruments can aid in the prompt identification of problems and the provision of thorough reports for the evaluation of vehicles.

Training and Certification: To retain competence in doing inspections, it is imperative that inspectors possess the requisite training, certification, and knowledge of the most recent industry standards. Ongoing training courses can improve their abilities and expertise, resulting in inspections that are more accurate and comprehensive.

Quality Control Measures: Enforcing strict quality control guidelines at every stage of the inspection procedure can support preserving the reliability and consistency of evaluations. Peer reviews, regular audits, and following established protocols can raise the standard of the inspection service as a whole.

Customer Feedback channels: One way to find areas for improvement is to set up feedback channels where customers can share their experiences with inspections. Improving customer satisfaction and trust in the inspection service can be achieved through immediately and effectively addressing consumer issues.

Effective Workflow Management: Improving the operational efficiency of conducting inspections can be achieved by streamlining workflow procedures, efficiently setting up appointments, and allocating resources. Timely service delivery is ensured by effective workflow management, all without sacrificing quality.

Compliance with Regulations: Maintaining the legitimacy and legality of the inspection service depends on compliance with industry standards and regulatory regulations. Adherence to regulations is a sign of professionalism and dedication to safety protocols.

Continual Enhancement Projects: Performance improvements can be achieved over time by fostering a culture of continuous improvement within the inspection service by getting input from inspectors, putting best practices into action, and keeping abreast of industry developments. A Vehicle Competency Assurance Technical Inspection service may efficiently fulfill customer requirements, optimize operations, and offer high-quality inspections by concentrating on certain performance enhancement variables.

By guaranteeing accurate assessments, dependable outcomes, and compliance with regulatory standards, a combination of these independent and dependent variables together improves the performance of automotive competency assurance technical testing services.

No.	Independent variables of VCATIS	Dependent variables of VCATIS
1	Equipment Availability(EA)	Vehicle Design & Technology(VDT)
2	Test Operator Skill & Training(TOST)	Regulatory compliance(RC)
3	Test Environment(TE)	Maintenance and vehicle condition(MVC)

Table 1: some variables of VCATIS.

Authors		Independent Variables			Dependent Variables		
		EA	TOST	TE	VDT	RC	MVC
1	[5]	■					
2	[11]		■				
3	[6]			■			
4	[19]				■		
5	[18]					■	
6	[14]						■

Table 2: Combination of Inconsistent variables of VCATIS

2.3.2.1. Key performance indicators & Metrics of VCATIS

In order to improve efficiency and effectively track vehicle inspection processes, it is imperative that businesses keep an eye on the key metrics and KPIs listed in the resources provided on vehicle inspection. These key metrics offer valuable insights into the performance of businesses and help them make decisions that will optimize their processes. The following are the seven industry-specific KPIs for tracking vehicle inspections:

Average Inspection Time: This statistic shows how long an inspection of a vehicle typically takes on average. Businesses can find inefficiencies in their inspection procedures and strive towards streamlining operations to lower costs and raise customer satisfaction by monitoring this KPI.

Number of cars Inspected Daily: Tracking the quantity of cars examined daily offers valuable information about the capability and effectiveness of an operation. It aids companies in comprehending how their workload is distributed and in allocating resources as efficiently as possible.

Percentage of Vehicles that Pass Inspection: This KPI calculates the proportion of cars that pass inspections successfully in order to assess the caliber of inspections performed. Businesses can evaluate their inspection standards and make necessary adjustments to raise the passing rate by monitoring this indicator.

Customer Satisfaction Rating: Knowing how successfully vehicle inspection services live up to client expectations depends on the customer satisfaction rating. Businesses can find areas for development, improve customer service, and foster enduring client loyalty by monitoring this indicator.

Number of Recurring Customers: The quantity of repeat business indicates client loyalty and contentment with the offered inspection services. Businesses can assess client retention rates and overall service quality by monitoring this indicator.

Revenue from Inspection Fees: Tracking the money received from inspection fees is crucial to evaluating the company's financial health. This statistic aids in assessing profitability and guiding well-informed pricing strategy selections.

Number of inspections conducted by each inspector: Businesses may assess the productivity levels and workload distribution of inspectors by keeping track of the number of inspections that each inspector completes. In addition to guaranteeing balanced workloads, it increases inspection performance.

Vehicle inspection companies may create improvements in performance, increase operational effectiveness, and provide consumers with high-quality services by regularly evaluating these key KPIs and measurements(This data is vehicle inspection core 7 KPIs metrics to track and how to calculate taken from Henry Sheykin (2023).

2.3.3. Vehicle Technical Performance inspection operation manual and Standards (2011 E.C.)

This manual is prepared to come up in practice for the directive of 2011 to regulate the vehicle technical inspection service. Therefore, the data's are available in the vehicle technical performance inspection operation manual of (2011 E.C.) prepared by the Federal Transport Authority. This is used to compare the Regulation or directives with the real world findings (from the institutional documents).

No.	Explanation	Measure	Standard
1	Vehicle Size/Total Appearance Not Greater Than	Mm	
1.1	Body Length	M	12.00
1.2	Body Height	M	4.2 With Loading/Without Loading
1.3	Door(Up To 30 Seats)	Quantity	1 For Passenger Right Side
	Greater Than 30 Seats	Quantity	2 For Passenger Right Side
	Size Of Door	Mm	Area 800 Height 1850
1.4	Entrance Step	Mm	At Least 420
	Lower Step From Ground	Mm	250
	Upper Step From The Lower Step	Mm	250
1.5	Body Overhang	Mm	

	Front	Mm	0.21 * Body Length
	Rear	Mm	0.30 * Body Length
1.6	The Space From The Ground Up To 30 Seat	Mm	At Least 250
	Above 30 Seat	Mm	At Least 300
1.7	Starting Angle	Degree	At Least 10
1.8	End Angle	Degree	At Least 12
2	Passengers Walk Space		
2.1	Distance From Floor To Roof	Mm	1900
2.2	All Seats Must Design Forward		
	The Space Between Inline Seats	Mm	700 + 30(Support)
2.3	Walk Way	Mm	350
2.4	Seat Size	Mm*Mm	400*400
2.5	Height Of Seat From Floor	Mm	400
2.6	Vehicle Steering		Right Side

Table 3: Total Standards of Vehicles in Ethiopia **[3]**.

2.3.4. The shortcomings of VCA Technical inspection service

Assurance of Vehicle Competency Like any system or process, technical inspection services could have some flaws that affect how effective and efficient they are. Typical flaws in these services include the following[37][20][26][7]:

Limited Scope: The technical inspection services for automotive competency assurance have a limited scope, which is one of their main drawbacks. These inspections frequently concentrate on particular technical facets of a car's operation or safety, sometimes omitting other important elements that could have an impact on the vehicle's overall competency.

Subjectivity: The possibility of subjectivity in the inspection procedure is a serious problem with these services. Evaluations and outcomes may differ because different inspectors may prioritize different criteria over others or interpret requirements differently.

Inadequate Training: The quality and dependability of the assessments carried out may be jeopardized if inspectors doing these technical inspections are not properly trained or qualified. This may lead to incorrect assessments and omitted shortcomings.

Resource Constraints: Vehicle competency assurance technical inspection services may also suffer greatly from a lack of resources, including personnel and equipment. It's possible that inspectors won't have enough time or access to sophisticated equipment for in-depth analyses. Lack of Transparency: Another issue that may arise is the inspection process's lack of transparency. In the absence of unambiguous communication regarding the evaluation standards, owners of vehicles might not completely comprehend the reasoning behind any conclusions or suggestions given during the inspection.

Complacency and Oversight: As inspection procedures become routine, there's a chance that complacency will set in, causing people to overlook new problems or requirements in vehicle competency assurance.

Financial Considerations: Financial limitations may have an effect on the caliber of technical inspections for vehicle competency assurance. Budget constraints might lead to people taking short cuts or skipping necessary inspections in order to save money.

In order to ensure that vehicle competency assurance technical inspection services meet their intended goals of improving road safety and vehicle performance, it is imperative that these flaws be addressed.

2.3.5. Kinds of enhancement options for VCA Technical inspection service

There are a number of tactical choices that can be taken into consideration in the context of technical inspection services for vehicle competency assurance in order to improve the effectiveness, efficiency, and general quality of the inspection procedure. By ensuring that cars go through extensive inspections, these tactical choices seek to meet safety and legal criteria. Here are a few crucial enhancement choices[7][20]:

Technology Integration: The car inspection process can be completely transformed by embracing cutting-edge technology like artificial intelligence (AI), data analytics, and Internet of Things (IoT) sensors. Putting automated inspection systems in place can decrease human error, speed up inspections, and increase accuracy.

Training and Certification Programs: To maintain high competency levels, inspectors must invest in ongoing training and certification programs. Inspectors' abilities can be improved and consistent quality of inspections can be ensured with regular training sessions on new technologies, laws, and best practices.

Quality Management Systems: Simplifying inspection methods, standardizing practices, and guaranteeing regulatory compliance can all be achieved by putting in place strong QMSs that follow global standards like ISO 9001.

Mechanisms for Customer Engagement and Feedback: Talking with clients and getting their opinions about inspection services might provide insightful information for advancement. Finding areas for improvement can be aided by putting customer satisfaction surveys into place and aggressively soliciting input.

Risk-Based Inspection Approach: This method enables the prioritization of inspections according to the importance of the vehicles or assets. By concentrating attention on high-risk regions, this strategy maximizes resources while enhancing efficiency and safety overall. Cooperation with Regulatory agencies: Establishing reliable alliances with regulatory agencies can help to ensure that industry norms and laws are followed. Close cooperation with authorities guarantees that inspection procedures adhere to industry standards and legislative mandates. Continuous Improvement Initiatives: Establishing a continuous improvement culture within the inspection services company is crucial to maintaining an advantage in a cutthroat industry. Ongoing improvements can be fueled by promoting creativity, asking staff members for suggestions, and carrying out frequent performance evaluations.

Data Management and Reporting Tools: Making use of cutting-edge data management systems and reporting tools can improve transparency, expedite the documentation process, and offer insightful information for making decisions. The ability to report in real-time makes it possible to quickly identify problems and solve them.

as D.M.Li. et al, states that A vehicle competency assurance technical inspection service can improve operations, provide better services, guarantee regulatory compliance, and eventually increase customer happiness by carefully putting these options into practice.

2.4.Concepts on different topics related to the study

2.4.1. Classification Schemes and the Transport Sector

The term "transport" refers to any transportation service provided by motor power carriers on the road, rail, or water, according to the FDRE's "Transport Proclamation No. 468/2005." Throughout the history of human technological evolution, there have been five different types of transportation: air travel, rail, river travel, road travel, and continuous flow systems. There are numerous forms or modes of road transportation, which can be further classified into two primary subcategories: motorized and non-motorized. Pedestrians, carts pulled by humans or animals, wheelbarrows, bicycles, tricycles, draught animals (e.g., horses, donkeys, camels, mules, elephants, etc.) and other hand-drawn vehicles fall within the category of no motorized vehicles[38].

Water transport is separated into local and international (marine) transport modes. Local transport mode includes river, lake, and canal transportation as well as transportation on large dams. The motorized vehicles are divided into freight transport and human transport vehicles. Freight transport vehicles include pickups and trucks, or Lories, with a load capacity of up to 500 quintals. Human transport includes the whole range of vehicles, beginning with bicycles and small cars and extending all the way up to cross-country buses and urban buses.

Transport by sea involves moving people and goods between ports in various nations across seas or oceans. Rail transportation has been a global feature for about 200 years, having begun during the Industrial Revolution in the 1810s and 1820s. There exist numerous varieties of rail transportation. There was a horse-drawn train in the first phase, then a steam-powered train, and finally a street car. The various forms of rail transportation followed, including the standard surface railroad, the metro or subway, the monorail, the guided bus, the trolley bus, etc. There are two types of rail transportation systems: heavy rail transit (HRT) and light rail transit (LRT).

The alternative means of transportation is air travel, which is relatively new and has a modern design. A historical connection exists between the use of balloons for navigation and the

emergence of air transportation. Nevertheless, the Wright Brothers' sequence of tests served as the foundation for the creation of the quickest transportation system in the world. Air travel can be classified as either domestic or international, or as either people or freight transportation, similar to the other forms of transportation mentioned above. Nowadays, the world connects its many regions with the help of airplanes that range in size from the tiniest, which can only hold the pilot, to the largest, which can carry hundreds of people and travel great distances over land and sea.

Lastly, a continuous flow system, which includes belt conveyors, submerged water or petroleum pipes, and slurry pipes, which are specifically used in mines to move soil and minerals that have been mixed with water, is the other way of transportation.

2.4.2. The Current Situation of Road Accidents in Developing Nations

Road traffic accidents are a major public health concern in developing nations because they cause a high number of fatalities and impairments. The following are some salient points about traffic accidents in developing nations[39]:

Road safety measures differ significantly between developing and high-income countries, and children in the former have greater fatality rates. Compared to drivers, who face greater hazards in wealthy countries, pedestrians, passengers, and cyclists are more vulnerable in underdeveloped countries.

Socioeconomic considerations: In developing nations, socioeconomic considerations like income levels frequently have an impact on the form of transportation that is chosen. Higher educated people typically drive own vehicles, whereas individuals with lower education levels are more likely to walk or take public transportation, such as buses or minibuses.

Policy Responses: At the national and international levels, public policy responses to the epidemic of road traffic accidents in developing nations have been comparatively quiet. In order to address this expanding issue, officials must acknowledge that traffic accidents represent a serious public health emergency and put the necessary measures into place.
In conclusion, road traffic accidents are a major problem in developing nations, disproportionately affecting disadvantaged communities and need immediate attention from decision-makers in order to lessen the effects on public health and safety[40][41].

2.4.3. Road Safety and the State of Traffic Accident in Ethiopia

Over 95% of all freight and passenger movement in the nation is handled by road transport. In whatever sector of manufacturing or service delivery, safety is a question that must be prioritized. Regarding this, it has been evident for some time now that the road transport industry is the one with the greatest number of safety issues when it comes to social and economic sectors.

Ethiopia imports 7% of its vehicles annually on average, making vehicles the primary mode of mobility in the nation[42]. Nonetheless, compared to other developing nations, Ethiopia has one of the lowest rates of automobile ownership, and all vehicles must undergo an annual vehicle inspection.

There are several variables that contribute to the high number of road traffic accidents and fatalities in Ethiopia, making road safety and the status of traffic accidents a major concern. Over time, the nation has experienced an increase in traffic accidents, underscoring the critical need for all-encompassing road safety management policies and initiatives[4].

Ethiopia is one of the African nations with the lowest rates of automobile ownership, according to the national vehicle fleet trend. The available yearly inspected and registered national vehicle-fleet data shows that, in the ten years (1994/5-2004/5), the motorization per 10,000 people climbed from 15 to 22, or almost 4% annually. Between 2001/2 and 2004/5, the number of vehicles in use expanded dramatically at a 10% annual pace. The significant growth rate of the vehicle population was mostly caused by the rise in station wagons and trailers. Every year, the quantity of private automobiles has grown by 8%. According to UN-ECA, the vehicle fleet in 2004–05 consisted of 37% private automobiles, 7% station wagons, 9% taxis, 9% buses, 21% small trucks, and 17% trucks and truck-trailers[42].

Ethiopia's car fleet is primarily made up of relatively old cars that have not received proper maintenance, similar to many other developing nations. The age of the nation's car fleet, however, is not supported by any comprehensive factual evidence. As stated in the previous study[42].

According to the "Addis Ababa road safety strategy" for the years 2017 to 2030, Addis Ababa experienced 400 fatalities annually and saw a 25% rise in motor vehicle traffic since 2009.

In conclusion, high rates of traffic fatalities and accidents provide a serious challenge to road safety in Ethiopia. In order to address this problem and make roadways safer for all users, a multifaceted strategy that includes strengthened enforcement tactics, public awareness initiatives, and improved infrastructure is needed.

2.4.4. Car vs. road safety systems

It's important to recognize the different contributions that road safety systems and car safety features make to improving road safety in general. By putting policies in place like sensible speed limits, well-thought-out infrastructure, and awareness programs, road safety systems work to ensure that everyone who uses the roads is safe. The purpose of these devices is to reduce the likelihood of collisions and the degree of injuries sustained in the event that one does occur[43].

However, the purpose of car safety features, especially active safety systems, is to improve the security of each specific vehicle and its occupants. These features include technology such as lane departure warning (LDW), autonomous emergency braking (AEB), electronic stability control (ESC), and anti-lock braking systems (ABS). Active safety systems warn drivers ahead of impending hazards or take action automatically when necessary to avert accidents or lessen their effects[8].

Vehicle safety features prioritize the protection of vehicle occupants and the employment of cutting-edge technologies to prevent crashes[7], while road safety systems provide a safe driving environment and encourage safe behaviors among all road users. Reducing the amount of accidents and fatalities on the roads and enhancing overall road safety depend on both of these factors[4].

2.4.5. A brief overview of vehicle inspection history: worldwide experiences

In history the periodic technical inspections of vehicles were introduced more than fifty years ago in various industrialized /motorized countries such as the UK. Initially, their main purpose was to ensure vehicle maintenance, and mechanical items like brakes and steering were checked. Over the years, the list of items tested has been continually expanded, in particular, to include emissions control, there have also been changes to the rules governing when and how often, and such inspections are carried out [44].

In the UK, a national vehicle inspection test, usually known as the 'MOT test' or the 'Ministry of Transport test', was first introduced in 1960 under the direction of the Minister of Transport. The test was originally relatively basic, involving check of brakes, lights and steering, which was to be carried out after the vehicle was ten years old and every year thereafter. In 1967, the testable age for an MOT was reduced to three years. The list of items tested has been continually expanded over the years. For instance, tire checks were added in 1968, whilst emissions testing for petrol-engine vehicles, braking system, rear wheel bearings, rear wheel steering and rear seat belts were added in 1991. A computerized administration system for issuing non-secure test certificates as well as for reporting annual MOT (roadworthiness) test results was introduced in 2005[44].

Most industrialized nations and some developing countries have national laws creating a framework for I/M (inspection and maintenance) programs. Implementation is typically carried out at the state or city level. Some developing countries have I/M programs with a track record of a decade or more of operation, with some U.S. states operating I/M programs for over 30 years. However, in more countries, such programs do not exist or are just getting underway. Although no country's track record is perfect, I/M programs in developing countries are more likely to suffer from low public awareness; lax enforcement; petty corruption, and a lack of data, funding, and institutional capacity to operate an effective program. This has led some observers to question whether I/M programs are being implemented too early in some countries; and whether other policy options should be given priority[7].

The efforts of Indonesian government in minimizing the incidence of traffic accidents are actualized in the provision of policy about the standard motor vehicles (feasible), which is through motor vehicle testing. This policy is contained in the government regulation number 22, year of 2009 about traffic and transportation then minister of transportation regulation number 133 year of 2015 about periodic motor vehicle testing. According to the regulation 133 year of 2015 motor vehicle testing is series of activities to test and/or examine parts or components of motor vehicle, trailer trains, and train carts.

2.4.6. The goals and operations of the vehicle inspection program.

The main goal of vehicle inspection programs is to guarantee that automobiles on the road adhere to safety and emissions regulations established by national or local governments[26]. By

locating and fixing any risks or flaws in cars that could endanger drivers, passengers, and other road users, these programs seek to improve road safety[4]. Authorities can lessen the possibility of accidents brought on by worn-out tires, malfunctioning lights, or other crucial parts by performing routine inspections[9].among the Functions of Vehicle Inspection Programs are:

Safety Compliance: Ensuring that automobiles adhere to safety standards is one of the main purposes of vehicle inspection programs. Inspections usually encompass components that are necessary for safe operation on public roadways, including as seatbelts, steering systems, tires, brakes, lights, and mirrors.

Emissions Testing: To evaluate how cars affect the environment, emissions' testing is a part of many regions' vehicle inspection programs. The goal of emission monitoring and regulation programs is to lower air pollution and encourage more environmentally friendly transportation methods.

Preventive Maintenance: By seeing possible problems before they become serious ones, vehicle inspections also function as a type of preventive maintenance. Frequent inspections assist owners in quickly addressing small flaws, averting future costly repairs or malfunctions.

Regulatory Compliance: Inspection programs make sure that cars adhere to the law's standards for emissions control and roadworthiness. It is frequently required to abide by these rules in order to register a car, renew a license, or transfer ownership.

Public Safety: Maintaining public safety on the roadways is ultimately the main goal of vehicle inspection programs. Authorities seek to lower the number of collisions, injuries, and fatalities related to vehicle faults or violations of safety laws by enforcing standards through inspections[9][41][4].

2.4.7. The fundamentals and recommended procedures for Technical Vehicle Inspection

A technical vehicle inspection is a thorough assessment of the mechanical and technical aspects of a car to make sure it is safe, operational, and compliant with laws and regulations. These checks are essential for preserving traffic safety and averting mishaps brought on by malfunctioning machinery. The following crucial elements are usually included in the foundations of technical vehicle inspections[7][12]:

Inspection Checklist: Inspectors utilize a comprehensive checklist to methodically evaluate different vehicle components. Important topics like engine performance, exhaust system, steering, suspension, tires, brakes, lights, and overall structural integrity are covered in this checklist.

Testing Procedures: To assess the performance of vital systems like pollution control and brakes, inspectors carry out particular tests. Brake testing might include examining the emergency brake function, brake fluid levels, rotor condition, and brake pad thickness. Testing for emissions guarantees that the car satisfies environmental requirements specified by law enforcement.

Diagnostic Tools: To complete comprehensive evaluations of electronic systems, engine performance, and onboard computer diagnostics, inspectors use diagnostic tools and equipment. With the aid of these instruments, possible problems that might not be apparent on visual inspection can be found.

Compliance Verification: Inspectors confirm that the car satisfies local authorities' specified safety and pollution criteria. If these rules are broken, an inspection may be unsuccessful and corrective action may be necessary before the evaluation is conducted again.

Record-keeping: For future reference, a thorough record of the test results, inspection findings, necessary repairs, and overall assessment is kept. This paperwork acts as a record of the state of the car when it was inspected.

In conclusion, Both car owners and inspectors may help improve road safety and guarantee that vehicles are in the best possible condition for operation by adhering to these principles and the suggested processes for technical vehicle inspections.

2.4.8. Technical vehicle inspection protocols in Ethiopia

In Ethiopia, vehicle owners are obliged to provide the vehicle in person and undergo a technical inspection when they go to the office for service. Imported vehicles and vehicles which undergo body changes have to also pass through mandatory technical inspections before they are licensed to operate on the road[31].

All areas are now required to adhere to the updated technical inspection system, which has been tightened and reviewed by the Federal Transport Authority. The yearly technical vehicle

examination and strengthening and concentrating on the controlling tasks can now are contracted out by the transport agencies based on the new procedure. Since 2005, the revised protocol has been in place. This means that private companies handle around 90% of the country's yearly car inspections[5]. Private companies conducting yearly inspections with a detailed assessment of sample evaluated vehicles are abruptly inspected by transportation officials. Each month, these organizations provide them with comprehensive reports. However, the vehicle competency authentication (VCA) and vehicle on spot checking Technical inspections are not outsourced; they are operating by government itself through DVLCA[31].

The Addis Ababa City Administration has been working to reorganize the transport bureau and to make vehicle and driver service delivery highly efficient. Thus, Addis Ababa City Government executive and municipal service organs Re-establishment Proclamation No. 35/2012 and Re-amendment Proclamation No. 43/2014, the city government has newly organized the Driver and Vehicle Licensing and Control Authority (DVLCA), which has 11 branches in each sub-city. Above 70% of vehicles in Ethiopia are registered in Addis Ababa City (DVLCA).

The powers and functions of DVLCA are mentioned below.

- Vehicle Registration
- Perform vehicle technical inspection and issues a specification.
- Perform annual inspections of vehicles by itself or through a legally delegated body.
- Take appropriate measures against drivers who violate transport regulations and laws.
- Issue and renew the driving proficiency license.
- Issue competency licenses to and make the necessary controls on individuals or organizations involved in transport services, driver training service institutions, and garage service.
- Issue working licenses and control organizations offering training on driving motorized vehicles; take appropriate corrective measures in case inappropriate functions are performed[31].

The services performed by the vehicle competency authentication (VCA) sector are detailed as follows:

- Technical inspection of the new motor vehicle for registration
- Technical inspection of motor vehicles for change service type.
- Technical inspection service for body changes of motor vehicles.
- Technical inspection of motor vehicle transferred from regions to AA.
- Technical inspection service for chassis changes of a motor vehicle.
- Technical inspection service for Motor changes of motor vehicle.
- Technical inspection of vehicles purchased at an auction.
- Technical inspections of vehicles for specification correction[31]

2.4.9. Ethiopia's vehicle inspection policies, laws, and administrative framework

In Ethiopia, the regulation of motor vehicles is governed by various policies, laws, and administrative frameworks to ensure road safety and compliance with standards. The country has established specific rules and regulations related to vehicle inspections to maintain the safety and roadworthiness of vehicles operating on its roads[17][4].

Legal Framework: Ethiopia has passed laws and rules requiring routine car inspections to evaluate vehicles' conditions and make sure they adhere to safety requirements. The formation of private vehicle inspection centers, which are in charge of carrying out these inspections is provided for under the legal framework.

Vehicle Inspection Centers: In Ethiopia, private vehicle inspection centers are essential to the execution of required vehicle inspections. These centers have the facilities and trained staff needed to thoroughly check cars and assess their roadworthiness.

Compliance and Enforcement: The Ethiopian government emphasizes compliance with vehicle inspection requirements to enhance road safety. Strict enforcement measures are in place to penalize non-compliance and malpractices at inspection centers.

Road Safety Measures: In addition to vehicle inspections, Ethiopia implements various road safety measures such as speed limitations, roadside signals, traffic rules enforcement, use of safety equipment like helmets and seat belts, and infrastructure improvements to reduce accidents and ensure safe transportation.

Challenges and Improvements: Ethiopia's vehicle inspection policies can be made more effective by continuing to improve their monitoring mechanisms, providing inspectors with training, and launching public awareness campaigns. However, issues like corruption, a lack of oversight, and uneven implementation may still make the system ineffective.

In general, Ethiopia's laws, policies, and administrative framework around vehicle inspections are designed to increase road safety, lower accident rates, and ensure that vehicles meet required standards through regular inspections by having authorized centers do routine inspections.

As stated in its Vision, the Addis Ababa City Transport Policy seeks "to see the transport service accessible to all and play a major role in the development of the city."

The main goal of the Addis Ababa City transport Policy is[49]:

- To give city people access to a dependable, economical, comfortable, safe, and efficient transport system.
- To empower the industry to support socioeconomic growth, sound governance, better people's quality of life, and environmental preservation in the city;
- To elevate the city's standing as a global hub by instituting smooth traffic flow via an advanced traffic management system.

2.4.9.1.Organizations and Frameworks

The Addis Ababa Driver and Vehicle License and Control Authority (AA-DVLCA) is responsible for regulating and overseeing driver licensing, vehicle registration, and control of transportation activities in Addis Ababa, Ethiopia. The authority plays a crucial role in ensuring road safety, compliance with regulations, and efficient management of the city’s transportation system[6].

Organizational Structure: In order to efficiently perform its duties, the AA-DVLCA is normally organized into a number of departments and units. The following are a few important departments under the authority[50][28]:

The licensing department: is in charge of granting licenses, administering driving examinations, and making sure drivers fulfill the prerequisites.

Department of Vehicle Registration: oversees the issuing of vehicle identifying documents, the registration of automobiles, and the upkeep of vehicle records.

Enforcement Unit: Charged for keeping the roads orderly by enforcing traffic regulations, carrying out inspections, and punishing offenders.

Administrative Division: Manages the division's general coordination of operations as well as administrative duties include maintaining records and providing customer service.

Framework: The framework within which the AA-DVLCA operates is guided by national laws, regulations, and policies related to transportation and road safety. Some key aspects of the framework may include[28][6]:

Law: The authority is governed by a set of laws that specify its functions, authority, and authority with regard to driver licensing, car registration, and traffic management.

Regulations: The authority's operations are governed by comprehensive regulations that cover a range of topics, such as the requirements for vehicle inspections, standards for license issuance, and sanctions for noncompliance.

Technology Integration: Incorporating technology into modern frameworks is common. Examples include automated traffic cameras, online services for vehicle registration or license renewal, and effective data management.

Collaboration: To improve road safety measures and expedite transport procedures, the AA-DVLCA may work with other governmental organizations, law enforcement agencies, transport groups, and others.

In conclusion, the organizational structure and framework of the Addis Ababa Driver and Vehicle License and Control Authority is designed to ensure effective regulation of drivers and vehicles in the city while promoting safety on the roads.

2.5.Gap discussion in studies

According to numerous studies, there are weaknesses in the practices and protocols used today in the technical inspection services sector for vehicle competency assurance. Several themes appear in numerous researches, despite the fact that these variations may vary from nation to nation.
Need for Standardized Protocols: Several studies point out that different nations and areas do not have standardized protocols. Variations in inspection quality and vehicle safety consequences may result from this inconsistency. To guarantee consistency in vehicle inspections, researchers propose creating worldwide rules that may be embraced by all (Gustafsson et al., 2021).
Training and Certification of inspectors: Another significant gap highlighted in studies is related to the training and certification of inspectors. Effective vehicle inspections depend heavily on the skill of the inspectors. Numerous studies do, however, point to a dearth of thorough training and certification programs. The precision and dependability of inspections can be increased by developing certification requirements and strengthening inspector training (Martinez et al., 2020).Ensuring that inspectors are adequately trained, certified, and regularly updated on new technologies and inspection techniques is crucial for maintaining the integrity of the inspection process. However, some studies have found deficiencies in the training programs available for inspectors, leading to gaps in competency[14].

Integration of Advanced technologies: The inspection process does not fully integrate cutting-edge technology like artificial intelligence (AI) and the Internet of things (IoT). Although these technologies have been studied in some depth, there is still little use for them in real-world scenarios. Future studies ought to concentrate on how these technologies are used and how effective they are in practical situations (Chen et al., 2019).As vehicle technology advances; it is becoming more and more necessary to include new technologies into the inspection procedure. Research has identified shortcomings in the car inspection industry's use of technology, including data analytics, computerized systems, and diagnostic instruments. It is imperative to bridge this technological divide in order to improve inspection efficiency and accuracy[8].

Impact Assessment of Inspections: Little is known about how vehicle inspections affect environmental and traffic safety in the long run. In order to determine the advantages of inspection programs and identify areas that require development, studies should evaluate their efficacy over extended time periods (Lee et al., 2022). On the other hand maintaining consistent

quality assurance practices is vital for ensuring the reliability of inspection results. Some studies have identified gaps in quality assurance processes, including lack of standardized procedures, inadequate monitoring of inspector performance, and insufficient feedback mechanisms. Addressing these gaps is crucial for upholding the credibility of technical inspection services[51].

User Perception and Compliance: Research frequently ignores how car owners feel about the inspection procedure and whether they follow the advice. Creating more efficient inspection programs and raising compliance rates can be facilitated by having a better understanding of user attitudes and behavior (Johnson et al., 2018).similarly, Technical inspection services must include top-notch customer service. Research has revealed deficiencies in customer service facets include openness in the inspection procedure, correspondence with car owners, and resolution of grievances or evaluations. Increasing client happiness and trust in the inspection service provider are two benefits of improving customer service[5].

The methods and procedures used to guarantee the safety, dependability, and regulatory compliance of cars are referred to as vehicle competence assurance technical inspection service procedures[13]. These protocols are necessary to guarantee the safety of drivers, passengers, and other road users as well as the operational integrity of vehicles[52]. A variety of tasks are covered by the technical inspection service methods, such as maintenance inspections, vehicle testing, and compliance evaluations[12]. To guarantee the safety and roadworthiness of cars, the vehicle inspection, sometimes referred to as the vehicle competency assurance technical inspection service, is a crucial procedure. But it has its own flaws, just like any other system[7]. Among the main flaws in technical inspection services for vehicle competency assurance are the following. Inconsistency in standards and enforcement, limited scope of inspection, lack of real-world performance assessment, resource constraints, emerging technology challenges, impact on older vehicles[8].

The role of technology provides substantial benefits for both firms and users. Even if, the existence of technology can raise customers concerns of privacy, confidentiality and the acceptance of unsolicited communications[53].These aspects of technology cause users to be wary of new technological applications. However, this study focuses on implementation of technology for service enhancement[53].this study points out that, enhancing service and

insufficient service capacity are inversely proportional, because when we enhance service accompanying cost will increase, when we provide insufficient service capacity the users waiting time will increase. Thus, a balance between service costs and customer waiting time must be considered.

Driver and vehicle standards Agency Business Plan(Britain), MOTs for cars, vans and motorcycles service, Delivers heavy vehicle testing service to vehicle operators in partnership with authorized testing facilities(ATF) working together in service improvement is the core focus across all their works. And in commercial vehicle service a key enabler to improve their commercial vehicles services is the transformation of their digital services, they will deliver a flexible digital platform to support their vehicle testing services that will enhance user experience, provide cleaner real-time test data together with enabling a future range of online service to their customers[3].this tells us, they implement flexible digital platform in their vehicle testing services or vehicle competency assurance services to enhance service, and they use authorized testing facilities(ATF) in service improvement. This is performed based on the users need. As discussed in the[36].

Motor vehicle registration system was designed in India to capture vehicle details for registration and more importantly capture number plate of vehicles using cameras. The captured image is then used to retrieve information about the vehicle using the character segmentation technique implemented by the optical character recognition (OCR) algorithm. The main challenge of this system is that, it does not have a trail record of unauthorized modification of vehicle particulars. Anyone with access credentials can log in and change vehicle particulars undetected without consent from the vehicle owner [45].

Another system was developed in Nigeria to aid in registration of motor vehicles. The system has a mobile-phone based interface which allows a customer to carry out registration using a mobile device and the registration details are stored directly in to the state board of internal revenue (SBIR) database. The web server serves as the point of entry to the website and any backend system that it might interface with. Vehicle owners or customers are able to supply their data and registration details at convenience provided they have internet access. At the end of a completed registration, a unique pin will be generated and will serve as the only authority that can allow easy access to the customer’s account as well as an authorized administrator. The main challenge

with this system is that it is limited to only vehicle registration and therefore cannot scale to vehicle transfers that involve change of vehicle ownership and confirmation of ownership transfer [46].

In Kenya, vehicle registration is done by the National Transport and Safety Authority (NTSA). There is the option of registering as an individual, dealer, agent, financial institution or company. The service offered include car registration, transfer of car ownership, change of particulars, duplicate logbook application, reflective number plate application, vehicle inspection and online car search. The main challenge is that the system can be highly tampered by unauthorized users and vehicle ownership details transferred to an unauthorized owner for malicious gain with the system not being able to record the fraudulent transactions[47][48].

The following might be used to summarize the topic of the shortcomings in the procedures and techniques utilized by the technical inspection services industry to ensure vehicle competency:
Uniform Protocols are Necessary: Variations in inspection quality and possible safety risks for vehicles result from a notable deficiency of uniform inspection protocols among various countries and areas. For inspection procedures to be consistent and reliable, it is imperative that global standards for vehicle inspections be established (Gustafsson et al., 2021). Training and Inspector Certification: Inspector skill and training play a major role in the effectiveness of vehicle inspections. On the other hand, inspector certification and thorough training programs are conspicuously lacking. For vehicle inspections to be more accurate and reliable, strong training and certification requirements must be established (Martinez et al., 2020).
The current methods of car inspections do not make full use of cutting-edge technologies like artificial intelligence and the Internet of things. Chin et al. (2019) suggest that in order to enhance efficiency and accuracy, future research ought to concentrate on incorporating these technologies into real inspection scenarios.
The evaluation of the inspections' influence on traffic and environmental safety has not received much attention. To find opportunities for improvement, thorough research is required to evaluate inspection programs' efficacy over long stretches of time (Lee et al., 2022).
The attitudes and behaviors of car owners towards the inspection process are frequently disregarded in the context of user perception and compliance. Johnson et al. (2018) suggest that

comprehending user views can aid in creating inspection programs that are more successful and raise compliance rates.

Quality Assurance Procedures: It's critical to keep constant quality assurance in inspection procedures. The deficiencies that have been found include non-standard operating processes, insufficient inspector performance monitoring, and inadequate feedback channels. For technical inspection services to maintain their credibility, these shortcomings must be filled (51).

Customer service: Technical inspection services must provide excellent customer service. Studies reveal shortcomings in areas of customer service include grievance management, communication, and transparency. Increasing client satisfaction and confidence in inspection service providers can be achieved through better customer service (5).

Vehicle Competence Assurance: To guarantee the safety, dependability, and regulatory compliance of vehicles, technical inspection services are vital. These services do, however, have limitations due to limited resources, inconsistent standards, and scope.

Technology in Service Enhancement: While technology can help services, privacy issues are brought up by it. Costs associated with improving services may rise, so it's important to strike a balance between them and client wait times.

Digital Transformation in Vehicle Services: By implementing a versatile digital platform, the Driver and Vehicle Standards Agency in the United Kingdom is upgrading its offerings, resulting in an improved user experience and real-time data accuracy.

Vehicle Registration Systems:

India: Captures vehicle details using optical character recognition (OCR) technology; nevertheless, the system is susceptible to unapproved changes.

Nigeria: A mobile phone-based registration interface that is restricted to registration duties and stores data in the SBIR database.

Kenya: Provides extensive services but struggles with fraudulent transactions and illegal manipulation.

Overall, the discussion emphasizes that in order to address the shortcomings in the technical inspection services sector for vehicle competency assurance, better customer service, enhanced quality assurance practices, comprehensive impact assessments, improved inspector training, and

integration of cutting-edge technologies are required. And also draw attention to the work and difficulties involved in guaranteeing vehicle safety and enhancing service effectiveness through technology developments.

Conceptual framework

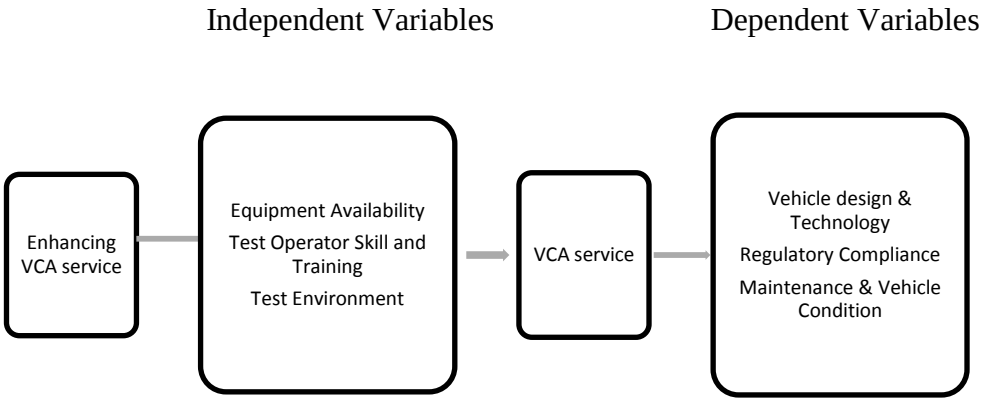


Figure (1): Conceptual framework of the study

Chapter Three

3. Research Methodology and material

3.1. Introduction

For this study, the researcher used a mixed-methods strategy. The quantitative and qualitative strategies are ones that entail gathering and evaluating data for a single study. In essence, this is an approach that involves gathering and evaluating both types of data. For the purpose of better understanding the study problem, it uses inquiry methodologies that entail gathering data concurrently or sequentially. Qualitative research is a humanistic research paradigm that centers around people as the primary focus of investigation and in-depth social phenomena[11].

Vehicle competency assurance service enhancement requires a systematic research approach that integrates various methodologies and tools. This approach involves understanding the complexities of vehicle systems, identifying key performance indicators, and simulating different scenarios to optimize competency assurance service. In this comprehensive research approach, several key steps need to be considered to ensure the service enhancement for vehicle competency assurance. This encompasses data collection and analysis, model development, scenario analysis, optimization, validation, sensitivity analysis, and implementation planning.

3.2. Research Design

To put it simply, a research design is the plan or framework for a study that serves as a guide for gathering and interpreting data. It is a process that is followed to finish a study. The blueprint for data collecting, measurement, and analysis is known as the research design. Actually, it's a map that's typically created to direct the investigation[57].

A mixed-methods research design combines both quantitative and qualitative research methods to provide a more comprehensive understanding of the research problem. This design is particularly useful in complex and dynamic contexts, such as vehicle competency assurance in Addis Ababa, where multiple factors and perspectives need to be considered.

A mixed-methods research design would be most appropriate in order to comprehend the technical inspection services concerns related to automotive competency assurance in Addis

Ababa DVLCA bole branch office. This strategy integrates techniques for gathering and analyzing data that are both quantitative and qualitative[57][4].

On the quantitative side, surveys could be administered to gather data on various aspects of the vehicle inspection process. These surveys could be distributed among vehicle owners, mechanics, and inspection station staff. The survey questions would aim to collect data on factors such as[4]:

1) The frequency of inspections
2) Inspection station wait times
3) Inspection-related expenses
4) The perception of inspection fairness
5) Failure rates of vehicles both before and after inspections
6) The degree of satisfaction with the inspection procedure

Focus groups and in-depth interviews with a range of stakeholders, such as car owners, mechanics, and employees of inspection stations, could be carried out in order to gather qualitative data. Richer, more nuanced insights into the perspectives and experiences of the many stakeholders surrounding the inspection process would be possible using these methodologies. They could assist in determining the root causes of problems, investigating viable fixes, and giving the quantitative data context[58].

Furthermore, observational studies of the inspection procedure at different stations may offer insightful information about the efficacy and efficiency of the inspections themselves. Analyzing the kinds and frequency of vehicle malfunctions found during inspections, as well as the time and materials needed to finish each inspection, could be part of this.

Through the integration of diverse methodologies, a mixed-methods research design will facilitate a thorough comprehension of the technical inspection services issues related to vehicle competency assurance in AA- DVLCA bole branch office. It would enable a more thorough and in-depth investigation of the problem by providing both quantitative data and rich qualitative insights.

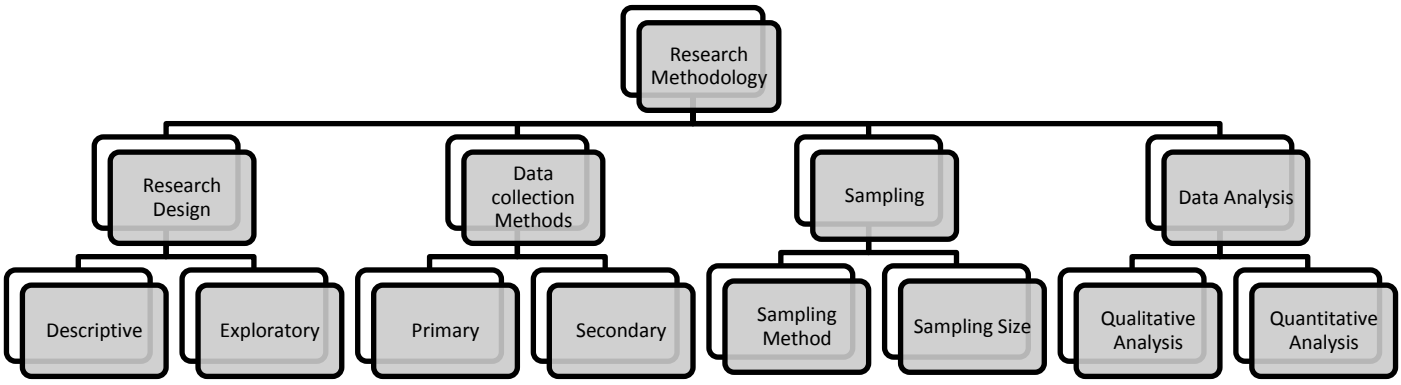


Figure (2): Research design framework

3.3. Study area

The study area is the Addis Ababa city administration DVLCA bole branch office on vehicle competency assurance service**.** Therefore, it is suitable for the study by its location, transport availability, wide number of customers. Therefore, by the cumulative result of these reasons bole branch office has been preferred for the study.

3.4. Data source

A thorough data source that can offer insights into the many facets of the service is crucial to comprehending the issues with the technical inspection service for automotive competency assurance in Addis Ababa DVLCA. Government reports and data on car inspections and road safety in Addis Ababa DVLCA would be among the best sources of information for this. These reports frequently include comprehensive data on the performance of technical inspection services, such as information on compliance rates, the kinds of infractions found, the difficulties inspectors encountered, and the inspection process' overall efficacy.

Insights into the particular problems influencing the competency assurance process can also be gained from surveys and studies on road safety and vehicle inspections in AA- DVLCA that are carried out by independent research organizations or academic institutions. These studies could bring to light prevalent issues including a deficiency of qualified staff, inadequate tools, corruption, or inefficiencies in the inspection processes[4].

Additionally, firsthand accounts of the difficulties encountered by the system can be obtained through interviews with stakeholders involved in the vehicle competency assurance technical inspection service, including government officials in charge of oversight, inspectors carrying out the inspections, vehicle owners going through the process, and representatives from pertinent industry associations. Systemic problems, operational bottlenecks, and possible areas for improvement can all be found with the aid of these interviews.

A thorough grasp of the issues with vehicle competency assurance technical inspection service in Addis Ababa can be attained by combining various data sources, which include government reports and statistics, surveys and studies, and stakeholder interviews. This multifaceted strategy guarantees a comprehensive examination of the pertinent issues and helps make well-informed decisions to raise the caliber and efficacy of the inspection procedure.

3.5. Sampling techniques

It is essential to use an appropriate data collection sample technique in order to examine the vehicle competency assurance technical inspection service at the Addis Ababa Driver and Vehicle License and Control Authority Bole Branch Office. The quality and dependability of the study's conclusions will be critically impacted by the sampling strategy selected.

A combination of these sampling strategies may be used to examine the technical inspection services for vehicle competency assurance at the Addis Ababa Driver and Vehicle License and Control Authority Bole Branch Office. This will guarantee thorough coverage while preserving data collection efficiency.

Random sampling: is a technique in which each person in the population has an equal probability of being chosen for the research. By using this technique, bias is lessened and the sample is guaranteed to be representative of the total population. Vehicles from the pool of those slated for inspection at the Bole Branch Office at a given time could be chosen at random by researchers.

Data Collection Techniques to answer each Research Question (RQ).

No	RQ	Data source	Data type	instrument
1	Assessing procedure	Internal documents, customers, on service	Qualitative	observations, Extraction
2	Sorting out variables	Feedback from inspectors and vehicle owners, service process	Quantitative and qualitative	Structured survey questionnaire, direct observation during testing sessions, Interview, discussion
3	Assessing Manuals and standards	Institutional document	Qualitative	extracting
4	Identify drawbacks	Feedback from inspectors and vehicle owners, service process	Qualitative and quantitative data	Structured survey questionnaire, direct observation during testing sessions. Interview, discussion
5	How can simulation models be developed	Site observation, service process observation	Quantitative data	Simulation software
6	Required Enhancement ways	Government databases, stakeholder, surveys and studies	Quantitative and qualitative	Thematic analysis, simulation model

Table 4: data collection technique of the study

3.6. Population and sample size determination (statistical scientific method)

3.6.1. Population:

The target population needs to be precisely identified in order to create enhancement for a technical testing service for vehicle competency assurance at Addis Ababa Driver and Vehicle License and Control Authority. People who are directly involved in the licensing, testing, and control of vehicles within the authority should make up the target population. Among them are:

Drivers: The primary target population should be drivers who are applying for or renewing their driver's licenses. These individuals are directly impacted by the competency assurance testing services provided by the authority.

Vehicle Owners: Another important segment of the target population is vehicle owners who need to ensure that their vehicles meet the required technical standards set by the authority.

Testing Personnel: The staff members responsible for conducting the technical testing should also be considered part of the target population. Their input and feedback are crucial in developing effective strategic options for improving the testing services.

Regulatory Authorities: Representatives from regulatory bodies or government agencies overseeing transportation and road safety regulations should also be included in the target population. Their insights can help align the strategic options with existing regulations and standards.

Stakeholders: It is essential to involve stakeholders such as road safety advocacy groups, insurance companies, and other relevant organizations that have a vested interest in ensuring the competency of drivers and vehicles on the road.

3.6.2. Sampling size determination

In theory, a census research may yield precise information about a specific population. However, it is frequently not feasible to serve the entire population due to time and financial constraints. Accordingly, sampling is one of the techniques that enable the researcher to examine a comparatively small number of units that are representative of the entire population.

48 active bole branch office customers in the vehicle sector will be chosen from a total of 54 (data from the focus group discussion). The researcher employed the widely recognized taro Yamane's sample size determination formula[59], as Chanuan, et.al. Conclude that, sample size determination of Yamane is suitable for survey research, which is displayed below, to determine the sample.

$$n = \frac{N}{1+Ne^2}$$

$$n = \frac{54}{1+54(0.05)^2} = 48$$

Where:

n = sample size

N = population size

E = margin of error or maximum tolerance error (0.05) %

3.7. Data collection methods:

1. Surveys: Surveys can be conducted among drivers, vehicle owners, and testing personnel to gather information on their experiences with the current testing process and their suggestions for improvement.

2. Interviews: Interviews can be conducted with experts in the field of vehicle testing and driver competency assurance to gather insights on the latest trends and best practices.

3. Observation: To pinpoint problem areas and acquire information on test duration, resource utilization, and results attained, observations of the present testing procedure can be conducted.
4. Data Extraction: Information for vehicle testing and driver licensing can be taken out of databases and systems that are currently in use by the Addis Ababa driver and vehicle license control authority.

3.8. Data analysis tools

A mixture of different data analysis tools can be used to investigate the vehicle competency assurance technical inspection service at the Addis Ababa Driver and Vehicle License and Control Authority Bole Branch Office. Examining the effectiveness, precision, and general functioning of the technical inspection procedure can be aided by these instruments. The following tools for data analysis are suggested:

Microsoft Excel: Excel is a user-friendly, widely-accessible, and versatile program. Basic data analysis operations like sorting, filtering, and producing graphs and charts can be accomplished using it. Excel is very helpful for basic computations and preliminary data investigation.

Simulation Software: Software such as Arena can be used to conduct discrete event simulation of the vehicle testing process. This can help in evaluating different scenarios for improving efficiency, reducing costs, and enhancing quality. In the study of Navin Gupta & Edwards J. Williams, they addressed that simulation improves service and profitability of an automobile service garage. The simulation model was built using Arena, a well-known and versatile simulation software package used at both Wayne state University and the University of Michigan-Dearborn for the teaching and practice of discrete-event simulation modeling. This model routinely used standard Arena® modules such as Create (customers' vehicles enter the

system), Dispose (customers' vehicles leave the system), Process (vehicles undergo evaluation, repair, or inspection), or Assignment (attributes such as type of repair, cost of repair, and duration of repair are assigned to a vehicle)[54][60][8].

3.9. Data analysis methods:

Thematic data analysis: is a qualitative data analysis technique that entails going through a dataset—such as focus group or interview transcripts—to find themes and discern patterns in the meaning of the data. Making meaning of the data is an active process that necessitates reflexivity, and it heavily relies on the researcher's subjective experience. A flexible approach that is appropriate for rookie researchers and those unfamiliar with qualitative analysis is thematic analysis, which enables researchers to derive new concepts and insights from the data. The procedure entails generating initial codes, compiling codes with corroborating information, and organizing codes into themes, examining and modifying themes, and ultimately crafting a narrative that narrates the data's tale[61].

Simulation: The vehicle testing procedure can be modeled using discrete event simulation, which can also be utilized to assess various scenarios for raising quality, reducing costs, and increasing efficiency[5][62][18][4].

3.10. Reliability and validity

To ensure the correctness and credibility of the findings, it is imperative to ensure the reliability and validity of the research when formulating strategic choices for the Addis Ababa Driver and Vehicle License and Control Authority's technical inspection service for vehicle competency assurance. Validity concerns how well the research actually measures what it is supposed to assess, whereas reliability deals with the consistency and stability of the research findings[4].

Reliability: In order to guarantee that the outcomes of research are consistent and repeatable, reliability is crucial. Researchers must use trustworthy techniques and protocols to collect data while creating strategic alternatives for technical inspection services for automotive competency assurance. When numerous researchers are involved in data collecting or analysis, this entails utilizing standardized tools, performing pilot studies, and guaranteeing inter-rater reliability.

To enhance reliability, researchers should also consider factors such as sample size, sampling techniques, data collection methods, and statistical analyses. By addressing these aspects meticulously, researchers can increase the reliability of their findings and ensure that they accurately reflect the phenomenon under investigation.

Validity: The degree to which a study measures what it purports to measure is known as validity, and it is another crucial component of research. Assuring the validity of the research in the context of creating strategic choices for technical inspection services for automotive competency assurance entails employing the right measuring tools, doing extensive literature evaluations, and matching research goals with data gathering techniques.

Internal validity, or the degree to which causal conclusions may be taken from the study, and external validity, or the applicability of the findings outside of the particular setting, are critical concepts for researchers to focus on. Researchers can improve the reliability and validity of their findings by tackling issues like measurement mistakes, confounding variables, and selection bias.

3.11. Data quality management

Adopting strong data quality management procedures is essential to guaranteeing the efficiency and dependability of the technical inspection service for vehicle competency assurance at the Addis Ababa Driver and Vehicle License and Control Authority Bole Branch Office. Here are some crucial actions that need to be performed[63]:

3.11.1. Data Collection:

- Clearly define the rules and procedures that must be followed in order to gather information on car inspections.
- Throughout the inspection process, make sure that all pertinent data is precisely and fully recorded.
- To avoid mistakes at the data entering stage, apply validation checks.
- Make regular data backups to guard against loss in the event of a system breakdown.

3.11.2. Data Storage:

- To save inspection data, make use of dependable, safe databases. Put access restrictions in place to guarantee that the data can only be viewed or altered by authorized persons. 3. Data Cleaning:
- Identify and fix any flaws or inconsistencies by periodically reviewing the data that has been gathered.
- Use automated tools or algorithms to help with the effective cleaning of massive datasets
- Standardize values and formats to increase uniformity amongst records.

3.11.3. Data Integration:

- To obtain a comprehensive view of each vehicle's inspection history, integrate data from various sources, such as historical inspection records or vehicle registration databases.
- Ensure that the integrated data is accurate and up-to-date by conducting regular synchronization processes.

3.11.4. Data Analysis:

- Employ advanced analytics tools to analyze inspection data and spot trends or patterns that might point to areas in need of improvement.
- Create dashboards or reports to share important findings with authority decision-makers.

3.11.5. Data Security:

- Implement encryption mechanisms to safeguard sensitive information obtained during inspections.
- Conduct frequent security audits to uncover vulnerabilities and address them promptly.
- Train personnel on best practices for handling confidential data securely.

The researcher may improve the precision, dependability, and utility of technical inspection service for vehicle competency assurance in AA-DVLCA Bole Branch Office by adhering to these data quality management standards.

3.12. Ethical consideration of the research

As with any research project, ethical issues are critical, particularly when creating alternatives for a public service such as technical testing for automotive competency certification. Several

ethical issues need to be taken into account in the context of the Addis Ababa Driver and Vehicle License and Control Authority[5][64]:

Informed consent: Individuals providing data or participating in the testing service should be aware of how their information will be used and protected. Researchers must make sure that all participants in the study are fully informed about the purpose of the research, their role in it, and any potential risks or benefits associated with their participation.

Privacy and confidentiality: Protecting participant privacy and confidentiality is crucial. Researchers should put safeguards in place to protect sensitive data that they gather so that it can't be accessed or disclosed by unauthorized parties.

Fairness and equity: All people should have equal opportunities to engage in the research, free from discrimination based on criteria like gender, color, or socioeconomic status, and it should be carried out in a fair and impartial manner.

Minimization of harm: To reduce any possible harm that the study may cause, researchers should take appropriate action. This involves making certain that there are no needless risks for participants to take and that there is little to no discomfort or annoyance.

Compliance with regulations: Respecting all applicable laws, rules, and moral principles that control research endeavors in the particular setting of Addis Ababa is imperative. This includes obtaining necessary approvals from institutional review boards or ethics committees.

Transparency: Throughout the research process, researchers should be transparent by accurately disclosing their techniques, findings, and any potential conflicts of interest.

Accountability: In order to maintain ethical standards at all times, researchers should be accountable for their actions and decisions during the study process.

3.13. Result dissemination mechanism

It is imperative to use a thorough and focused approach when sharing the findings of a case study that used discrete event simulation to develop strategic options for vehicle competency assurance service within the Addis Ababa Driver and Vehicle License and Control Authority. To optimize

the impact of the study's conclusions and suggestions, the dissemination method should target important stakeholders, decision-makers, subject-matter experts, and the general public[54].

Executive Summary: The communication process should start with a succinct yet educational executive summary that outlines the main goals of the research, the methodology used, the significant conclusions, and the suggested strategic solutions. For occupied stakeholders who might not have time to read the complete report, this summary need to be easily available and offer an overview of the entire case study.

Comprehensive Report: It is necessary to provide a comprehensive report that describes the full process of creating strategic choices for vehicle competency assurance service using discrete event simulation. In-depth explanations of the methodology, data sources, analysis methods, outcomes, and policy and practice implications should all be included in this study. It must be thorough enough to act as a resource for anyone looking to learn more about a deeper understanding of the study.

Stakeholder Workshops: Setting up stakeholder workshops is a useful strategy for getting the case study's findings in front of the appropriate people. These workshops can offer an engaging forum for outlining important discoveries, talking about ramifications, getting input, and encouraging cooperation among interested parties in order to put the chosen strategic choices into action.

Policy briefs: Condensing complicated information into manageable suggestions for legislators and government representatives can be accomplished by creating succinct policy papers based on the case study's results. The policy implications derived from the study should be specifically outlined in these briefings, together with concrete recommendations for improving Addis Ababa's vehicle competency assurance services[11].

Digital Platforms: Making use of online forums, social media accounts, and websites can increase the dissemination activities' reach. Posting case study-related summaries, info graphics, videos, or interactive tools can expand the audience and encourage interaction with a variety of stakeholders both domestically and internationally.

Academic Publications: Research findings from case studies can be validated and disseminated to a scholarly audience by publishing them in respected academic publications. Scholarly publications have the potential to foster information exchange within academic communities and encourage additional study on related subjects.

Press Releases and Media Coverage: You may help educate the public about the significance of automotive competency assurance services in Addis Ababa by distributing press releases that highlight important findings from the case study and interacting with media outlets for coverage. Media attention can also spark conversations about enhancing traffic safety protocols and pique the interest of a wider audience.

Feedback Mechanisms: Stakeholders can offer feedback on the findings and suggestions of the case study by setting up feedback mechanisms like questionnaires, feedback forms, or special email addresses. Receiving feedback can aid in improving implementation strategies and guaranteeing that the opinions of stakeholders are taken into consideration.

Industry Partner Collaboration: Working with industry partners that provide vehicle competency assurance services can help exchange best practices, foster information exchange, and get industry support for putting the case study's recommended strategic choices into action. Interacting with trade associations or businesses in this field can improve outreach initiatives in pertinent professional communities[15].

The disclosure mechanism for a case study on creating strategic options for vehicle competency assurance service through discrete event simulation in Addis Ababa Driver and Vehicle License and Control Authority can effectively reach diverse audiences and generate meaningful impact by utilizing a multifaceted approach that includes executive summaries, detailed reports, stakeholder workshops, policy briefs, digital platforms, academic publications, press releases, feedback mechanisms, and collaboration with industry partners.

3.13.1. Steps to develop DES model:

1. Describe the goals and objectives: Clearly state the goal of the simulation, together with the precise skill areas that will be evaluated and the elements of the technical testing service that will be simulated.

2. Determine important parameters and variables: Establish which important variables, such as test types, vehicle types, testing apparatus, and examiner experience, have an impact on the technical testing service for vehicle competency assurance service.
3. Data collection and analysis: Gather relevant data on vehicle performance metrics, testing procedures, historical test results, and other necessary information to inform the simulation model.
4. Model development: Make use of programming languages or simulation tools to create a comprehensive model that faithfully reflects the technical testing service procedure. Determining entities, events, queues, resources, and scheduling logic are all included in this.
5. Validation and verification: Validate the simulation model by comparing its outputs with real-world data or expert opinions to ensure its accuracy in representing the actual technical testing service.
6. Scenario testing and sensitivity analysis: Perform sensitivity analysis and a variety of scenario tests to assess the impact of changing input parameter values on the simulation model's results.
7. Implementation and integration: Make sure the simulation model is compatible with the present procedures and systems by integrating it into Addis Ababa's technical testing service framework.
8. Training and maintenance: When staff members use the simulation model, teach them on its use. You should also create a maintenance plan that includes updates to the model for changing requirements or new data[65][66][67][62].

Chapter Four

Data Presentation and Analysis

4.1.Introduction

This analytical component is organized to answer the appraisal's research questions. The results of the study, an analysis of the data obtained from the semi-structured interviews, and the interpretation of the whole work are provided. Semi-structured Questionnaire's, the site observations, and the document/content analysis done. The outcomes of the document/content analysis are presented and discussed first.

Understanding the effectiveness, efficiency, and potential development areas of the Technical Inspection Service procedures and methods used by the Addis Ababa Driver & Vehicle License and Control Authority Bole Branch Office depends on the presentation and analysis of data. A variety of data collection methods, including surveys, interviews, observations, and institutional document reviews, can be employed to obtain meaningful information that will enhance the authority's overall performance.

4.1.1. Collected Data Findings:

A thorough dataset can be created by means of key staff interviews, owner's questionnaires, on-site observations of the authority, and institutional document analysis pertaining to technical inspection services. This data could provide important details about current policies and practices, point out fundamental flaws and challenges the authority faces in practical implementations, and draw attention to areas that need reform right now.

4.1.2. Shortcomings and Obstacles:

The results of the data collection could clarify some of the fundamental flaws and challenges that the Addis Ababa Driver & Vehicle License and Control Authority Bole Branch Office have carrying out its technical inspection services. These could involve problems like ineffective workflow procedures, a lack of integration with contemporary technology, staff workers who are not properly trained, inconsistent enforcement of laws, or service delivery delays. Developing successful solutions to overcome these obstacles requires an understanding of these issues.

4.1.3. Performance Enhancement Factors:

Finding the critical areas that directly affect the authority's overall efficiency and effectiveness is essential to improving the fundamental performance variables of its technical inspection services.

Increasing customer satisfaction, guaranteeing safety standard compliance, streamlining internal and external communication channels, optimizing resource allocation, accelerating inspection turnaround times, and promoting an improvement-oriented culture within the company are some of the main factors that can lead to improved performance.

4.2.Data analysis

The data collection work and detecting findings was done in accountability based on reality and by focusing on the process and current situation of the technical inspection, and by trying to identify the problems and gaps, it was possible to collect the findings needed for this study through data collection tools such as interviews, questionnaires, observation and institutional documents. The researcher uses thematic and simulation modeling methods to analyze the data's found through interviews, focus group discussion, questionnaires, observation and institutional documents. And Arena® software/Microsoft Excel as tool, the research consists of numerical and theoretical analysis. Based on this reality, the data analysis process was provided as follows, relative to the institution's vehicle service procedure and technical inspection manual.

4.2.1. The vehicle technical inspection service procedure:

According to proclamation No. 19/2010 E.C. for Vehicle Identification, Inspection, and Registration, Technical inspections service by the Driver and Vehicle License and Control Authority (DVLCA) in Addis Ababa ensure that vehicles meet safety and environmental standards. The Addis Ababa DVLCA's vehicle technical inspection service methods typically involve the following steps (from the institutional documents):

1, Appointment Scheduling: Vehicle owners are required to schedule an appointment for the technical inspection service at the authorized DVLCA inspection centers. They can usually complete this over the phone or online in the out sourced services like Annual inspection service. But in the Government issued services like road side checking or vehicle service sector, appointment scheduling is not necessary.

2, Document Submission: On the day of the appointment, the automobile owner must provide all necessary paperwork, including the insurance documents, the certificate of vehicle registration, and any other relevant paperwork.

3, Vehicle Inspection: The car will be carefully inspected by knowledgeable inspectors at the DVLA location to make sure it is safe to drive. This means inspecting a number of components, such as the lighting, suspension, brakes, exhaust system, tires, and overall structural integrity. 4, Emission Testing: In accordance with environmental regulations, emission testing may also be performed to ensure the vehicle meets the necessary emission standards.

5, Safety Checks: When relevant, inspectors will assess the condition of important safety features such as seat belts, airbags, mirrors and windscreen wipers.

6, Compliance Verification: The vehicle will be inspected to ensure that any aftermarket modifications, tinted windows, or other additions comply with local regulations.

7, Outcome Notification: After the inspection, the car's owner will be informed of the results. If the examination is satisfactory, the vehicle may receive a certificate of roadworthiness.

8, Rectification of Defects: In the event that an inspection reveals any issues, the owner will be notified of the necessary corrections or repairs to guarantee compliance with regulations.

9, Re-Inspection (if required): If significant defects are found during the initial inspection, a re-inspection can be required after the owner has made the necessary repairs.

10, Issuance of Certification: The DVLCA will issue a certification of roadworthiness, indicating that the vehicle has passed the technical inspection, once all procedures have been successfully completed.

Before utilizing their cars on public roads, owners can ensure that they comply with safety and environmental regulations by following the processes set forth by the Addis Ababa Driver and Vehicle License and Control Authority (DVLCA).

4.2.2. The vehicle technical inspection service work flow process:

According to proclamation No. 19/2010 E.C. for Vehicle Identification, Inspection, and Registration, The bole branch office vehicle technical inspection service is managed by the Driver and Vehicle License and Control Authority and follows a predetermined workflow approach to ensure the safety and compliance of cars on the road. Below is a detailed description

of the standard procedure for conducting technical examinations on vehicles (from the institutional documents):

Arrival at Inspection Centre: The driver or the owner of the vehicle brings the car to the inspection center of their choice at the appointed time and day.

Document Verification: To make sure all legal criteria are satisfied, officials at the inspection center check the required documentation, including driver's licenses, insurance documents, and registration papers for vehicles.

Initial Visual Inspection: The car is first visually inspected to look for any obvious flaws, repairs, or alterations that would compromise its safety or legal compliance.

Technical Testing: The car is put through a battery of technical tests, some of which include emission testing, suspension inspections, brake testing, evaluations of the lighting system, and other pertinent analyses based on legal requirements.

Conformity Assessment: The vehicle's conformity with the authority's safety requirements and regulations is evaluated in light of the technical test results.

Issuance of Inspection Report: An inspection report outlining the results of the technical inspection procedure is created following the conclusion of all tests and evaluations.

Making decisions: Roadworthiness and compliance standards are met or not by the vehicle, depending on the inspection report that authorities have reviewed.

Certificate of Issuance: The owner or driver receives a certificate of compliance or roadworthiness if the car passes all examinations.

By following this structured workflow process, the Driver and Vehicle License and Control Authority's safety standards and regulations are more likely to be followed by cars operating in Addis Ababa.

4.2.3. Vehicle technical performance inspection operation manual (2011 E.C.)

This manual is prepared to come up in practice for the directive of 2011 to regulate the vehicle technical inspection service. Therefore, the following are taken from the vehicle technical

performance inspection operation manual of (2011 E.C.) prepared by the Federal Transport Authority. This is used to compare the Regulation or directives with the real world findings (from the institutional documents).

4.2.3.1.The organization of inspection center:

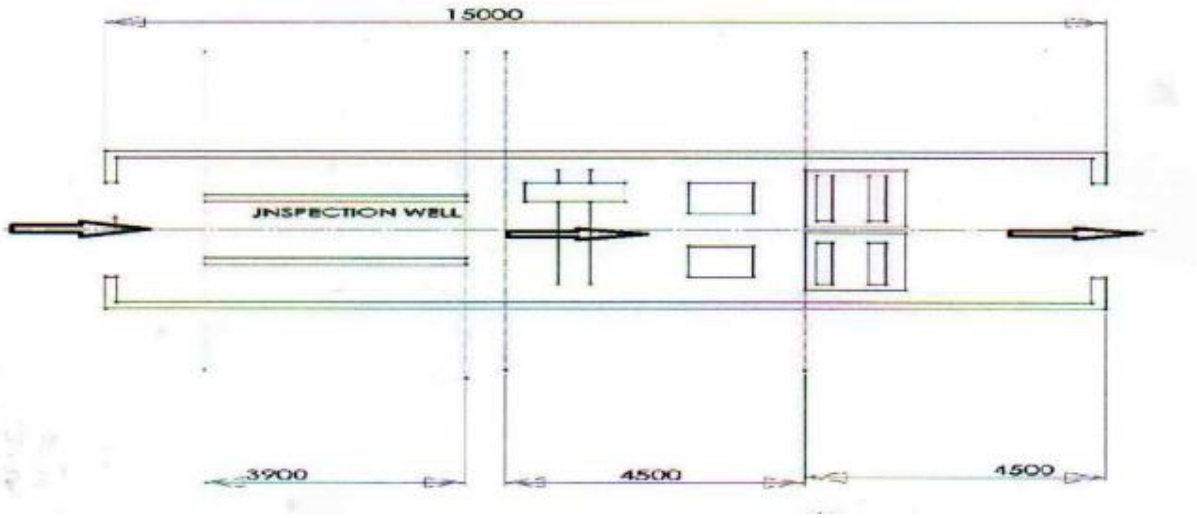


Figure 3: the organization of inspection center (in mm.)(From the institutional documents).

4.2.3.2.Visual inspection standard:

Visual inspection takes place in two steps, which are:

1. Vehicle external part inspection

2. Vehicle internal part inspection

Vehicle external part inspection

This inspection will be done in two directions; these are vehicle upper external part and vehicle lower external part.

4.2.3.3.Standards for inspections with equipment:

The use of the equipment, vehicle and location in the manual, as well as the inspection carried out following the inspection strategy and system, are used as a combination of criteria to pass or fail the results obtained from each equipment.

Inspection one: Vehicle Side Slip Test (M/Km):

1. Suspension Efficiency Test (%).
2. brake efficiency test (%)

Inspection two: Head light tester

Inspection three: Vehicle smoke size

Inspection four: Tire Tread size Inspection:

General requirement of test lane (with roller type for class 2 and 3 test station)

1. The lane should be suitable for: vehicles tested in class 2 & 3 test station.
2. Automatic testing procedure plus manual individual wheel testing.
3. All results can be displayed in graphs in order to analyze any faults.
4. Test results and test station information can be printed (in different colors).
5. The lane should have system for entering saving and managing customer- and vehicle data on the central data base.
6. the system should have:
   - PC Control system includes PC, Keyboard, Mouse, and Printer.
   - 32" or larger flat screen monitors – wall mounted
   - Infra- Red or PDA remote control one man operation.
   - Analogue dial or Bar Graph display, selectable by operator.
   - ≥ 4 cell weighing system
7. the test lane having the following equipment can be connected to a PC to transform it in to a communications and network platform
   - Side slip tester
   - Suspension tester
   - Brake tester
   - Headlight tester
   - Emission tester
   - Control Cabinet
   - PC display/Analogue display
   - Monitor/ Simultaneous display
   - Printer
8. Headlight tester: the tester should fulfill the following requirements.
   - The beam tester should equip with a digital incident light meter.
   - Should have aligning/ aiming device such as mirror spirit levels of the laser and the beam setter box.

- Adjustment of vertical beam deviation with an accuracy of +/- 2cm at 10m distance.
- Adjustment of horizontal beam deviation with an accuracy of +/- 3cm at 10m distance.
- Maximum working height ≥ 140 cm.
- Minimum working height ≤ 24 cm.
- Proper alignment with car light = mirror panel/ laser laying unit.
- Horizontal alignment of the chamber = water level collimator.
- Base frame = one-way mobile base/Rail base.
- Headlamp adjustment: for law beam and high beam lamp.
- Use for automobile, trucks, motorcycles.
- Data transmission: RJ45/ LAN/cable/wireless/ USB.
- Should be compatible with Halogen, Xenon and LED technology.
- Conforms to latest Regulations covering gas discharge headlights.
- Brilliancy = ≥ 24 lux at 25m +/- 5cm

General requirement of test lane (with plate type for class 4 test station)

The lane should fulfill the following requirements:

1. The lane should be suitable for: vehicles test in class 4 test station.
2. Automatic testing procedure plus manual individual wheel testing.
3. All results can be displayed in graphs in order to analyze any faults.
4. Test results and test station information can be printed (in different colors).
5. PC, monitor and analog, simultaneous display
6. The lane should have system for entering saving and managing customer- and vehicle data on the central data base. The system should have:
   - PC Control system includes PC, Keyboard, Mouse, and Printer.
   - 32” or larger flat screen monitors – wall mounted
   - Infra- Red or PDA remote control one man operation.
   - Analogue dial or Bar Graph display, selectable by operator.
   - weighing system

7. The test lane having the following equipment can be connected to a PC to transform it in to a communications and network platform
    - Side slip tester
    - Suspension tester
    - Brake tester
    - Headlight tester
    - Emission tester
    - Control Cabinet
    - PC display
    - Printer

4.2.4. The data collected from VTI centers & their analysis.

4.2.4.1. Data Collected From Vehicle Competency Assurance Service through Focus Group Discussion

The following Data's has found by focus group discussion Participating six technical inspectors and one team leader of the bole branch office.

Name of Sub-City: bole,

Inspection center's Name: bole branch office,

Target Group: (VCA Team),

Number of participants: 6 Date: 21/08/2016

No.	Focus point	Unit	Qty.	Per day	Per month	Percent
1	Total working hours			8	176	
2	Total vehicles inspected			36	792	
3	Total inspection time of the VIC			8	176	
4	Number of vehicles that pass inspection			14	308	38.8
5	Number of vehicles that fail inspection			22	484	61.2
6	Total number of surveyed customers			54	1188	
7	Number of satisfied customers			14	308	
8	Number of repeat customers			14	308	
9	Average inspection fee	1500		54,000	1,188,000	
10	Number of inspectors		6			
11	Number of Team leader		1			

***Table 5*:** Data collected from focus group discussion

From Vehicle Inspection Core 7 KPIs Metrics To Track And How To Calculate (Henry Sheykin 2023). The following 7 KPIs of the bole branch office vehicle inspection center were calculated using the Focus Group Discussion Data. Therefore:

Average inspection time=Total inspection time/Number of inspections

AIT = TIT/NI → 8/12= 40 min.

- NB: in the inspection center the team is structured by 6 inspectors, two inspect one vehicle two technicians in sub team are needed, one sub team of technicians inspect 12

vehicles per day and 36 vehicles inspected totally by the main team per day (12*3sub team=36), therefore the average inspection time indicates the time taken to inspect one vehicle.

Number of Vehicles Inspected Per month= Total Vehicles Inspected per day * Total Working days in month

NVIM = TVID/TWD →36 * 22= 792

Percentage of Vehicles That Pass Inspection= (Number of Vehicles That Pass Inspection/Total Number of Vehicles Inspected) *100

% Vpi= Nvpi/Tnvi→ (14/36) * 100 = 38.8%

Percentage of Vehicles That Fail Inspection= (Number of Vehicles That Fail Inspection/Total Number of Vehicles Inspected) *100

% Vfi= Nvfi/Tnvi→ (22/36) * 100 = 61.2%

Customer Satisfaction Rating (%) =(Number of Satisfied Customers/Total Number of Surveyed Customers) * 100

(NSC/TNSC) * 100 →(26/54) * 100 = 26%

Revenue Generated From Inspection Fee =Total Number of Inspection Conducted * Average Inspection Fee

RGIF = TNIC * AIF → 36*1500 = 54,000 per day

Number of Inspections Conducted By Each Inspectors =Total Number of Inspections/ Number of Inspectors

TNI/NI → 36/6= 6

4.2.4.2.Data Collected From Vehicle Competency Assurance Service bole center Through Site Observation:

The research has observed the real world situation of vehicle technical inspection service, the office arrangement, the structure of the inspection center, the work flow and process on the ground in person. Therefore, the findings are provided as follows:

The overall setting and working area of the vehicle inspection center do not meet the standards outlined in the Vehicle Technical Performance Inspection Operation Manual (2011 E.C.). The office is satisfactorily arranged but is far from the technical inspection site. The office is located on the third floor of the Meklit Building, while the inspection center is on the ground floor, adjacent to the roadside. The primary issue is that the inspection center is makeshift, located on the roadside, and lacks any equipment. The analysis, decision-making, and certification office is on the third floor, resulting in many trips up and down the building, which makes the service delivery quite tedious. The office infrastructure and facilities are well-organized; each inspector has their own chair, table, computer, and printer. However, the equipment is outdated, the waiting area is not stable or comfortable, and the main issue is the lack of an integrated computer system with the inspection equipment.

In the Bole branch office inspection center, there are no testing machines or other inspection equipment. According to the research's observation, there is no modernity, no permanent standard inspection center, and no equipment to aid the inspection process. The inspection practices are outdated, with all activities carried out in a traditional manner. Due to the lack of technical inspection machines or equipment, the functionality does not meet the requirements. The workflow system and procedure settings deviate from the guidelines. The reality is as follows:

First of all, the vehicle can arrive at the inspection area through the owner or their legal representative. After parking the vehicle safely, the owner or representative goes to the pre-audit (document checker). Then, they proceed to the front desk, where the front desk attendant receives the necessary documents and gives the owner or representative the technical inspection form. The owner or representative is responsible for filling out the form carefully and then goes

to the VCA team to provide the form to the team leader. The team leader must understand the case to sign the form and finally gives a work order to a pair of inspectors.

The inspectors visually inspect the vehicle, as there is no machine or other equipment implemented in the center. After completing the inspection, they return to the office with the owner or representative. The owner or representative waits in the waiting area while the inspectors analyze the inspection results for a few minutes. They then make a decision and provide a computer-printed specification (competency certificate). Using this specification, the owner or representative goes to the front desk to finalize the case.

Finally, if the vehicle fails the inspection, the technicians must provide a list of corrections in writing and schedule an appointment for the owner or representative to return after making the necessary corrections.

Figure 4: Bole branch technical inspection service inspection center

4.2.4.3.Data Collected from Vehicle spot checking Service through Site Observation:

The research was observing the current condition of the vehicle spot-checking process, the structure of the inspection team, the arrangement of the inspection equipment and facilities, and the workflow and process on the ground in person. Therefore, the findings are provided as follows:

The inspection team is composed of six inspectors and one team leader. While the inspection takes place at selected roadside sites, the duty of the inspectors is to test the vehicle's technical status by visual inspection, and the team leader oversees the entire process. Unfortunately, there are no machines, equipment, or facilities that assist the inspection process in different ways. However, there are newly purchased, state-of-the-art machines that are not functional at the head office. The reason for their non-functionality is a lack of well-trained personnel in the authority office. Specifically, at the Bole branch office, there is no inspection machinery, equipment, or

trained personnel; the spot-checking is done solely by visual inspection, which is insufficient to ensure roadworthiness.

The workflow adheres to the guidelines without deviation. Since there is no machinery or equipment involved, regulatory attention is minimal, and the procedure remains transparent. As the study observes the testing process, the team first schedules temporary, convenient sites. They then travel to the site based on the schedule, using cones to start and stop vehicles for continuous visual testing. If the vehicle passes the test, a certificate valid for three months is issued. However, if the vehicle fails, the inspector prepares three penalty forms and schedules an appointment in five days. The driver or owner returns after addressing the issues, and the inspector rechecks the vehicle. If the corrections are satisfactory, the technician issues a competency certificate, which is then given to the driver or owner. If the driver or owner exceeds the appointment time for corrections, an additional daily penalty is applied.

***Figure 5*:** The idle new inspection machine of DVLCA due to lack of trained man power stored in Kality Addis Yard for a years.

4.2.4.4.Data Collected From Vehicle annual inspection Service through Site Observation:

The research was witnessing the state of the vehicle annual inspection procedure at the ABH annual inspection center, as well as the organization of the inspection team, the placement of the facilities and equipment, and the work flow. Consequently, the following are the findings:

The inspection team consists of two inspectors and one team leader. However, according to the standard, there should be four inspectors and one team leader. The inspection takes place at a permanent location, where the inspectors are responsible for testing the vehicle's technical status through visual inspection and the use of machines and equipment. The working area is arranged according to the standard. However, the machines and equipment, such as the brake and side-slip tester, headlight tester, and smoke tester, are old. The office facilities are not well-arranged; there are not enough computers or printers, and the office space is narrow. There is no comfortable customer waiting area. Although the machines and equipment are old, but, they are functional, the standard inspection process takes 20 minutes, but according to researchers' observations, it took 35 minutes or more. For the vehicle inspection, the vehicle must physically arrive at the inspection center, after which the inspector receives the key and necessary documents and continues with the inspection.

- First, the inspector inspects visually.
- Second, braking and side slip by machine
- Third, head light system by equipment.
- Finally, the smoke amount with equipment.

After all the necessary inspections have been completed, the inspector print out the test results and gives to the driver/owner a competency certificate.

4.2.4.5.Data Surveyed From Vehicle Competency Assurance Service bole center Through Questionnaire:

Questionnaire is prepared for the fulfillment of Second Degree (Master of Science) in industrial Engineering, Faculty of Mechanical and Industrial Engineering, Addis Ababa University (AAU), Addis Ababa Institute of Technology (AAiT) .This questionnaire is conducted only for the Mere research purpose and its confidentiality is strictly maintained. Any comments to be made here or opinions forwarded will not be used otherwise for whatever reasons. This data collected by questionnaire is used as a supplementary input for the research.

The number of Respondents Participated in This survey was 48; these 48 well-structured questionnaires were prepared and successfully gathered. The data collected through this questionnaire is summarized as follows.

Main Points	S.N	Question Code	Total Number of Respondents For each question	sex		Liker Scale				
				M	F	V.poor	poor	satisfactory	high	v.high
regarding the procedure	1	a	48	42	6	1	0	35	7	5
	2	b		39	9	12	10	21	1	4
Regarding problems/challenges	1	c		44	4	16	11	14	2	5
of VCA/TIS process in relation to	2	d		46	2	25	12	10	1	0
directives/guide lines	3	e		40	8	8	3	27	9	1
	4	f		43	5	5	1	33	7	2
	5	g		45	3	17	5	19	5	2
	6	h		37	11	20	10	14	1	3
			Total in Number	336	48	104	52	173	33	22
			Average	42	6	13	6.5	21.625	4.125	2.75
			Total in %	87.5	12.5	27.1	13.5	45.1	8.6	5.73

***Table 6*:** Summary of findings through Questionnaire.

Total No. of Respondents	Male	Female	V.Poor	Poor	Satisfactory	High	V.High
In Number	42	6	13	6.5	21.625	4.125	2.75
In (%)	87.5	12.5	27.1	13.5	45.1	8.6	5.73

Table 7: final summary of findings

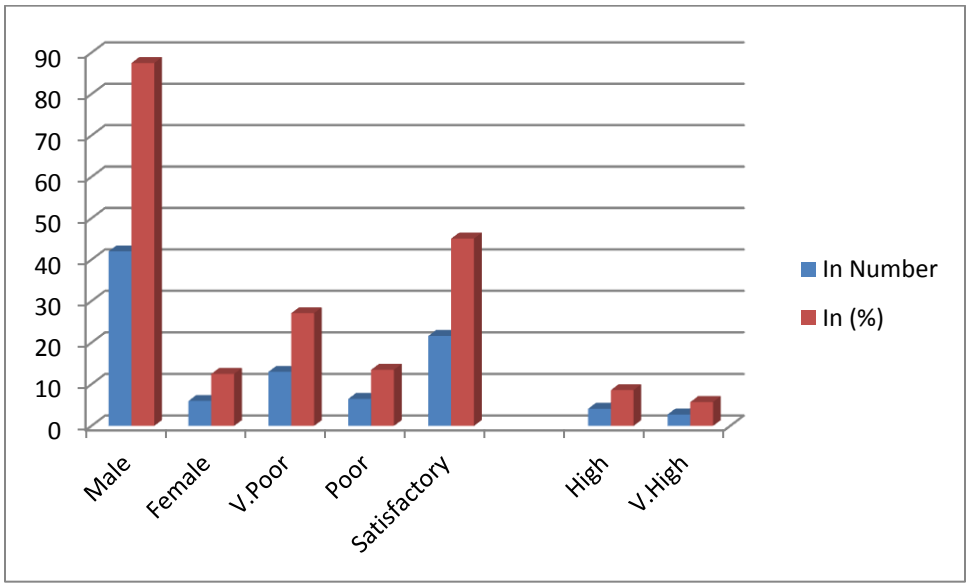


Figure 6: Column chart of Questionnaire data

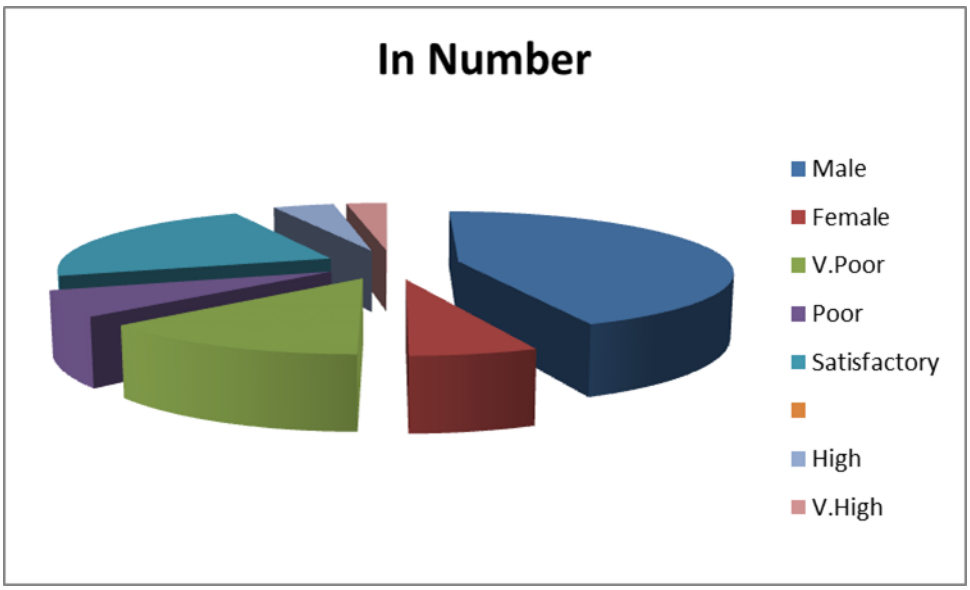


Figure 7: Pie chart of Questionnaire data

4.2.4.6.Data collected From Vehicle Competency Assurance Service bole branch by interview:

This interview guideline is designed for the fulfillment of Second Degree (Master of Science) Industrial Engineering, Faculty of Mechanical and Industrial Engineering, Addis Ababa University (AAU), Addis Ababa Institute of Technology (AAiT) .The purpose of this interview is solely research-related, and confidentiality is strictly upheld. Any feedback left on this page or views shared won't be utilized for any other purpose.

In the interview process, seven (7) experts participated. These experts were chosen by the researcher, believing they are the primary and most suitable sources for obtaining important professional and reliable information for the research. Based on this, the findings were compiled and analyzed as follows. These interview findings are crucial for answering the research questions of the study.

4.2.4.7.Data Collected from Vehicle spot checking Service through interview

Vehicle spot checking (road side testing) is one of the non -out sourced governmental services in bole branch office to monitor the vehicles competency in order to reduce road traffic accident in Addis Ababa. To know the current status of the service and to find out the gaps in the bole branch office the study has collected data through interview.

4.2.4.8.Data Collected from Vehicle Annual Inspection Service through interview

According to proclamation No.681/2010 for vehicle identification, inspection, and registration, which was approved by the House of Representatives, Ethiopia has also passed a national law in this area. Article 25: A car cannot be used on a road until it has been examined and there's a sticker for an annual inspection on it. However, as per Article 26 of the declaration stating that a selected few vehicles, like: cars, may be excluded from inspection involved in inventory management, global transportation, and specialized mobile equipment with a maximum speed of under 20 km/h, and wheelchair-accessible vehicles. Furthermore to the proclamation that has been adopted nationwide; many rules and guidelines are created in accordance with including guidelines for car inspection facility certification and licensure, a standardized checklist to utilize within the car inspection procedure.

Vehicle annual inspection is one of the outsourced governmental services in DVLCA to monitor vehicle competency annually and reduce road traffic accidents in Addis Ababa. To assess the current status of the service and identify problems at the Bole branch office's annual inspection centers, the research plans to select one of the 10 inspection centers(due to problem similarity) and collect data through interviews and site observations. Therefore, data will be collected through interviews with two vehicle annual inspection technicians. The reason for selecting these technicians is that they are experts in the service, are aware of many gaps that need improvement or enhancement, and are likely to provide truthful information.

	Summary of the interview responses	
No.	**Provided Question**	**Compiled Responses**
		There is no transparent procedure
		The system network is corrupted
1	Procedure	The writen procedure is not implemented on the ground
2	Gaps/Cahllenges	Lack of inspection area(spply)
		Lack of Training(Technical)
		Lack of making awareness
		Lack of resource Availability
3	Technology Impleme	No Technology implemented
		Lack of Resources, like inspection Machine and other
		Necessary Equipments
		Lack of training to Adopt the state of Art
		Because of poor leadership commitment and decission
		Making

***Table 8*:** compiled ideas of interview.

No.	Independent Factors of VCATIS	Dependent Factors of VCATIS
1	Service quality	Customer satisfaction
2	Test Operator Skill & Training	Regulatory compliance
3	Inspection center	vehicle inspection performance
4	Resource Availability	Technology Adoption
5	Financial issue	Technology implementation

***Table 9*:** Variables of VCATIS from the findings.

4.3.Analysis of the Qualitative Data's in bole vehicle technical inspection centers. Thematic Analysis by (Qualitative Coding Software/Delve).

4.3.1. Observed Qualitative Data from the Bole Branch Vehicle Inspection Center: A Thematic Analysis

The observations gathered from the Bole Branch Vehicle Inspection Center are examined in this theme analysis. The information shows serious weaknesses in the infrastructure, the inspection procedure, and the provision of services as a whole. The primary themes found through site observations will be covered in length in this analysis, which will also offer a thorough grasp of the problems influencing service quality.

Themes Identified:

1. Standard non-compliance:

- Deviations from the Operation Manual: The general layout and workspace of the vehicle inspection center do not adhere to the requirements specified in the Vehicle Technical Performance Inspection Operation Manual (2011 E.C.).
- Disjointed Office and Inspection Areas: Although the office is arranged adequately, it is inconveniently positioned on the third floor of the Meklit building, far from the ground-level inspection area.

2. Inadequate Facilities for Inspection:

- Inadequate Equipment: Because the inspection facility is located by the side of the road and lacks the essential tools, accurate inspection procedures are hampered.
- Lack of Modern Technology: Conventional and ineffective inspection procedures are used since there is no computer system that is interconnected with the inspection tools.

3. Problems with Facilities and Infrastructure:

- Outdated Office Equipment: Although inspectors possess their own desks, seats, computers, and printers, these items are antiquated and have seen better days, which reduce efficiency and productivity.

- Unstable Waiting Area: The unsteadiness and discomfort of the customer waiting area negatively impacts their overall experience.

4. Inefficiencies in Workflow:

- Complex Workflow: There are several steps in the workflow, which necessitates movement for car owners or representatives between the ground-level inspection area and the third-floor office.
- Manual and Visual Inspections: Inspections are carried out visually due to a lack of testing apparatus and other equipment, which may jeopardize the precision and dependability of the inspection results.

5. Lack of Use of Current Inspection Techniques:

- Conventional Procedures: The center employs antiquated procedures and technologies for inspection, which results in inefficiencies and possible errors in the inspection process.
- Lack of Functionality: The center is unable to achieve the necessary standards and functionality for vehicle inspections due to the lack of technical inspection machines or equipment.

6. Inadequate Procedures:

- Document handling: There is a chance for delays and mistakes during the multiple stages of the vehicle inspection procedure when documents are manually reviewed and turned over.
- Inspector Pairing: Visual assessment is used to conduct inspections by pairs of inspectors, which is out of compliance with current requirements that call for automated systems and technological equipment.

7. Difficulties in Service Delivery:

- Difficult Process: Both inspectors and car owners find the procedure, which entails numerous "ups and downs" between floors, to be tiresome and uninteresting.
- Customer Experience: The complicated procedure and outdated facilities have a detrimental effect on the customer experience, which causes annoyance and aggravation.

In conclusion, the thematic analysis reveals a number of serious operational shortcomings in the Bole Branch Vehicle Inspection Center. It will take major infrastructural upgrades, the integration of contemporary technologies, workflow process simplification, and adherence to established standards to address these problems. By addressing these issues, the center will be able to improve both the experience of vehicle owners and inspectors and the caliber of its inspection services.

4.3.2. Theme Analysis of Qualitative Data Gathered from Administrative Wing and Vehicle Inspection Service Inspector Interviews at Bole Branch Office

First of all, the performance metrics, flaws, difficulties, present practices, and real-world characteristics of the vehicle technical inspection service are highlighted by the qualitative data acquired through interviews with inspectors and the administrative branch of the DVLCA's Bole Branch Office. The main themes that were found will be examined in detail in this thematic analysis, with particular attention paid to the areas of vehicle inspection, technology implementation, inspector training, resource availability, leadership dedication, technology integration, administrative decision-making, regulatory instability, and neglect.

Themes Identified:

1. Vehicle Inspection Area:

- Inadequate Facilities: There isn't enough room or infrastructure in the vehicle inspection area to perform comprehensive and effective inspections. The quality of the inspection is affected because the current setup does not adhere to the necessary requirements.
- Traffic Jams: An excessive number of cars create traffic jams, which delay and hurriedly scrutinize vehicles. This has an impact on consumer satisfaction as well as the inspectors' performance.

2. Implementation of Technology:

- Outdated Systems: The inspection center employs antiquated technology, which reduces inspection accuracy and efficiency. The adoption of contemporary tools and equipment is lagging significantly.

- Lack of Integration: Data fragmentation and inefficiencies in the inspection process result from the lack of integration of current technological systems.

4.3.3. Thematic Analysis of Site Observation data at Bole branch office vehicle spot checking team

Key themes pertaining to the vehicle spot-checking program at the Bole branch office are highlighted by the observation data. Let's use a thematic analysis approach to dissect the data into primary themes and sub-themes in order to provide a thorough analysis.

1. The Goal and Significance of vehicle Spot-Checking

Assistance with Annual Inspection: Spot checks on vehicles are thought to be an essential addition to the yearly inspection routine.

- Unscheduled Nature: Spot-checking is not scheduled, unlike the annual inspection that occurs on a regular basis. This allows for more impromptu and possibly more insightful evaluations of the state of the vehicle.
- Control Mechanism: Spot-checking serves as a control mechanism to guarantee the annual inspection program's efficacy and lower the number of traffic incidents.

2. Issues Found in the Inspection Protocol

Inattention on the part of DVLCA:

- Structural Problems: The program's framework isn't well-organized.
- Human Resources: Insufficiently trained staff members prevent the inspections from being completed successfully.

Lack of Equipment:

- Technological Support: The absence of the tools and machinery required for inspections makes them more difficult.

Problems with Procedures:

- Transparency: The process's lack of transparency could jeopardize its legitimacy and efficacy.

Communication and Awareness:

- Public Awareness: There hasn't been a big push to educate people about the presence and significance of vehicle spot-checking.

3. Suggested Remedies

Authority Action: The appropriate authority office (DVLCA) has to handle the issues.

- Strategic Development: It is recommended that the best way to permanently overcome these challenges is to develop and implement strategic solutions.

Evaluation and Suggestions:

The data points to a number of important problems and possible places where the vehicle spot-checking program should be strengthened. The principal suggestions derived from this investigation are:

1. Improve Human and Structural Resources:

- Training Programs: Put in place thorough training initiatives to guarantee the qualifications of the staff members performing inspections.
- Organizational Framework: To increase efficacy and efficiency, provide a precise, well-organized framework for the inspection program.

2. Make Technology and Equipment Investments:

- Modern Tools: To support comprehensive and precise vehicle inspections, make an investment in contemporary inspection tools and technology.

3. Enhance Transparency and methods:

- Clearly Stated Guidelines: To foster confidence and guarantee justice, clearly state the methods and guidelines for the inspection process.
- Regular Audits: To uphold high standards and continuously enhance the inspection procedure, conduct audits on a regular basis.

4. Raise Public Awareness:

- Awareness Campaigns: Hold public education events to educate the public about the value of spot-checking vehicles and how it improves road safety.
- Stakeholder Engagement: To get input and enhance the program, interact with stakeholders such as the general public, car owners, and inspection personnel.

5. Create Strategy Outlines:

- Long-term Strategies: Create and carry out strategic plans to methodically solve the challenges that have been identified.
- Continuous Improvement: Use a methodology focused on ongoing enhancements to the inspection program in response to user input and fresh discoveries.

The vehicle spot-checking program can be greatly strengthened by addressing these themes, which will increase vehicle safety and decrease traffic accidents.

4.3.4. The Bole Branch Office's Vehicle Spot Checking Team Interview Data Analysis

Several fundamental issues with the vehicle spot-checking service are shown by the interview data gathered from the Bole branch office's vehicle spot-checking team. The following are the main themes that emerged from the interview feedback:

1. Lack of Transparent Procedures:

- Separate Process Transparency: There are no independent, transparent processes in place for the existing car spot-checking program. This ambiguity may cause irregularities and mistrust of the inspection procedure.

2. Inadequate technologies and Training:

- Manpower Shortage: There is a severe lack of skilled workers who are knowledgeable about the technologies involved in vehicle spot-checking. The effectiveness and precision of the inspections are hampered by this deficiency.

3. Administrative Challenges:

- Decision Making and Commitment: There is a deficiency in the administrative wing's ability to make decisions and demonstrate a dedication to improving the vehicle spot-

checking service. This lack of leadership has a detrimental impact on the service's implementation and advancement.

4. Lack of Public Awareness:

- Awareness Campaigns: Not enough is being done to educate the public about the advantages and protocols of spot-checking vehicles. This communication breakdown makes it difficult for people to comprehend and value the service.

5. Inspection Process Monotony:

- Inspection Process Boredom: People think the inspection procedure is tedious and uninteresting. The inspection crew may become less motivated and focused as a result of this perception.

Interpretation and Suggestions:

Thematic analysis identifies a number of crucial problems that must be solved in order to enhance the car spot-checking service. The following suggestions are put out in light of these themes:

1. Improve Procedural Transparency:

- Create Clearly Defined Guidelines: To guarantee consistency and foster confidence among stakeholders, clearly define and disseminate protocols for the vehicle spot-checking process.

2. Make technologies and Training Investments:

- Training Programs: Put in place thorough training programs for the inspection team to improve their competence with the newest technologies.
- Upgrade Technology: To assist the inspection process and increase accuracy, make an investment in cutting-edge machinery and technology.

3. Boost Administrative Support:

- Leadership Commitment: Promote prompt action and a resolute commitment from the administrative branch to give the vehicle spot-checking service top priority and support.
- Policy Development: Create guidelines that stress the value of the inspection program and allot the required funds.

4. Raise Public Awareness:

- Awareness Campaigns: Start educating the public about the benefits of vehicle spot-checking and the operational procedures involved. To reach a large audience, use a variety of media platforms.
- Community Engagement: Interact with the community to get their opinions and make program improvements based on those comments.

5. Invigorate the Process of Inspection:

- Process Improvement: Implement modifications to give staff members a more enjoyable and less repetitive inspection process. Rotation of responsibilities, frequent feedback sessions, and rewards for exceptional work are a few examples of this.
- Innovation: Look into creative ways to expedite the inspection procedure and add some dynamism and interest for the benefit of both personnel and car owners.

These fundamental problems may be resolved, greatly enhancing the vehicle spot-checking service at the Bole branch office and resulting in a more reliable and efficient inspection program that promotes road safety.

4.3.5. Data Analysis of ABH Annual Vehicle Inspection Center through site observation

Theme 1: Insufficient Manpower:

- Observation: In contrast to the typical requirement of four inspectors and one team leader, the inspection team consists of two inspectors and one team leader.
- Implications: The current team members' workload is exacerbated by the understaffing, which may have an impact on the effectiveness and completeness of the inspections.

Theme 2: Substandard equipment and facilities:

- Equipment Condition: The tools and apparatus used for inspections, including the smoke detector, headlight tester, brake and side slip tester, are outdated but still work well.
- Office Facilities: The workspace is cramped and ill-organized, and there aren't enough computers or printers in the office.
- Lack of a comfortable waiting room for consumers may have an impact on their level of happiness and overall experience receiving services.

Theme 3: Standards and the Inspection Process:

- Procedure Steps: There are multiple steps in the inspection process:

1. The inspector's visual examination.

2. Machine testing for side slide and brake wear.

3. Equipment-based headlight system testing.

4. Equipment-based testing of smoke emissions.

- Duration Discrepancy: Although observations show that the examination typically takes 30 minutes or longer, the normal duration is 20 minutes. This disparity could be brought about by understaffing, ineffective equipment, or other operational hiccups.

Theme 4: Handling Documentation and Physical Arrival:

- Arrival of Vehicles: In order for an inspection to occur, vehicles need to physically arrive at the inspection center.
- Documentation Process: Before beginning an inspection, inspectors obtain the car keys and all required paperwork. The inspector prints the test findings and gives the driver/owner a competency certificate after finishing all required inspections.

Detailed Analysis:

1. Insufficient Manpower:

- Effect on Operations: The current workforce is under more pressure due to the inspector shortage as compared to the standard requirement. Longer inspection delays, less attention to detail, and maybe inspector burnout can result from this.
- Suggestions: Hiring more inspectors to fulfill the standard requirement can assist more equitably share the workload, increase the effectiveness of inspections, and improve the overall quality of services.

2. Poor Facilities and Equipment:

- Old Equipment: Despite being operational, these machines may require regular maintenance and may introduce errors in testing. Reliability and inspection speed can be increased by upgrading the equipment.
- Decent Office Facilities: Administrative effectiveness is hampered by a shortage of printers and computers as well as small office spaces. Processes can be streamlined and employee working conditions can be enhanced by providing sufficient resources and upgrading office layout.
- Customer waiting place: Customers' experiences and level of satisfaction with the service can be greatly improved by providing a comfortable waiting place.

3. Standards and Inspection Procedures:

- Detailed Steps: To guarantee vehicle safety and compliance, each stage of the inspection procedure is essential. The time needed for each inspection can be decreased by streamlining these procedures and making sure inspectors have the resources they need.
- Time management: By addressing the causes of the longer inspection periods, it will be possible to bring the procedure closer to the allotted 20 minutes. This could entail improving training, upgrading equipment, or optimizing processes.

4. Physical Arrival and Documentation Handling:

- Handling Efficiency: It is important to handle keys and papers as efficiently as possible, as well as printing out results. To cut down on delays, this can entail streamlining the system and digitizing documents.

- Final Certification: Upholding trust and adhering to legal requirements depends on the timely and accurate delivery of the final competency certificate.

In summary: There are a number of areas for improvement in the ABH Annual Vehicle Inspection Center, including staffing levels, equipment conditions, office space, and process efficiency, according to the theme analysis. By addressing these problems with focused interventions, the car inspection service can become more dependable and successful overall, improving client satisfaction and standard compliance.

4.3.6. Analysis of Qualitative data from ABH Vehicle Annual Inspection Center Inspectors

Several gaps in the service delivery are highlighted by the qualitative data gathered from inspector interviews at the ABH Vehicle Annual Inspection Center.

Themes Identified:

1. Problems with Inspection sites:

- Poor Facilities: According to inspectors, the physical inspection sites are frequently unsuitable for carrying out comprehensive vehicle inspections due to their small size, lack of cleanliness, and general unsuitability.
- Congestion: The inspection areas are severely congested, which causes delays and hurried inspections that may lower the standard of the services rendered.

2. Non-Revised Guidelines:

- Outdated Rules: It has been a while since there has been a revision to the rules and criteria used for vehicle inspections. Inspectors believe that the safety regulations and new car technology are not sufficiently reflected in these antiquated standards.
- Absence of Updates: The inspection criteria are not updated on a regular basis to reflect changes in safety regulations and vehicle technology.

3. Corrupted System Network:

- Network Failures: The inspection process is hampered by frequent system outages and network failures, which result in delays and inefficiencies.

- Data Integrity Issues: Reports of data loss or tampering raised questions among inspectors on the accuracy of the data entered into the system.

4. Lack of Decision-Making Power:

- Authority and Autonomy: Inspectors believe they don't have enough power to decide important matters while conducting inspections. This results in a reliance on higher authority, which causes the inspection procedure to lag.
- Bureaucratic Delays: Bureaucracy frequently impedes decision-making, which causes delays in finding solutions to problems and putting improvements into place.

5. Inspectors Are Not Receiving the Required Training:

- Skill Gaps: As a result of inadequate training programs, inspectors' abilities and knowledge are significantly lacking. Inspectors believe they lack the necessary tools to handle the technology and procedures of contemporary car inspection.
- Continual Education: Inspectors are unable to stay current with developments in the sector due to a lack of opportunities for professional growth and continual education.

6. Inadequate Regulatory Body Control Mechanism:

- Insufficient Oversight: The regulatory body's supervision and control over the inspection centers are insufficient. This results in disparities in service quality between various places and irregularities in the inspection procedure.
- Compliance concerns: Due to lax enforcement by the regulatory authority, certain centers do not follow the established norms and rules. This poses serious compliance concerns.

7. Insufficient Dedication to Adopting Novel Technology:

- Resistance to Change: There is a lack of commitment from the authority office and the inspection center owners to adopt new technology that could enhance the inspection procedure.
- Technological Advancement: Investment in innovations in technology that could increase efficiency, accuracy, and the general caliber of vehicle inspections is conspicuously lacking.

In conclusion, the ABH Vehicle Annual Inspection Center has several significant shortcomings that the theme analysis has identified. A comprehensive strategy is needed to close these gaps, one that involves modernizing facilities, updating standards, improving the system network, giving inspectors more authority, supplying the required training, bolstering regulatory control, and making a commitment to technological developments. These actions are necessary to raise the standard of care and guarantee the dependability and safety of car inspections in Addis Ababa.

4.4.Model toward improvement of the problems

4.4.1. Discrete Event Simulation.

In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time[34]. Simulation aim to simplify the complexity of a real system [35]. A computer-based modeling technique called discrete event simulation is used to comprehend and examine the behavior of complex systems. It entails simulating how the system will behave over time while taking into account the occurrence of discrete events that affect the state of the system. Arrivals, departures, failures, and other systemic shifts are examples of these events. Heiman [36] considers Discrete event simulation (DES) is applied to many domains to help solve problems from defense to Transportation and others, it helps users understand complex issues and learn how to handle related problems.

Discrete-event simulation originally proved its worth and power as a process improvement tool within the manufacturing service sector of the economy[12]. For example, [13]used simulation to analyze a telephone call center handling both inbound and outbound traffic. Another study described an application in which simulation was used to enhance services provided by car-park systems[12]. In this study the client was the management of a repair and service shop for privately owned vehicles; this shop provides repair and replacement service for exhaust systems, brakes, steering, suspension, and climate-control vehicle systems. It can be understood here that, how to associate the three fundamental terms, vehicle competency assurance, service enhancement and discrete event simulation to achieve a goal.

Inspection services for vehicle competency assurance Variables for discrete event simulation modeling are the elements and constraints taken into account while modeling the technical inspection procedure for cars using discrete event simulation[54]. Such as, key variables vehicle characteristics, inspection criteria, resource allocation, process flow, queue dynamics, staffing levels and skills, regulatory compliance, failure analysis and rework, performance metrics and environmental factors are used to develop DES simulation model [55].

In this study Arena Software is used for simulation modeling. Because, Arena makes it possible to simulate a variety of vehicle scenarios and procedures, which makes it possible to model in detail many aspects of vehicle competency assurance. This covers safety procedures, maintenance plans, and vehicle performance testing.

4.4.2. Goals and Objectives of the Simulation at Addis Ababa DVLCA:

The goal of the simulation at Addis Ababa Vehicle License and Control Authority is to assess and evaluate various skill areas related to the technical testing service for vehicle licensing. The simulation aims to replicate real-world scenarios encountered by vehicle inspectors and testers to ensure that they possess the necessary competencies to perform their duties effectively.

4.4.2.1.Skill areas evaluated:

Technical Knowledge: The simulation will test the inspectors' understanding of vehicle mechanics, safety regulations, emission standards, and other technical aspects related to vehicle testing.

Attention to Detail: Inspectors will be evaluated on their ability to meticulously inspect vehicles for any defects or non-compliance with regulations.

Communication Skills: The simulation will evaluate how well inspectors explain any problems discovered during the inspection process to car owners in a clear and professional manner. Decision Making: Based on their observations during the simulated tests, inspectors will have to decide whether or not to mark a vehicle as pass/fail.

Time management: In order to guarantee that activities are completed on time, the simulation may also assess how well inspectors manage their time while conducting inspections.

4.4.2.2.Elements of the technical testing service simulated:

Vehicle Inspection Process: The simulation will imitate the sequential steps involved in examining a car, including examining the brakes, tires, lights, emissions, safety features, and other important parts.

Documentation Review: The capacity of inspectors to examine and confirm vehicle documentation, including insurance certificates, registration documents, and passed inspection records, may be examined.

Problem identification: The purpose of the simulation is to test inspectors' ability to correctly detect and categorize a variety of frequent defects that are discovered in cars during inspections.

Regulatory Compliance: Inspectors must exhibit their familiarity with local laws and guidelines pertaining to the safety and emissions of motor vehicles.

To sum up, the simulation at the Addis Ababa Vehicle License and Control Authority simulates a number of aspects of the real inspection process and attempts to evaluate inspectors' competency in critical skill areas necessary for providing technical testing services successfully.

4.4.3. Important parameters and variables

The technical testing service for vehicle competency assurance in Addis Ababa vehicle license and control authority involves various tests to ensure the roadworthiness of vehicles. Several parameters and variables play a significant role in this process.

Test Types: The type of tests conducted on vehicles is a crucial variable. Generally, there are two types of tests: emission tests and safety inspections. Emission tests measure the level of pollutants released by a vehicle’s exhaust system, while safety inspections assess the overall condition of the vehicle, including its brakes, suspension, lights, and other essential components.

Vehicle Types: The nature of the vehicle being tested also affects the testing procedure. For example, because of their larger size and possible impact on public safety, commercial vehicles are tested more thoroughly than private automobiles. Accurate testing of emissions systems in electric or hybrid vehicles may require specialized equipment.

Testing Equipment: The accuracy and efficiency of the testing process are greatly impacted by the availability and caliber of testing equipment. Even small problems that less sophisticated instruments might miss can be found by advanced equipment. Testing equipment must have regular calibration and maintenance performed on it in order to remain accurate and dependable.

Examiner expertise: Another important factor to consider is the amount of training and expertise of the examiners administering the exams. Only safe and roadworthy cars are issued licenses or permits to drive on public roads thanks to the enhanced ability of properly trained examiners to spot such problems. Examiners can stay current on new laws, regulations, and best practices for vehicle inspection methods with the support of ongoing training programs(Addis Ababa Driver and Vehicle License and Control Authority-Technical testing Regulations and Procedures Manual, 2021),(United Nations Economic Commission for Africa - Road Safety Annual Report, 2020),(International Road Transport Union - Best Practices for Vehicle Inspection & Maintenance, 2019).

4.4.4. Collected Input Data's used to Develop DES Model

The data was collected based on the following key performance metrics; these are the indicators of the reality at work which the researcher collected by in work observation within 10 work days respectively in bole branch office vehicle technical inspection center. Therefore, the simulation model can be constructed based on the following real data's as an input, then analyzing and comparing the different outputs/scenarios of the simulation model to assist reliable and implementable enhancement options. The importance of the simulation model in this study is not negligible and serves as a reinforcement of the cumulative results.

- Vehicle arrival time
- Service time
- Resource utilization data
- Process flow

4.4.4.1. Recorded Arrival time of Vehicle inspection service in bole inspection center during observation

Average Arrival time of Vehicle Inspection Service in Bole Inspection Center (21/05/2024-25/05/2024)

Arrival Day	Recorded Arrival Time	Remark
Day 1	6.4	
Day 2	6.8	
Day 3	5.4	
Day 4	5	
Day 5	6	
Sum	29.6	
Mean	5.92	

***Table 10*:** Average vehicle arrival time

4.4.4.2. Inspection time data of vehicle inspection service in bole branch inspection center in work observation: Day one (03/06/2024-07/06/2024)

Average inspection time of Vehicle Inspection Service in Bole Inspection Center

Observation Day	Average recorded inspection time of each day	Remark
Day 1	37	
Day 2	35.4	
Day 3	35.2	
Day 4	37.8	
Day 5	38.6	
Sum	184	
Average	37	

***Table 11*:** average inspection time to complete the inspection service of a single in bole branch inspection center.

The data above represents the average time it takes for a vehicle to complete its inspection after finishing the registration process and being sent to the vehicle qualification team. This was determined by observing the work in real-time. However, the time standard set by the institution to complete a vehicle inspection is 25 minutes, which differs significantly from the actual situation. Nevertheless, this data aligns with the results from the focus group discussion and the calculations made using Henry Sheykin's KPIs formula. The reasons for this discrepancy include a lack of resources and modern procedures, failure to implement technologies, insufficient capacity-building training, and inadequate attention from the regulatory body, as confirmed by interviews and field observations.

4.4.4.3.Resource availability of technical inspection service in bole branch vehicle inspection center:

No.	Resource Type	Availability	Qty.	Remark
1	Inspection center	available	1	Sub standard
2	Inspection lane	Non available	0	
3	Inspection machine	Non available	0	
4	Lighting system tester	Non available	0	
5	Smoke tester	Non available	0	
6	Inspector	available	6	1 team leader
7	Training	Non available	0	
8	Integrated computer system with the inspection equipment's	Non available	0	
9	Other small equipment's like scope gauge and safety instruments	Non available	0	

***Table 12*:** resource availability of the inspection center in bole branch

4.4.4.4. Process Flow of VCA technical inspection service in bole inspection center

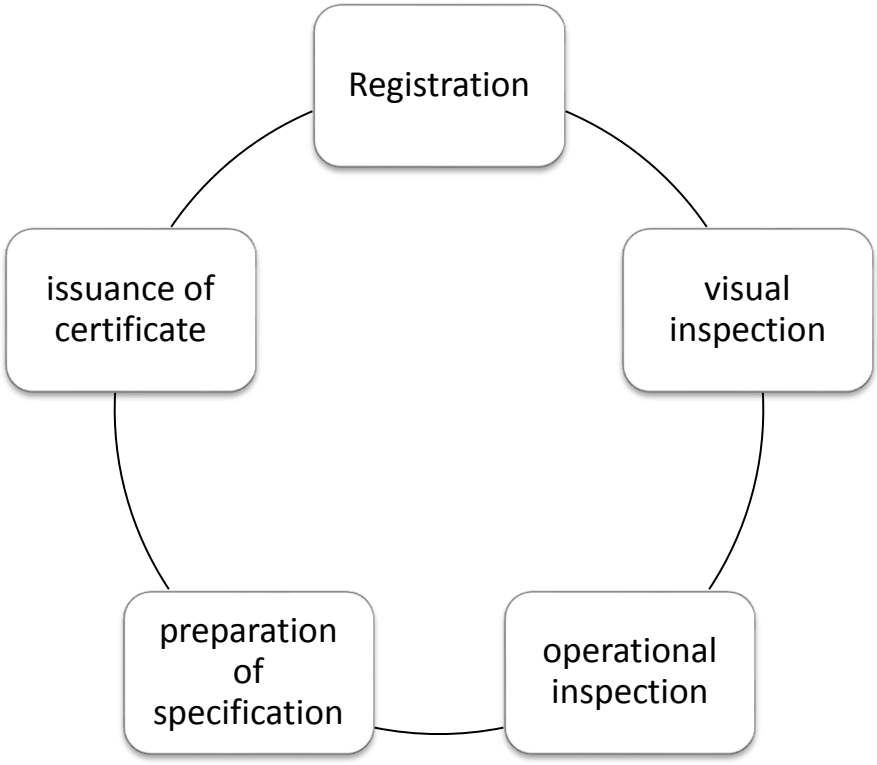


Figure 8: Process Flow of VCA technical inspection service in bole branch office

The researcher took the following actions to build a discrete event simulation model in Arena for enhancing the provision of services in automobile technical inspection:

4.4.5. The problem statement and objectives

Problem statement: poor or substandard service delivery in vehicle technical inspection

- Objectives:
    1. Reducing waiting time.
    2. Optimizing resource utilization.
    3. Reducing inspection time.
    4. Reducing Queue length.

Input data:

- Type of process: Vehicle Technical Inspection
- Arrival rate:
- Service time:
- Resource:
    - Inspectors:
    - Machine:
- Simulations run length:
- Entity:

Specific rule (Logic): Cars arrive, wait for an available inspector and machine, undergo inspection, and then leave the system.

Step to create the model in Arena.

Set up the model environment:

- Create Arena Simulation Software
- Create a new model

Define entities:

- Create an entity called “car”

Create arrivals:

- Use the “create” module to define the arrival rate of cars.

- Set the “Time between arrivals” to be exponential.

Define resources:

- Use the “Resource” module to define the resources.
  - ✓ Create a resource for “inspector” with a quantity of.
  - ✓ Create a resource for “machine” with a quantity of.

Process module:

- Use the “process” module to represent the inspection process.
- Set the process to “seize delay release”
- Assign resources “inspector” and “machine”.
- Set the delay to a triangular distribution with a mean of x.

Queue:

- The “Queue” is automatically managed by Arena when you define the process module. You can observe the queue length in the result.

Define logic:

- Cars arrive at the inspection center (create module).
- Cars wait for an available inspector and machine (process module with resources)
- Cars undergo inspection (delay in process module).
- Cars leave the system (dispose module).

Dispose module:

- Use the “dispose” module to represent the cars leaving the system after inspection**.**

Run length:

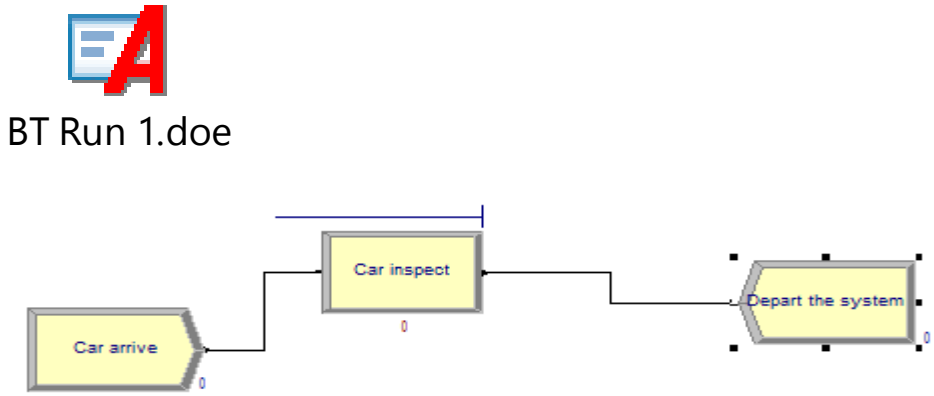
- Set the simulation run length to 8 hours (480 minutes).

Conduct multiple simulation runs with different input parameters to analyze how changes impact system performance metrics like throughput, waiting times, and resource utilization.

4.4.6. Steps to Implement in Arena:

1. Open Arena and create a new model.
2. Add a "Create" Module:
    - Right-click on the canvas and select "Create".
    - Set the "Name" to "Arrive".
    - Set "Entity Type" to "Car".
    - Set "Time between Arrivals" to "EXPO (5.92)".
3. Add a "Process" Module:
    - Right-click on the canvas and select "Process".
    - Set the "Name" to "Inspect".
    - Set "Action" to "Seize Delay Release".
    - Click "Add" to add resources:
        - Select "Resource" as "Inspector" and set the quantity to 1.
        - Select "Resource" as "Machine" and set the quantity to 0.
    - Set the "Delay Type" to "TRIA" and set the parameters to (30, 37, and 45) based on inspection time variability.
4. Add a "Dispose" Module:
    - Right-click on the canvas and select "Dispose".
    - Set the "Name" to "Depart".
5. Connect the Modules:
    - Connect the "Create" module to the "Process" module.
    - Connect the "Process" module to the "Dispose" module.
6. Run Setup:
    - Go to "Run" > "Setup".
    - Set "Replication Length" to 480 minutes (8 hours).
    - Set the number of replications as needed.
7. Run the Simulation:
    - Click on the "Run" button to start the simulation.

Scenario 1



Simulation model of the existing inspection center of bole branch office

Scenario 2:

Car Arrival Module:

- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 5 minutes

Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 2), Machine (Quantity: 1)
- Delay Type: Constant
- Delay: 30 minutes

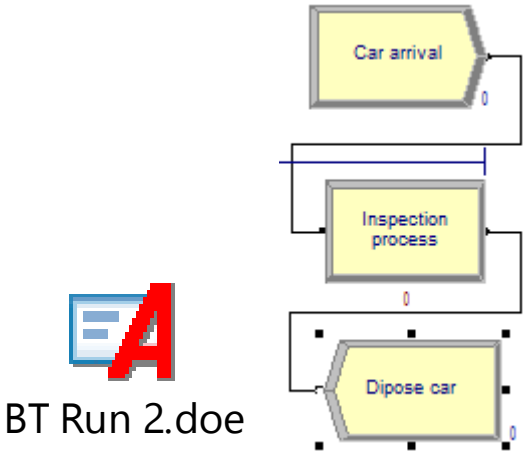
Dispose Module:

- Name: Dispose Car

Resource Module:

- Resource Name: Inspector
- Quantity: 2
- Resource Name: Machine

- Quantity: 1



Scenario 3:

Car Arrival Module:

- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 4.5 minutes (Exponential)

Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 1), Machine (Quantity: 1)
- Delay Type: Constant
- Delay: 25 minutes

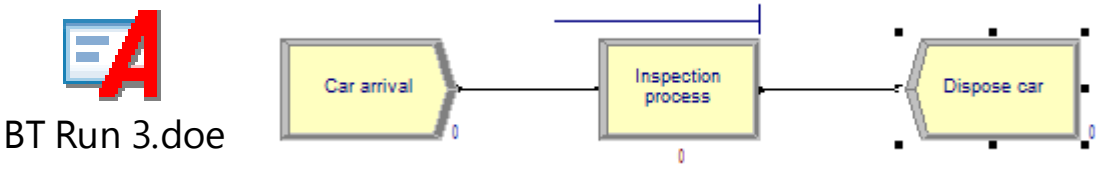
Dispose Module:

- Name: Dispose Car

Resource Module:

- Resource Name: Inspector
- Quantity: 4
- Resource Name: Machine

- Quantity: 2



Scenario 4:

Car Arrival Module:

- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 6 minutes (Exponential)

Inspection Process Module:

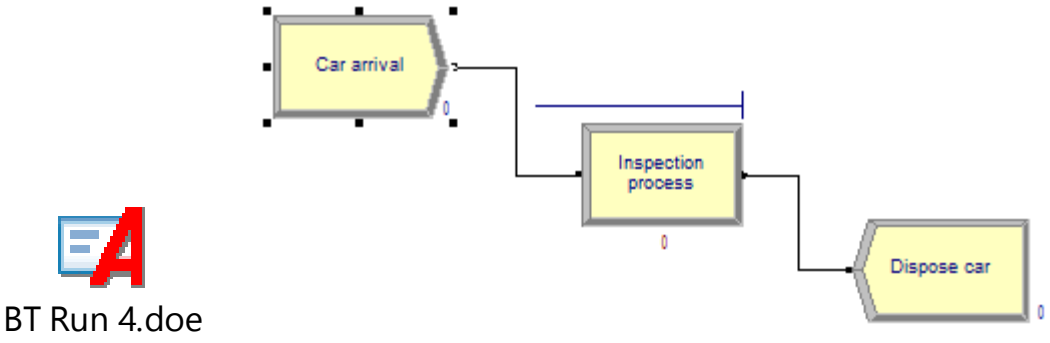
- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 1), Machine (Quantity: 1)
- Delay Type: Constant
- Delay: 25 minutes

Dispose Module:

- Name: Dispose Car

Resource Module:

- Resource Name: Inspector
- Quantity: 4
- Resource Name: Machine
- Quantity: 2



Scenario 5:

Car Arrival Module:

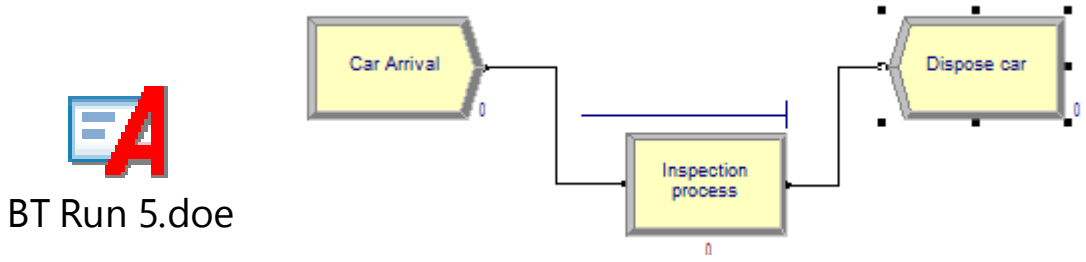
- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 8 minutes (Exponential)

Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 1), Machine (Quantity: 1), standard inspection center(Quantity: 1), Lighting system tester(Quantity: 1), Smoke tester(Quantity: 1)
- Delay Type: Constant
- Delay: 20 minutes

Dispose Module:

- Name: Dispose Car



Scenario 6:

Car Arrival Module:

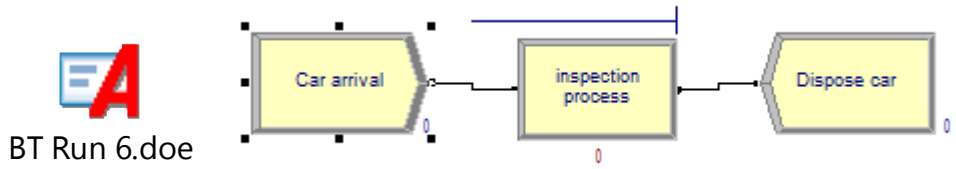
- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 8 minutes (Exponential)

Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 1), Machine (Quantity: 1), standard inspection center(Quantity: 1), Lighting system tester(Quantity: 1), Smoke tester(Quantity: 1)
- Delay Type: Constant
- Delay: 20 minutes

Dispose Module:

- Name: Dispose Car



Scenario 7:

Car Arrival Module:

- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 10 minutes (Exponential)

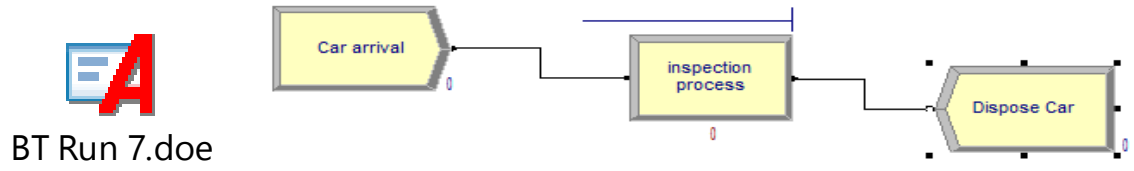
Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release

- Resources: Inspector (Quantity: 1), Machine (Quantity: 1), standard inspection center(Quantity: 1), Lighting system tester(Quantity: 1), Smoke tester(Quantity: 1)
- Delay Type: Constant
- Delay: 20 minutes

Dispose Module:

- Name: Dispose Car



Scenario 8:

Car Arrival Module:

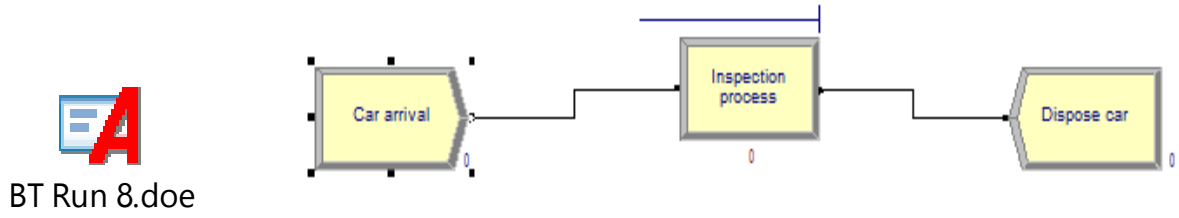
- Name: Car Arrival
- Entity Type: Car
- Time Between Arrivals: 10 minutes (Exponential)

Inspection Process Module:

- Name: Inspection Process
- Action: Seize Delay Release
- Resources: Inspector (Quantity: 1), Machine (Quantity: 1), standard inspection center(Quantity: 1), Lighting system tester(Quantity: 1), Smoke tester(Quantity: 1)
- Delay Type: Constant
- Delay: 15 minutes

Dispose Module:

- Name: Dispose Car



Simulation model of the proposed inspection center

4.5. Analysis of the simulation Results:

Identification of inefficiencies, bottlenecks, or opportunities for improvement in the vehicle technical inspection service by evaluation of the output data produced by the simulation runs. The following are the selected parameters which should be evaluated.

1. Average Waiting Time: Check the average waiting time for cars in the queue.
2. Resource Utilization: Check the utilization rate of inspectors, machine and other equipment's. Like:
   - Inspector
   - Inspection machine
   - Lighting tester equipment
   - Smoke tester equipment
   - Standard inspection center
3. Queue Length: Check the average and maximum queue length.
4. Inspection Time: Ensure the inspection time is within acceptable limits.
5. Work in progress (WIP).
6. Number of cars in (NI).
7. Number of cars out (NO).

After conducting multiple simulation runs with different input parameters it shall be compare how changes impact system performance metrics like throughput, waiting times, and resource utilization.

No.	Scenario List	Performance metrics						Resource Utilization(RU)						
		AWT	QL	IT	WIP	NI	NO	INS.	MC.	SIC	LT	ST	Rank in preference	
1	Scenario 1	204	21	33	22	36	12	1	0	0	0	0	6	
2	Scenario 2	208	34	30	35	86	16	2	1	0	0	0	7	
3	Scenario 3	0	90	0	92	92	0	4	2	0	0	0	8	
4	Scenario 4	109	24	25	26	54	38	4	2	0	0	0	3	
5	Scenario 5	149	26	20	27	50	24	6	1	1	1	1	5	
6	Scenario 6	149	14	20	15	50	24	4	1	1	1	1	4	
7	Scenario 7	127	9	20	10	40	24	2	1	1	1	1	2	
8	Scenario 8	68	5	15	6	40	32	2	1	1	1	1	1	

Table 13: *impact of changes on system performance metrics*

All scenarios are compared as shown in the summary table. The average waiting time (AWT) is reduced from 204 minutes to 68 minutes. Queue length is reduced from 90 cars to 5 cars. Inspection time is reduced from 37 minutes to 15 minutes. Work in progress is minimized from

92 to 6 cars. The number of cars entered for inspection in scenarios 2 and 3 is high, but too few cars are leaving the system due to the existing high delay. On the other hand, the rate of cars entering and leaving the system in scenario 8 is very good. In this scenario, 40 cars entered the system for inspection, and 32 cars left the system after completing the inspection process. Additionally, 6-8 cars are in progress to complete the inspection process, and there is smart resource utilization. Therefore, scenario 8 is preferable for improving vehicle inspection service at Bole Vehicle Inspection Center.

4.6. Chapter summary

4.6.1. Summary of the Qualitative data Analysis:

The Bole Branch Vehicle Inspection Center's thematic analysis identifies a number of serious problems that jeopardize the effectiveness and caliber of the vehicle inspection services offered. The information draws attention to important issues with infrastructure, technology, workflow, leadership, training, and regulatory procedures, among other areas. The main conclusions and recommended solutions are outlined below:

Infrastructure and Facilities: The inspection facilities are antiquated, insufficient, and not in conformity with accepted standards. The physical layout is awkward, with a disorganized office and inspection room, antiquated office equipment, and a shaky customer waiting area. The Suggested Solution is to improve customer satisfaction and expedite processes, rearrange the workspace and make an investment in new equipment.

Technology Implementation: The inspection center does not integrate current technology and instead depends on outdated systems. This leads to inspection procedures that are ineffective and possibly prone to errors. The Suggested Solution is to improve accuracy and efficiency, use contemporary inspection equipment and networked computer systems.

Workflow and Procedures: The workflow is laborious and intricate, necessitating needless floor transfers and largely depending on both visual and manual inspections. The Suggested Solution is Utilize digital technologies to streamline the workflow by centralizing the inspection procedure and minimizing the necessity for handling physical documents.

Resources and Training for Inspectors: There is a severe dearth of chances for continuing education and professional development, and inspectors receive insufficient training. Furthermore, the amount of human and material resources is restricted. The Suggested Solution is Provide chances for ongoing education and provides thorough training programs. In order to guarantee comprehensive and efficient inspections, allocate more resources.

Administrative and Leadership Practices: There is a sense that the leadership is not as committed to enhancing inspection services. Prompt and efficient problem solving is hampered by centralized decision-making and bureaucratic bottlenecks. Recommendation To improve responsiveness and efficiency, cultivate a supportive leadership environment, decentralize decision-making, and simplify administrative procedures.

Regulatory and Compliance Issues: Compliance becomes difficult due to frequent changes in regulations and inconsistencies. The regulatory body's oversight and control measures are inadequate. The Suggested Fix: To guarantee adherence to regulations and uniformity among inspection facilities, bolster supervision and formulate steady, uniform regulatory guidelines.

Customer Experience and Public Awareness: Customers are not satisfied with the inspection procedure since they find it to be time-consuming and inconvenient. Additionally, the general public is not well-informed about the significance of car inspections. The Suggested Remedy: To increase the efficacy and transparency of the inspection process, launch public awareness campaigns and include stakeholders.

Development of Strategy and Ongoing Enhancement: To systematically address the gaps and issues found, strategic development is required. The Suggested Fix: To strengthen the inspection program, create and implement long-term strategic plans that emphasize stakeholder feedback and ongoing development.

Through addressing these issues, the Bole Branch vehicle Inspection Center may raise the caliber of its services and guarantee car inspections that are more precise, effective, and pleasant for customers. This will ultimately help the larger community by lowering traffic incidents and increasing vehicle safety.

4.6.2. Summary of the simulation model

The numerical values of the assessment in bole vehicle inspection center were trying to track by KPIs metrics formulas used by Henry Sheykin(2023) results the customer satisfaction rate 26% and average inspection time for a unit car to complete the inspection process is 40 minutes and other key performance indicator parameters are tracked. In addition to this, the most accurate and sound analysis is takes place through discrete event simulation by Arena software as tool. This simulation model has been constructed by acceptable input data's gathered from work observation and every value is recorded carefully. Therefore, the simulation model was run with 8 trials by changing the input parameters.

The 8 Runs are compared as it shows on the summary table (42). The average waiting time (AWT) is reduced from 204 minutes to 68 minutes, Queue length is reduced from 90 cars to 5 cars, Inspection time is reduced from 37 minutes to 15 minutes, work in progress is minimized from 92 to 6 cars, the number of cars interred for inspection in scenario 3 and 2 is high but too little cars are leaving the system because of the existed high delay in the system. On the other hand the rate of IN and Out in scenario 8 is very good, because 40 cars interred the system for inspection and 32 cars leave the system by completing the inspection process, 6-8 cars are in progress to complete the inspection process and there is smart resource utilization, that's why scenario 1 is preferable to improve vehicle inspection service in bole vehicle inspection center.

Chapter five

5. Conclusion and Recommendation

5.1. Conclusion

Based on the findings of the key performance indicators (KPI's), the research recommends that in order to improve overall service delivery, the Bole Branch Office Vehicle Technical Inspection Center should make modifications to its processes and access to resources. For instance, utilizing Henry Sheykin's KPI calculations, the customer satisfaction percentage is only 26%, showing a stark need for service enhancement.

The Bole branch office's vehicle inspection center's layout deviates from the Vehicle Technical Performance Inspection Operation Manual (2011 E.C.). The inspection center specifically lacks the required testing apparatus as well as an organized, standardized testing facility. The roadside location of the current inspection area is inadequate, and the procedure of providing services is opaque. There is no technological integration, the workflow is drawn out and intricate, the testing protocols do not align with the inspection manual, and the absence of inspector training programs prevents the organization from embracing new technologies.

Additional information gleaned from surveys shows that services need to be improved. According to the Likert scale's final summary, the overall number of "poor" and "very poor" responses (19.5) greatly outweighs the total number of "high" and "very high" responses (6.9), with "satisfactory" responses coming in at 21.625. This outcome makes it clear that improving service quality is essential to lowering the proportion of bad and satisfactory reviews.

The state of the inspection area, technology implementation, inspector training, resource availability, leadership commitment, technology integration, administrative decision-making, regulatory instability, and a lack of focus on these areas are critical issues affecting the vehicle competency assurance technical inspection service at the DVLCA branch office in Bole. These elements highlight how urgently the Bole branch office vehicle inspection center has to improve its services.

Henry Sheykin's (2023) KPI metrics formulas were used to track the quantitative assessment values of the technical inspection service provided by the Bole automobile inspection center. The results showed other KPI parameters, including a customer satisfaction rate of 26%. Nevertheless, discrete event simulation with Arena software produced the most convincing

scenarios for recommending parameters for service enhancement, and this method yielded the most accurate and perceptive analysis.

5.2. Recommendation

The following suggestions and options should be taken into consideration for the DVLCA Bole Branch in Addis Ababa's vehicle competency assurance technical inspection service, which is dealing with a number of issues.

Infrastructure Improvement:

- Upgrade inspection Facilities: Invest in modernizing the vehicle inspection area to meet international standards. This includes installing proper lighting, ventilation, and safety measures.
- Regular maintenance: establish a routine maintenance schedule to ensure the inspection area remains in optimal condition.

Technology Implementation:

- Adopt advanced inspection technology: integrate advanced diagnostic and inspection tools, such as computerized diagnostic systems, to improve accuracy and efficiency.
- Digital record-keeping: implement a digital system for record-keeping and data management to streamline processes and enhance transparency.

Training and development:

- Comprehensive training programs: develop and implement continuous training programs for inspectors to keep them updated on the latest inspection techniques and technologies. Certifications and workshops: encourage inspectors to obtain relevant certifications and attend workshops to improve their skills and knowledge.

Resource allocation:

- Adequate resource provision: ensure the availability of necessary resources, such as tools equipment, and spare parts, to facilitate smooth operation.
- Budget allocation: secure adequate budget allocation for continuous improvement and resource replenishment.

Leadership and management

- Leadership commitment: foster a culture of commitment and accountability among leadership to prioritize vehicle competency assurance.
- Performance monitoring: implement performance monitoring systems to evaluate and improve leadership effectiveness.

Technology Integration:

- System Integration: integrate various technological systems, such as inspection tools, record-keeping software, and communication platforms, to enhance overall efficiency. Automated scheduling: Utilize automated scheduling systems to manage inspection appointments and reduce wait times.

Administrative decision-making:

- Data-Driven Decision: Use data analytics to inform administrative decisions, ensuring they are based on accurate and up-to-date information.
- Stakeholder Engagement: Involve stakeholders, including users and internal customers, in the decision-making process to ensure their needs and concerns are addressed.

Regulatory Stability:

- Policy Advocacy: Advocate for stable and clear regulatory policies that support consistent vehicle inspection standards.
- Compliance Monitoring: Establish mechanisms to monitor and ensure compliance with regulatory requirements.

Focus on Quality Service:

- Customer feedback Systems: Implement robust feedback mechanisms to gather insights from users and stakeholders, and use this feedback to drive continuous improvement. Quality Assurance Programs: Develop quality assurance programs to maintain high standards in vehicle inspection services.

Collaborative Efforts:

- Partnerships and Collaborations: Form partnerships with technology providers, training institutions, and regulatory bodies to enhance capabilities and resources.
- Community Engagement: Engage with the community to build trust and awareness about the importance of vehicle competency assurance.

5.3. Implementation and Validation plan

Assessment phase: Conduct a thorough assessment of current conditions and prioritize areas for improvement.

Planning phase: Develop a detailed plan with timelines, budget estimates, and resource requirements.

Execution Phase: Implement the strategic options, starting with the most critical areas.

Monitoring Phase: Continuously monitor progress and make adjustments as needed.

Evaluation Phase: Evaluate the effectiveness of implemented strategies and make necessary improvements.

By systematically addressing each of these areas, the bole branch office of DVLCA can enhance its vehicle competency assurance technical inspection service, ensuring higher standards, efficiency, and customer satisfaction.

5.3. Future research area

The following should be the main topic of research in order to address the deficiencies in the technical inspection service for vehicle competency assurance at the DVLCA in Addis Ababa:

1) Service Efficiency and Process Optimization: Investigate ways to streamline the inspection process to reduce wait times and improve throughput.
2) Technological Integration: Explore the implementation of modern diagnostic tools and automated systems to enhance the accuracy and reliability of inspections.
3) Staff Training and Development: Assess the current training programs and identify gaps in technical knowledge and skills among inspection staff.
4) Customer Satisfaction and Feedback Mechanisms: Study customer satisfaction levels and develop effective feedback systems to incorporate customer insights in to service improvement.
5) Regulatory and Compliance Framework: Examine the existing regulatory framework and compliance standards to ensure alignment with national and international best practices.
6) Quality Assurance and Control Measures: Develop and evaluate quality assurance protocols to maintain high standards in vehicle inspections.

6. Reference

[1] D. Sangiorgi, “BUILDING UP A FRAMEWORK FOR SERVICE DESIGN RESEARCH,” no. April, pp. 415–420, 2009.

[2] S. Holmlid, “Design Inquiries 2007 Stockholm www.nordes.org,” 2007, [Online]. Available: www.nordes.org

[3] V. Standards Agency, “Driver and Vehicle Standards Agency business plan, 2018 to 2019,” 2018, [Online]. Available: www.gov.uk/contact-dvsa

[4] Road Safety Performance Review - Albania. 2019. doi: 10.18356/fc854c83-en.

[5] A. A. Science, “‘ An Assessment of Annual Vehicle Inspection Practices and challenges in Addis Ababa .,’” 2019.

[6] H. G. Abebe, “Road Safety Policy in Addis Ababa: A Vision Zero Perspective,” *Sustain.*, vol. 14, no. 9, pp. 1–22, 2022, doi: 10.3390/su14095318.

[7] I. PA Government Services, “Vehicle Inspection and Maintenance Programs: International Experience and Best Practices,” no. October, 2004, [Online]. Available: www.paconsulting.com

[8] Congressional Research Services, “Issues in Autonomous Vehicle Testing and Deployment Issues in Autonomous Vehicle Testing and Deployment,” 2021.

[9] P. Tapak, M. Kocur, M. Rabek, and J. Matej, “applied sciences Periodical Vehicle Inspections with Smart Technology,” pp. 1–21, 2023.

[10] S. Yerpude and T. K. Singhal, “Customer Service Enhancement through ‘On-Road Vehicle Assistance’ Enabled with Internet of Things (IoT) Solutions and Frameworks: A Futuristic Perspective,” *Number*, vol. 15, no. April, p. 2017, 2018, [Online]. Available: http:www.serialsjournals.com

[11] N. Erlambang, B. S. Haryono, and R. Hermawan, “Policy Implementation in Transportation Office of Kediri City Regarding to Motor Vehicle Testing,” *J. Ilm. Adm. Publik*, vol. 006, no. 02, pp. 170–177, 2020, doi: 10.21776/ub.jiap.2020.006.02.1.

[12] F. L. Ii, “North American Standard Level I,” 2015.

[13] D. P. S. Representative, “Vehicle Inspection Operations & Training Manual for Official Vehicle Inspection Stations (Vehicle Safety Inspection),” vol. 87, 2015.

[14] “Human C apital Management”.

[15] World Bank, “Project Appraisal Document on a Proposed Credit in the Amount of Sdr213 Million (Us$300 Million Equivalent) To the the the Federal Democratic Republic of Ethiopia for a Transport Systems Improvement Project,” *Ann. Trop. Med. Parasitol.*, vol. 102, no. SUPPL. 1, 2016.

[16] E. Hagos, T. Brijs, K. Brijs, G. Wets, and B. Teklu, “Safety Culture among Transport Companies in Ethiopia: Are They Ready for Emerging Fleet Technologies?,” *Sustain.*, vol. 15, no. 4, pp. 1–16, 2023, doi: 10.3390/su15043232.

[17] A. Ababa, “Addis Ababa City Road And Transport Bureau Environmental And Social Management Framework Ethiopia Transport Systems Improvement Project-Transip (Final Draft),” No. February, 2016.

[18] H. G. Abebe, “Road Safety Policy in Addis Ababa: A Vision Zero Perspective,” *Sustain.*, vol. 14, no. 9, 2022, doi: 10.3390/su14095318.

[19] S. Das, S. R. Geedipally, K. Dixon, X. Sun, and C. Ma, “Measuring the Effectiveness of Vehicle Inspection Regulations in Different States of the U.S,” *Transp. Res. Rec.*, vol. 2673, no. 5, pp. 208–219, 2019, doi: 10.1177/0361198119841563.

[20] D. M. Li *et al.*, “Abundance of toxic and non-toxic microcystis sp. in Lake Hongze and its correlation with environmental factors,” *Huanjing Kexue/Environmental Sci.*, vol. 37, no. 2, pp. 573–579, 2016, doi: 10.13227/j.hjkx.2016.02.023.

[21] A. J. M. Muzahid, S. F. Kamarulzaman, M. A. Rahman, S. A. Murad, M. A. S. Kamal, and A. H. Alenezi, “Multiple vehicle cooperation and collision avoidance in automated vehicles: survey and an AI-enabled conceptual framework,” *Sci. Rep.*, vol. 13, no. 1, pp. 1–27, 2023, doi: 10.1038/s41598-022-27026-9.

[22] Rockville, “Comprehensive Case Management for Substance Abuse Treatment,” *U.S Dep. Heal. Hum. Serv.*, p. 135, 2015.

[23] G. Informal *et al.*, “New Assessment / Test Method for Automated Driving (NATM) Guidelines for Validating Automated Driving System (ADS) – amendments to ECE / TRANS / WP . 29 / 2022 / 58 Ⅳ . Applying a multi-pillar approach to the NATM,” vol. 4, no. June, pp. 21–24, 2022.

[24] EU, “Regulation (EU) 2018/858 On the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles,” *Off. J. Eur. Union*, vol. 2018, no. L151/1, 14.6.2018, 2018, [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0858&from=EN

[25] J. Klemenc, D. Šeruga, T. Svetina, and J. Tršelič, “Vehicle Technical Inspection Results in Relation to EU Directives and Selected EU Countries,” *Stroj. Vestnik/Journal Mech. Eng.*,

vol. 69, no. 11–12, pp. 455–470, 2023, doi: 10.5545/sv-jme.2023.595.

[26] E. Colaboradoras, T. Inspection, and P. T. Inspection, “Roadworthiness testing contribution to vehicle safety and environment”.

[27] N. A. Repository, “Local Car Assembling Industry in Ethiopia Opportunities and Challenges Masters of Business Administration in Industrial Management Addis Ababa Science and Technology,” no. June, 2018.

[28] A. A. C. R. and T. B. (AACRTB), “Ethiopia Transportation System Improvement Project,” no. February, pp. 1–148, 2016.

[29] I. Law and D. Law, “1.1.1.1 International Law,” no. February, pp. 1–33, 2017.

[30] “Evaluation of Behavioral Competencies for Automated Driving AVSC ’ s Mission,” no. November, pp. 1–14, 2021.

[31] “ፌዴራል ትራንስፖርት ባለስልጣን,” 2010.

[32] E. Edvardsson and E. Enquist, “Quality improvement in governmental services: The role of change pressure exerted by the ‘market,’” *TQM Mag.*, vol. 18, no. 1, pp. 7–21, 2006, doi: 10.1108/09544780610637659.

[33] E. M. Id, S. A. Id, and N. A. Id, “Enhancement of Intra-hospital patient transfer in medical center hospital using discrete event system simulation,” pp. 1–19, 2023, doi: 10.1371/journal.pone.0282592.

[34] A. Maria, “Introduction to modeling and simulation,” *Winter Simul. Conf. Proc.*, pp. 7–13, 1997, doi: 10.1145/268437.268440.

[35] J. I. De Irigon and F. Cornelius, “Towards Realistic DTN Simulations for Public Transport Networks,” *2021 Int. Conf. Commun. Syst. NETworkS, COMSNETS 2021*, vol. 2061, pp. 396–403, 2021, doi: 10.1109/COMSNETS51098.2021.9352854.

[36] C. Strauss *et al.*, “Optimizing emergency medical service structures using a rule-based discrete event simulation—a practitioner’s point of view,” *Int. J. Environ. Res. Public Health*, vol. 18, no. 5, pp. 1–22, 2021, doi: 10.3390/ijerph18052649.

[37] R. Selung, I. Wasliah, and E. A. Pratiwi, “No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析 Title,” no. January, pp. 1–23, 2014.

[38] F. Kelemework and H. Kassa, “Assessment of the Current Extension System of Ethiopia : A Closer Look at Planning and Implementation,” no. December, 2006, doi: 10.13140/RG.2.2.31809.20328.

[39] M. Babar *et al.*, “Road Accident Data Collection Systems in Developing and Developed Countries : A Review,” vol. 1, pp. 336–352, 2022.

[40] M. Khatib, A. Gaidhane, Z. Quazi, and N. Khatib, “Prevalence pattern of road traffic accidents in developing countries — a systematic review,” no. July, 2015, doi: 10.5455/ijmsph.2015.09012015334.

[41] K. NISHII, M. ESMAEL, and K. SASAKI, “Road Traffic Accident Trend in Developing Countries- The Policy Implications,” *J. East. Asia Soc. Transp. Stud.*, vol. 10, pp. 1978–1990, 2013.

[42] D. Thorniley, The Global Economic and Business Outlook. 2014.

[43] European Automobile Manufacturers’ Association (ACEA), “Active Safety Systems: What Are They and How Do They Work?” ,” *RoadSafetyFacts.eu*, 2019.

[44] S. Cairns, J. Anable, T. Chatterton, and R. Wilson, “Vehicle inspections – from safety device to climate change tool,” *MOT Proj. Work. Pap.*, no. November 2010, pp. 1–16, 2014.

[45] T. K, A. R. K, P. R. D, and R. K. M, “Efficient Licence Plate Detection By Unique Edge Detection Algorithm and Smarter Interpretation Through IoT,” 2017, [Online]. Available: http://arxiv.org/abs/1710.10418

[46] N. Thuo, “A Blockchain-based prototype for car registration,” 2020, [Online]. Available: http://hdl.handle.net/11071/12030Followthisandadditionalworksat:http://hdl.handle.net/11071/12030

[47] “Technology Operational Efficiency And Service Delivery In The Public Sector: National Transport And Safety Authority In Kenya Sawe, B., & Cheluget, J.”.

[48] R. M. Mogire, “Road Users’ Perception of National Transport and Safety Authority Road Accident Reduction Strategies in Kenya,” *J. Manag. Bus. Adm. 2*, vol. 2, no. 1, pp. 1–8, 2017.

[49] TRANSPORT POLICY OF ADDIS ABABA., “Transport Policy of Addis Ababa,” no. August, pp. 1–47, 2011, [Online]. Available: https://chilot.me/wp-content/uploads/2011/08/transport-policy-of-addis-ababa.pdf

[50] A. DANIEL, “Determinants of Customer Satisfaction on the Case of City Government of Addis Ababa Driver and Vehicle Licensing and Control …,” 2022, [Online]. Available: http://repository.smuc.edu.et/handle/123456789/7108%0Ahttp://repository.smuc.edu.et/bitstream/123456789/7108/1/abi final jun22 dan.pdf

[51] Federal Highway Administration [FHWA], “Gap Analysis Primer,” no. March, 2015, [Online]. Available: https://ops.fhwa.dot.gov/publications/fhwahop15007/index.htm

[52] I. Cieslik, V. J. Expósito Jiménez, H. Martin, H. Scharke, and H. Schneider, “State of the Art Study of the Safety Argumentation Frameworks for Automated Driving System,” *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 13415 LNCS, pp. 178–191, 2022, doi: 10.1007/978-3-031-14862-0_14.

[53] M. J. Bitner, S. W. Brown, and M. L. Meuter, “Technology infusion in service encounters,” *J. Acad. Mark. Sci.*, vol. 28, no. 1, pp. 138–149, 2000, doi: 10.1177/0092070300281013.

[54] E. J. Williams and N. Gupta, “Simulation Improves Service and Profitability of an Automobile Service Garage,” *Proc. 16th Eur. Simul. Symp.*, vol. 5, no. Cd, p. 7, 2004.

[55] I. Habli, I. Ibarra, R. S. Rivett, and T. Kelly, “Model-based assurance for justifying automotive functional safety,” *SAE Tech. Pap.*, vol. 26262, pp. 1–16, 2010, doi: 10.4271/2010-01-0209.

[56] G. Xie, “Naval Postgraduate,” *Security*, no. December, p. 79, 2006.

[57] Research Methodology :

[58] E. M. Mazengia, A. Kassie, A. Zewdie, and G. D. Demissie, “A qualitative study of perception related to risky driving behavior in Debre Markos City, North West Ethiopia, 2021,” *BMC Public Health*, vol. 23, no. 1, pp. 1–9, 2023, doi: 10.1186/s12889-023-15862-x.

[59] U. Chanuan, C. Kajohnsak, and S. Nittaya, “Sample Size Estimation using Yamane and Cochran and Krejcieand Morgan and Green Formulas and Cohen Statistical PowerAnalysis by G*Power and Comparisons,” *Apheit Int. J.*, vol. 10, no. 2, pp. 76–88, 2021.

[60] E. R. Authority, “Rp1 36,” vol. 3, 2003.

[61] Mohanis, “No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析 Title,” *Block Caving – A Viable Altern.*, vol. 21, no. 1, pp. 1–9, 2015.

[62] M. L. Lindegren, M. R. Lunau, M. M. P. Mafia, and E. Ribeiro da Silva, “Combining Simulation and Data Analytics for Oee Improvement,” *Int. J. Simul. Model.*, vol. 21, no. 1, pp. 29–40, 2022, doi: 10.2507/IJSIMM21-1-584.

[63] CSA, “Ethiopian Data Quality Assessment Framework (EDQAF),” no. September, p. 78, 2011.

[64] M. M. Leach and J. J. Harbin, “Psychological ethics codes: A comparison of twenty-four countries,” *Int. J. Psychol.*, vol. 32, no. 3, pp. 181–192, 1997, doi: 10.1080/002075997400854.

[65] E. S. Shenoy *et al.*, “HHS Public Access,” vol. 38, no. October 2014, pp. 246–261, 2019, doi: 10.1177/0272989X17713474.A.

[66] J. Janekova, J. Fabianova, and M. Fabian, “Assessment of economic efficiency and risk of the project using simulation,” *Int. J. Simul. Model.*, vol. 18, no. 2, pp. 242–253, 2019, doi: 10.2507/IJSIMM18(2)467.

[67] S. Panda, N. P. Padhy, and R. N. Patel, “Modelling, simulation and optimal tuning of TCSC controller,” *Int. J. Simul. Model.*, vol. 6, no. 1, pp. 37–48, 2007, doi: 10.2507/IJSIMM06(1)4.082.

[68] “Revised Draft SD Indicators Framework for Africa 10-12-2010.”

[69] M. Malan, Economic development and sustainable resource use in Africa. 2022.

Appendix 1:

Regarding the "Proclamation No. 681/10 for the Identification, Inspection, and Registration of Vehicles," Definitions[31]:

1. "Vehicle" refers to any kind of wheeled motor vehicle used on public highways that is not specifically designated as a carriage, bicycle, motor vehicle, semitrailer, or trailer, excluding special military vehicles;

2. A "motor vehicle" is any vehicle propelled by mechanical or electrical power along a route;

3. "Registered vehicle" refers to a car that has been registered in the owner's name after the title has been certified and all required paperwork has been completed.

4. A "truck" is any motor vehicle, including a truck tractor, that is built or modified with the primary purpose of transporting commodities of any kind;

5. "Motorcycle" refers to a "motor vehicle with less than four wheels" whose unlade weight does not exceed four hundred pounds, not including any sidecar attached to it.

6. "Private Vehicle" refers to any type of motor vehicle used for personal purposes, excluding trucks, motorcycles, public transportation vehicles, truck tractors, and specialty mobile equipment;

7. A "public service vehicle" is a car that is used to transport people and falls under the commercial and motor omnibus categories;

8. A public transport vehicle that can accommodate no more than twelve passengers is referred to as a "commercial motor car";

9. A public transport vehicle with space for more than twelve passengers is referred to as a "motor omnibus";

10. "Truck Tractor" refers to a motor vehicle designed or modified to be used primarily for towing other vehicles; it is built such that it can only tow a portion of the weight of the vehicle and the load it is towing.

11. Any vehicle created, modified, or employed for any kind of agricultural, horticultural, livestock rearing, building, excavation, or road construction is referred to as "Special Mobile Equipment"; vehicles intended for the conveyance of people or products are not included in this category;

12. "Semi-trailer" refers to a vehicle designed or modified to be utilized and utilized for transporting people or products while being pulled by a motor vehicle, and designed in such a

way that a portion of its load and weight rest on or are borne by another vehicle;
13. "Trailer" refers to a vehicle without an independent source of propulsion that can be fastened to and pulled by a motor vehicle, as long as it is built such that none of its weight is supported by the vehicle pulling it; side cars that are affixed to motorcycles are not included in this definition;
14. "Annual inspection sticker" refers to a one-year-valid badge that certifies a car's technical suitability for use on public roads;
15. A vehicle classified as an "inventory vehicle" is one that is retained for sale as part of the stock of a manufacturer, dealer, re-builder, or wrecker;
16. All applications, customs paperwork, technical inspection forms, communications, and other papers needed for correct title certification and yearly inspection as per this Proclamation are referred to as "official records";
17. "Official register" refers to the database that contains all information regarding vehicle title certification and yearly inspections;
18. "Inspection period" refers to the time frame for yearly vehicle inspections;
19. "Vehicle inspection" refers to a technical examination carried out to make sure a car is technically sound.

Appendix 2:

In-Depth Interview Guidelines to be administered to Selected Key Informants

General Guideline.

This interview guideline is designed for the fulfillment of Second Degree (Master of Science) Industrial Engineering, Faculty of Mechanical and Industrial Engineering, Addis Ababa University (AAU), Addis Ababa Institute of Technology (AAiT) .The purpose of this interview is solely research-related, and confidentiality is strictly upheld. Any feedback left on this page or views shared won't be utilized for any other purpose. We appreciate your willingness to participate in the interview in advance.

Background Information of the respondents:

Name of Sub-City ……Inspection center's Name: ……Target Group…….

, Sex….Age……Position: ……

Educational background of interviewee, (a)below (b) Diploma (c) Degree (d) Above

Work Experiences in the specific sector, (a) <5 (b) <10 (c) <15 (d) > 15

Part **A-Regarding Procedures**

1. Is there problems in the procedures of vehicle competency assurance technical inspection service in your inspection center? Yes or No,

1.1. If yes explain how?

.....
.....
.....
.....

1.2. If no explain how?

……
……
……
…….

2. If there is problems in the procedure of your vehicle inspection center explain according to?

(a)Administrative…….

(b) Technical…….....

(c) Regulatory ……

(d) Others……

Part B: Regarding Problems/challenges of vehicle competency assurance Technical inspection service process:

1. Is there any problem in relation to process of vehicle competency assurance technical inspection service in your inspection center? 1.1. If yes / No, explain problems/challenges from the supply Side:

……

……

1.2. Explain problems/challenges from the demand side?

……

……

2. What are the gaps in implementation of modern vehicle competency assurance technical inspection service in bole branch office?

(a)Administrative……

(b) Technical …….....**.....**

(c) Regulatory ……

(d) Others……..

3. Have you observed any factor which is associated with socio-cultural and economic context of the customers, which negatively affects the vehicle competency assurance technical inspection service in bole branch office inspection center?

If so, please specify...

Part C: regarding Technology implementation:

1. Is there any technology implemented in vehicle competency assurance technical inspection service in your inspection center?

If yes specify the technology?

.....

.....

.....

If No, why?

.....

.....

.....

Part c:Remarks and suggestions related:

What do you suggest in relation to existing challenges/problems and in further enhancement of the performance of vehicle competency assurance technical inspection service in the center?

_____

_____

_____

THANK YOU!!!

Appendix 3:

Questionnaires to be filled by the Respondents

Questionnaire is prepared for the fulfillment of Second Degree (Master of Science) in industrial Engineering, Faculty of Mechanical and Industrial Engineering, Addis Ababa University (AAU), Addis Ababa Institute of Technology (AAiT) .This questionnaire is conducted only for the Mere research purpose and its confidentiality is strictly maintained. Any comments to be made here or opinions forwarded will not be used otherwise for whatever reasons. Thank you in Advance for volunteering to take part in the study.

Name of Sub-City ……Inspection center's Name: ……Target Group (Owners)

, Sex….Age……Position: ……

Educational background of Respondent, (a)below (b) Diploma (c) Degree (d) Above

Work Experiences in the specific sector, (a) <5 (b) <10 (c) <15 (d) > 15

I. Regarding to the procedures:

	Questions	**Liker scale**				
		Very low	low	satisfactory	High	Ver Hig

I. Regarding to the procedures:	**1.** How is the fairness of the procedures for vehicle competency assurance technical inspection service in your inspection center?					
	2. If there is existing problems regarding the procedures of vehicle competency assurance technical inspection service explain?					
II. Regarding Problems/challenges of vehicle competency assurance Technical inspection service process in relation to directives/guidelines:	**1.** If you think that there are any challenges in relation to the process of vehicle competency assurance Technical inspection service, what do you recommend from the supply (and regulatory) side?					
	2. What are the existing challenges, from the demand side?					

	3. If you have observed any disparity between existing laws and the implementation of the Laws in practices, explain?					
	4. How do you explain the discrepancy between the actual implementation and the specified Standard provided in directives / guidelines?					
	5. How do you explain the inspection center arrangement put in place to the implementation of Existing laws and directives related to vehicle inspection centers and their functions?					
	6. How do you explain the level of commitment shown by the responsible					

	government Institutions to improve the vehicle competency assurance technical inspection service?					

Appendix 4:

Observation Checklist

Name of Sub-City ……Inspection center's Name: ……Target Group (VCA Team)

Name of observer: ……Date: ……

1. How the overall setting and the working area of vehicle inspection centers is arranged?

……

2. How about the office infrastructure and facilities in placement?

……

3. How about the machine/equipment types?

.....

4. How are the functionalities of each specific machine/equipment as per the requirement?

…….

5. Work flow systems and procedures settings (whether deviates from the guideline or not)

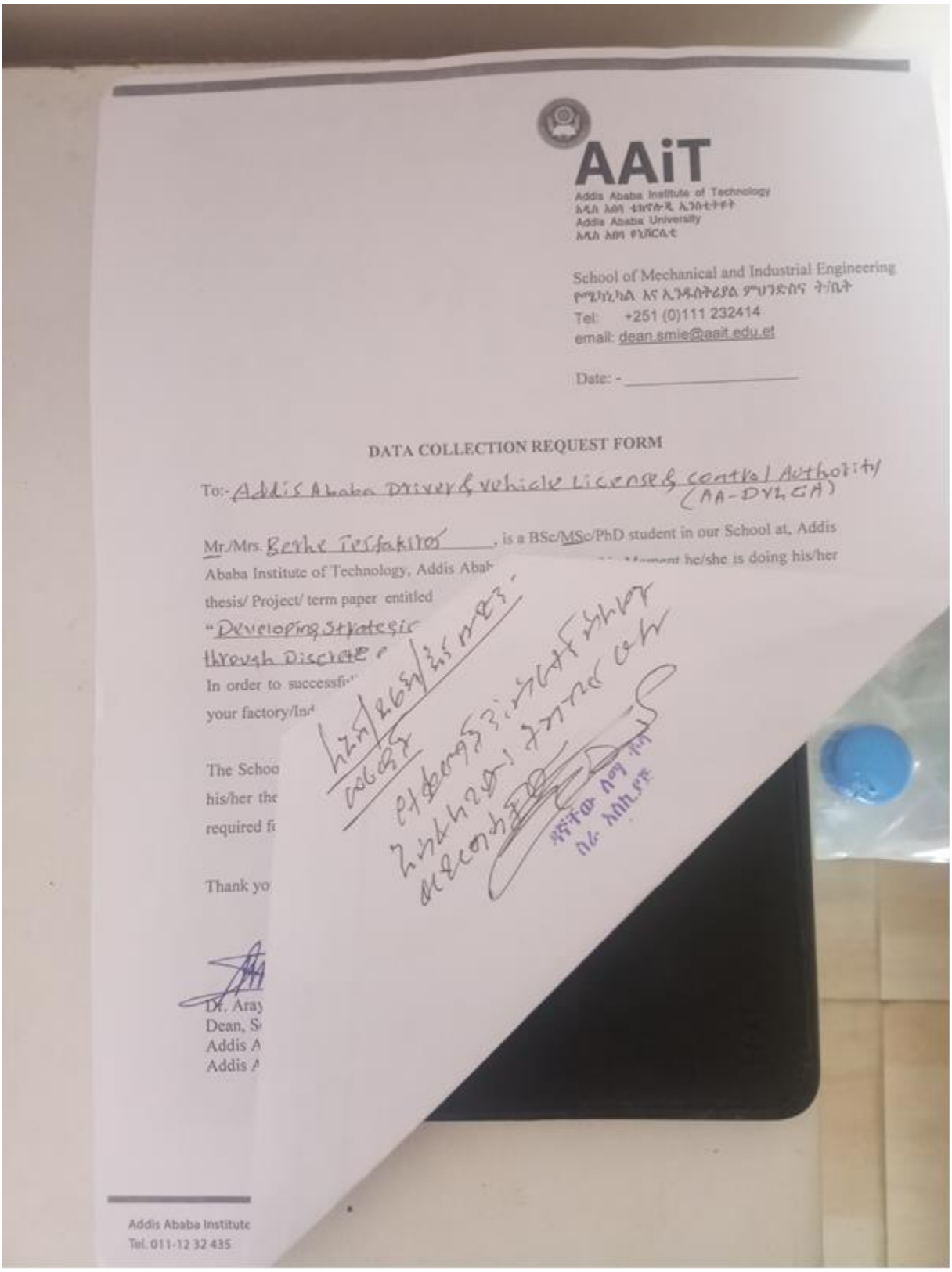
……..

Appendix 5:

በአሽከርካሪ ተሽከርካሪ ፍቃድ ቁጥጥር ባለስልጣን ቦሌ ቅርንጫፍ ተሽከርካሪ ብቃት ማረጋገጥ የስራ ክፍል የሚሰጡ አገልግሎቶች ለአገልግሎቶቹ የሚያስፈልግ ቅድመ ሁኔታ እና ለአገልግሎቶቹ የተቀመጠ ሰዓት

ተ.ቁ	የአገልግሎቱ አይነት	የተቀመጠ ቅድመ ሁኔታ	ለአገልግሎቱ የተቀመጠ ሰዓት /በደቂቃ/
15	የተሽከርካሪ የአካል ለዉጥ አገልግሎት	[illegible]	1 ሰአት
16	የተሽከርካሪ የሞተር ለዉጥ አገልግሎት መስጠት	[illegible]	43 ደቂቃ
17	የተሽከርካሪ የሻንሲ ለዉጥ አገልግሎት መስጠት	[illegible]	47 ደቂቃ
18	የተሽከርካሪ የአገልግሎት ለውጥ መስጠት	[illegible]	42 ደቂቃ
19	የተበላሸ ሰሌዳ፣ ሊብሬና ቦሎ ምትክ መስጠት	[illegible]	22 ደቂቃ
20	የጠፋ ሰሌዳ፣ ሊብሬና ምትክ መስጠት	[illegible]	50 ደቂቃ
21	የጠፋ ቦሎ ምትክ መስጠት	[illegible]	20 ደቂቃ
22	ለተበላሸ ሰሌዳና ሊብሬ ምትክ መስጠት	[illegible]	29 ደቂቃ
23	[illegible]	[illegible]	16 ደቂቃ
24	በገቢዎችና ጉምሩክ ትዕዛዝ ቀረጥ ነጻ ማንሳት	[illegible]	22 ደቂቃ
25	ክክልል ወደ አዲስ አበባ የተሽከርካሪ ፋይል ዝዉዉር	[illegible]	40 ደቂቃ
26	ከአዲስ አበባ ወደ ክልል የተሽከርካሪ ማዛወሪያ ቅጽ አገልግሎት	[illegible]	23 ደቂቃ
27	የተሽከርካሪ ምዝገባ ስረዛ አገልግሎት መስጠት፣	[illegible]	43 ደቂቃ
28	የተሽከርካሪ ቴክኒክ ምርመራን ስፔስፊኬሽን ማዘጋጀት	[illegible]	25 ደቂቃ
29	ሊብሬና ሰሌዳ በአደራ የማስቀመጥ አገልግሎት	[illegible]	85 ደቂቃ

Appendix 6:



AAiT
Addis Ababa Institute of Technology
አዲስ አበባ ቴክኖሎጂ ኢንስቲትዩት
Addis Ababa University
አዲስ አበባ ዩኒቨርሲቲ

School of Mechanical and Industrial Engineering
ሜካኒካል እና ኢንዱስትሪያል ምህንድስና ትምህርት ቤት
Tel: +251 (0)111 232414
email: dean.smie@aait.edu.et

Date: -

DATA COLLECTION REQUEST FORM

To:- Addis Ababa Driver & vehicle License & control Authority (AA-DVLCA)

Mr./Mrs. Berhe Tesfakiros, is a BSc/MSc/PhD student in our School at, Addis Ababa Institute of Technology, Addis Aba... he/she is doing his/her thesis/ Project/ term paper entitled "Developing Strategic through Discrete ..." In order to successfu... your factory/In...

The Schoo... his/her the... required fi...

Thank yo...

Dr. Aray...
Dean, S...
Addis A...
Addis A...

Addis Ababa Institute...
Tel. 011-12 32 435