Impacts of pavement Condition and Geometric Characteristics on Traffic performance at Mid-Block Road Segment

(In the case of Addis Ababa city)

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ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL & ENVIRONMENTAL ENGINEERING

Impacts of Pavement Surface Condition and Geometric Characteristics on Traffic performance at Mid-Block Road segments

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By: -

Yematawork Tasse Endale

A Thesis Submitted to the School of Graduate Studies in

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Master of Science

In

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Advisors; -Dr.-Bikila Teklu Wodajo

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The undersigned have examined the thesis entitled "***Impacts of pavement condition and Geometric characteristics on traffic performance at mid-block Road Segment: In the case of Addis Ababa City Road***" presented by Yematawork Tasse, a candidate for a degree of masters' science in a road and transport engineering and herby certify that it is worthy of acceptance.

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Undertaking

I hereby confirm that the research work titled "***Impacts of pavement condition and Geometric characteristics on traffic performance at mid-block Road Segment: The case of Addis Ababa City Road***" is my original work. I conducted this research under the guidance and supervision of Dr. Bekila Tikelu. This work has not been previously submitted for assessment or to obtain a degree at any other university. I have duly acknowledged all sources of materials used in this thesis.

Signature: _______________

Undertaker's Full Name: Yematawork Tasse

Place of Undertaking: Addis Ababa, Ethiopia.

Date: December,2023

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Abstract

This study focuses on investigating the influence of pavement condition and geometric characteristics on traffic performance in different segments of Addis Ababa city. The research was conducted on five collectors and one sub-arterial urban street, specifically examining pavement distress, lane width, lane number, walkway width, road gradient, traffic volume and travel speed. The statistical analysis revealed that certain geometric factors, such as lane number and width, remained consistent across the segments and did not significantly affect travel speed. However, walkway width and road gradient exhibited notable variations in different sections. Further analysis indicated that walkway width had a weak correlation with travel speed, as indicated by a p-value exceeding 0.05. Consequently, walkway width was excluded from the multiple regression model, suggesting that it does not have a significant impact on travel speed between Coca-Cola-Mesalemia and Tikelhaimanot to Mexico Square.

In this study, the impact of various factors on travel speed in different sections of Addis Ababa city was examined. Variables such as traffic flow, road grade and pavement condition were found to significantly influence travel speed, as indicated by their p-values being less than 0.05. To compare travel speed between distressed and non-distressed sections, travel speed was conducted during off-peak hours, keeping other factors constant (driver behaviour and environmental factors). The results showed a significant reduction in average speed in the distressed sections compared to the non-distressed sections, with reductions ranging from 53.42% to 68.85%. The study suggests that, in addition to rehabilitation, implementing periodic maintenance and ensuring proper geometric design can greatly improve traffic performance in these road segments and the economic analysis shows that distress rating between failed to very poor has more expense than of a distress rating poor to Good.

Keywords: -Pavement condition, Traffic performance and Geometric characteristic

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List of Abbreviations and Acronyms

Addis Ababa City Road Authorities	**ACRA**
Addis Ababa university	**AAU**
Asphalt concrete	**AC**
American Society for testing material	**ASTM**
Average travel speed	**ATS**
Analysis of Variance	**ANOVA**
Corrected deduct value	**CDV**
Ethiopian Road Authorities	**ERA**
Engineer Zewdie Eskinder & CO.PLC	**EZECO**
Highway capacity manual	**HCM**
Highest Deduct Value	**HDV**
International roughness index	**IRI**
Level of service	**LOS**
Pavement condition index	**PCI**
Passenger car unit	**PCU**
Road Grade	**RG**
Statically package for the social sciences	**SPSS**
Total Deduct Value	**TDV**
Traffic flow	**TF**

CHAPTER ONE

1. Introduction

1.1 Background

Maintaining and developing road infrastructure is essential for promoting economic growth and facilitating efficient traffic flow. Failing to prioritize road maintenance and rehabilitation can result in deteriorating road conditions, leading to traffic congestion and decreased vehicle speeds. These consequences can have adverse effects on the economy, including increased transportation expenses and reduced effectiveness in delivering goods and services. Hence, governments and transportation agencies must prioritize road maintenance and rehabilitation to sustain functionality and foster economic growth. (Eyob, 2022)

Urban streets, which include arterials and collectors, occupy a middle position in the hierarchy of street transportation facilities, situated between local streets and multilane suburban and rural highways. The functioning of vehicles on urban streets is impacted by three primary factors: the characteristics of the street environment, the interplay between vehicles, and the influence of traffic signals. These factors collectively determine the capacity of an urban street and the level of service it provides to its users. (Michael R.Morris, Neil J.pedersen and Robert E.Skinner,Jr, 2010)

Facilities refer to continuous stretches of roadways, bicycle paths and pedestrian walkways that consist of interconnected points and segments. These facilities can be either directional or non-directional and are defined by two endpoints. The Highway Capacity Manual (HCM) categorizes facilities into various types, including freeway facilities, multilane highway facilities, two-lane highway facilities, urban street facilities, pedestrian and bicycle facilities. (Michael R.Morris, Neil J.pedersen and Robert E.Skinner,Jr, 2010).

1.2 Statement of problem

In Addis Ababa City, traffic congestion has become a significant problem. Various studies have been conducted to evaluate the traffic performance of the city and most of them have identified traffic volume, traffic light timing, geometric characteristics and environmental factors as the main causes of congestion. However, there has been limited research on the impact of pavement condition on traffic performance in the city

To address the issue of traffic congestion, it is crucial to thoroughly investigate all the factors contributing to the problem. Hence, the objective of this study is to assess the effects of pavement conditions and geometric characteristics on traffic performance within the mid-block section of Addis Ababa city roads. The mid-block section was chosen to minimize the influence of intersections and roundabouts on speed, as suitable study areas meeting the requirements were not found. By examining these factors, the study aims to enhance our understanding of congestion causes and offer valuable insights into potential solutions to enhance traffic flow in the city.

1.3 Objective of the study

1.3.1 General objectives

The general objective of this study is to examine and quantify the effects of pavement conditions and geometric characteristics on traffic performance in a specific study area. By evaluating indicators such as the pavement condition index (PCI) and various geometric factors like walkway width, lane number and road gradient, the study aims to quantify factors that impact traffic performance.

1.3.2 Specific objective

- To measure the effects of Geometric characteristics, such as road grade, walkway width, lane number and lane width on traffic performance
- To quantify impacts of pavement condition on traffic performance

1.4 Limitations of the Research

The limited availability of suitable mid-block road segments meeting the study requirements posed a challenge due to ongoing maintenance activities. This constraint affected the selection of road segments for analysis, resulting in a reduced sample size. This limitation has an impact on the generalizability of the study findings. Additionally, the pavement condition survey vehicles of Addis Ababa City Road Authority and Ethiopian Road Administration were not operational for two years, necessitating the manual collection of data on-site.

1.5 Significant of the study

The traffic performance in Addis Ababa city has become a pressing concern, with multiple research studies highlighting factors such as road capacity, traffic volume, traffic light timings and the presence of intersections and roundabouts as contributors to the declining performance. In light of this, the significance of this research lies in its investigation of the influence of pavement conditions on traffic performance, specifically in mid-block sections. By focusing on these sections, the study aims to raise awareness among the road maintenance sector and Geometric design about the importance of giving attention to mid-block areas. The findings of this research can provide valuable insights and recommendations for improving traffic performance through targeted maintenance and proper design efforts in these critical sections of the road network

1.6 Scope of the study

The scope of this study centres on the mid-block road segments within Addis Ababa City. A careful selection process was employed to identify and include various road segments that fulfilled the necessary criteria for assessing the effects of pavement conditions and geometric characteristics on traffic performance. The evaluation of traffic performance focused on the indicator of speed, while the assessment of pavement condition utilized the Pavement Condition Index (PCI). Additionally, the study took into account important geometric characteristics such as lane number, walkway width, lane width and road grade. By examining these factors, the study aims to provide a comprehensive understanding of how pavement conditions and geometric features impact traffic performance in the mid-block sections of Addis Ababa City.

1.7 Research outline

In terms of Research outline, this research paper follows a structured approach to present the findings and analysis. The paper begins with an introduction that provides background information on the issue of traffic performance in Addis Ababa City and the significance of studying the impact of pavement conditions on traffic performance in mid-block sections. This is followed by a comprehensive literature review that explores previous studies and research related to the topic.

The methodology section outlines the research design, data collection methods and analysis techniques employed in the study. The results section presents the findings of the study, including the assessment of pavement conditions, geometric characteristics and their impact on traffic performance. The discussion section interprets the results, compares them with existing literature, and provides insights into the implications of the findings. Finally, the conclusion summarizes the key findings, highlights the significance of the study, and suggests recommendations for future research and road maintenance practices. Overall, the paper is organized logically and coherently, allowing readers to easily follow the research process and understand the implications of the study.

CHAPTER TWO

2. Literature Review

In recent years, there has been a growing interest among researchers, particularly in developing countries, in studying the condition of pavement surfaces. Those has prompted a review of fundamental concepts related to pavement condition, traffic performance and geometric characteristics. This chapter aims to provide a comprehensive overview of these aspects, drawing insights from various researchers' perspectives.

2.3 Factors affecting Traffic Performance

Various researchers have explored different factors that influence traffic performance, including traffic volume, the presence of intersections and roundabouts, traffic light timing and other variables. However, in this particular study, the focus is on investigating the impact of pavement condition and geometric characteristics on traffic performance.

2.3.1 Impacts of Geometric Characteristic on Traffic performance

The traffic performance of Al-Fallah intersection in Baghdad, Iraq was evaluated using SYNCHRO 10 Software and the Highway Capacity Manual. The researchers conducted operational analyses of the existing geometry of the intersection. Traffic volume data was collected during peak hours over a period of three days, along with vehicle speed measurements using speed guns or radar. The geometric configuration of the road was also taken into account. The findings of the study revealed that Al-Fallah intersection experiences significant congestion on four approaches, resulting in a minimum level of service (level F). However, with the proposed geometric design, it is projected to operate at level of service D in the design year (2038), with an average delay of 41.3 seconds per vehicle. (Dr. Abdul-Razzak Tarish Ziboon1, 2019)

A study examined the impact of pavement condition on headway and average travel speed (data conducted manually) by collecting field measurements for various geometric characteristics, including the number of lanes, distance, road category, carriageway width, median presence, shoulder availability and type, shoulder width, and footpath width. The data was analyzed using SPSS modeling and the findings indicated that the average shoulder width had the weakest correlation with both average headway and speed. In simpler terms, compared to other measured geometric characteristics, the width of the shoulder had the least influence on the headway and speed of vehicles..(Sekhar & Verghese, 2020)

$$Y_1 = 20.257 - 3.335X1 + 0.004X2 + 0.341X3 \quad \text{Equation 2-1}$$

Where Y_1 is the Average speed in kmph, X_1- Shoulder width in m, X_2 – Flow in PCU/h and X_3 – PCI value

$$Y_2 = 4.249 - 0.37 Z_1 + 0.262 Z_2 \quad \text{Equation 2-2}$$

Where Y_2 is the Average time headway in seconds, Z_1 – PCI value and Z_2 – Shoulder width in meter

Study was conducted in Adama city to assess the capacity of four intersection approaches. The evaluation was performed using SIDRA intersection software, taking into account traffic volume and geometric characteristics such as the number of lanes, lane width and median width. The level of service was used as an indicator of traffic performance. The findings revealed that the level of service was classified as F initially. However, when the capacity of the intersection was increased, the level of service improved to a safe level. (Mekonen, 2015)

In Mebya, Tanzania, a study was conducted to assess the impact of pavement condition on the level of service. The focus of the study was on five segments of a Two-Lane class II highway road. Data was collected through visual inspection of pavement condition, traffic volume and road geometric characteristics such as vertical grade, lane width and passing zones. To ensure optimal comfort and convenience for vehicles, it is recommended to upgrade the road segments' geometric features to meet the minimum requirements. Furthermore, the introduction of climbing lanes in areas with steep slopes is suggested. (Hamisi Chengula, 2020).

2.3.2 Impacts of pavement condition on traffic performance

The study conducted on the Klaten Kartosuro Road, focusing on a 21.6km section, aimed to examine the impact of pavement condition on vehicle speed and motor vehicle emissions. The researchers utilized the Pavement Condition Index (PCI) as an indicator to assess the pavement condition, along with considering the average travel speed. By conducting a pavement condition survey following the ASTMD6333 standard and calculating the average travel time for each section, it was found that the PCI value indicated an overall very poor pavement condition. This poor condition likely contributed to the reduction in vehicle speed.(Setyawan et al., 2015).

The study on traffic congestion in major urban cities of Nigeria found that 87.2% of the respondents, totalling 171 individuals, acknowledged experiencing traffic congestion in their cities of residence. In contrast, 12.8% (25 respondents) disagreed with the presence of traffic congestion. Additionally, the study revealed that 52.3% of the respondents believed the state of roads in their cities to be poor, while 47.7% considered them to be at least good. The respondents also emphasized that the condition of roads, particularly those with potholes, significantly contributes to traffic congestion by impeding the smooth flow of vehicles. (Etika, 2012)

Table 2-1 Causes of Traffic Congestion

Rank	***Causes of congestion***	***No***	***Percentage***
1	Poor driving habits	163	82.1
2	Poor parking habits	155	79.1
3	Poor road network	151	77
4	Inadequate road capacity	147	75
6	Lack of parking facility	139	70
7	Poor traffic control management	128	65.3
8	Poor drainage	124	63.3
9	Presence of heavy vehicles	112	57.1
10	Poor designed junction roundabout	102	52
11	Lack of pedestrian facility	98	50
12	Malfunctioning vehicle	79	40.3
13	Poor road pavement	74	37.8
14	Presence of construction activities	68	34.8
15	Lack of road furniture	59	30.1
16	Too many taxis	46	23.5
17	Excessive speeding	42	21.4
18	Frequent use of sirens	33	16.8
19	Poor weather	10	5.1
20	Other	0	0

***Source:* -** Studies about traffic congestion in Nigeria

According to Table 2-1, poor road pavement was identified as a cause of congestion, with 34.7% of the respondents considering it to have a significant impact on road performance. This ranked it 13th among the various causes of congestion that were examined.

Congestion is often present on the road, even during periods of moderate traffic flow, due to various factors such as defects like potholes, offline manoeuvring, driver behaviour, and the absence of crossing facilities. These factors contribute to the occurrence of congestion on the road (S. B. Raheem, 2015)

The research conducted on the impacts of pavement condition on traffic performance found that pavement deformation, including corrugations, depressions, rutting, and shoving, leads to traffic congestion and a decrease in traffic performance. This deformation occurs in both flexible and rigid pavements, and the evaluation of this result was carried out using Plaxis software. Additionally, an analysis of variance (ANOVA) was performed to compare the p-values of distressed and non-distressed pavements for different types of vehicles.. (B. Suresh, 2018)

Researchers are studying the impact of deteriorated pavement conditions on traffic performance in various countries. They are examining different parameters and considering different classes of pavement to understand how poor pavement conditions affect traffic performance taking Average travel speed as an indicator.

The study conducted in Pakistan to investigate the impacts of pavement condition on traffic performance at 6.5km road segment, which was designated as the test section. This section was divided into thirteen 500m segments, further divided into five 100m sections, and then subdivided into four 25m sub-sections. Each sub-section had a cross-sectional area of 25m x 10.8m. Average travel speed and pavement condition were surveyed at each sub-section, with the pavement condition index (PCI) calculated using an Excel template. Outlier data in the PCI was considered as drivers changing their direction due to pavement distress. Regression analysis was conducted to correlate the PCI and average travel speed, revealing a significant impact of adverse pavement conditions on traffic performance. (Shabbar Ali & Choudhary, n.d.).

The Study was to examine the influence of pavement defects on traffic operational performance on a multi-lane highway in Egypt. The researchers assessed pavement conditions using the pavement condition index, which was determined manually and analysed using micro paver software. Average travel speed, measured through spot speed and percentile speed methods for different vehicle classes, served as an indicator for traffic performance. After analysing the data, it was found that lane width and shoulder width had a weak relationship with the indicators and were excluded from the analysis. However, the study revealed that the pavement condition index had a significant impact on the performance of large vehicles, while its effect on light vehicles was less pronounced. (Ibrahim H. Hashim 1, Rania M. Badawy 2,* and Usama Heneash 2, 2023)

Hazratullah Paktin and other two researchers Ahsanullah Mangal and Mohammad Qadeem Afghan state that the riding quality condition of the road in many parts of the Kabul city is poor and drivers have to decrease their speeds which make the stream less sufficient. Many pavement distresses are clearly visible which seem sever as far as the rating of pavement condition is concerned and this leads to traffic congestion. (Hazratullah Paktin1, 2021)

2.4 Traffic performance measures

In the field of traffic engineering, there are several commonly used measures to assess traffic performance. These measures include the volume-to-capacity ratio (v/c ratio), level of service, crash rates, vehicle delay, travel time, mode share, and capacity. These measures help evaluate and analyse various aspects of traffic performance.

Table 2-2 Traffic performance indictor

Assessment Criteria / ***Congestion metric***	**Simplicity**	**Erase of Data Collection**	**Stability**	**Repeatability**	**Magnitude of Congestion**	**City comparison**	**Continuous Value**
Speed	Y	Y	Y	Y	Y	N	Y
Travel Time	Y	Y	Y	Y	N	N	Y
Delay	N	N	N	Y	N	N	Y
LOS and Volume	Y	Y	Y	Y	N	N	Y

Source: - Measuring urban traffic congestion,2012

Y-Yes and N-No, in this study speed is used as per HCM2010 for urban street facility

An urban street facility meets or exceeds 1mil or 2mil the level of service indicator is better to be with Average travel speed (Michael R.Morris, Neil J.pedersen and Robert E.Skinner,Jr, 2010).In this study speed is taken as an indicators of traffic performance.

2.5 Pavement condition

Pavement condition refers to the overall wellness or hilliness of the road surface. The performance of road pavement is evaluated based on its ability to meet the functional and structural requirements.

Pavement condition is influenced by various types of distresses or defects, such as alligator cracking, bleeding, block cracking, bumps and sags, corrugations, depressions, edge cracking, joint reflections, lane/shoulder drop-off, longitudinal and transverse cracking, patching and utility cut, polished aggregate, potholes, rutting, shoving, slippery surfaces, swelling, weathering, and ravelling. (Conshohocken w. , 2011)

In Egypt, a survey was conducted on a rural two-lane, two-way highway consisting of thirteen sections to assess the condition of the pavement. The investigation utilized the pavement condition index as one of the indicators. The results showed that the mean pavement condition index was 54.8, indicating that the overall pavement condition is poor (Ibrahim H.Hashim a*,Mohamed A.Younes b,Saad A.EL-hamrawy c, 2018)

During a case study conducted in April 2005, the streets of Addis Ababa city were functionally classified as arterial streets and the condition of the pavements was assessed. A pavement condition survey was conducted in each study area, and the results revealed that almost all test roads had very low pavement condition index (PCI) values. The most prevalent types of distresses observed were ravelling, corrugation, bumps, and sags, which accounted for more than 75% of the distress densities in the arterial road network. These findings indicate that the overall condition of the pavement is not in a healthy state.(Alebachew, 2005).

2.5.1 Flexible (Asphalt Concrete) Pavement distress and measurement

Distress in pavement depends on the specific type of distress observed. Different types of distress categories have different methods for measuring severity. For instance, the severity of a pothole is determined by its area, while alligator cracking severity is assessed based on both the area and width of the cracks. On the other hand, routing severity is determined by the depth of the rut. Each of Distress has been grouped into one of the following Categories**.**

2.5.1.1 Patching and pothole

A. Pothole

Pavement surfaces can have potholes of different shapes and sizes, including bowl-shaped holes. Circular potholes are typically required to have a minimum diameter of 150 mm. For irregular-shaped potholes, a circle with a diameter of 150 mm should be able to fit inside them. (E.Pagan-ortiz, May 2014)

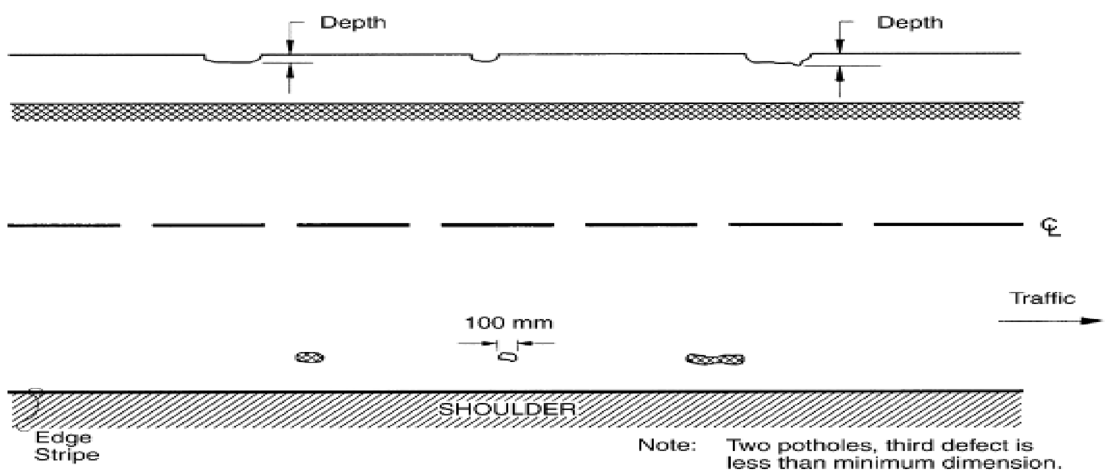


Figure 2-1 Measuring pothole

Source :-Distress identification manual for long-Term Pavement performance program

B. Patching and utility cut patching

Patching refers to the process of removing and replacing a section of the pavement surface that is equal to or greater than 0.1m2. It can also involve applying additional material to the pavement after its original construction. On the other hand, when a patch section is created for utility crossings that run either longitudinally or transversely to the road, it is referred to as utility cut patching.

2.5.1.2 Surface Deformations

A. Rutting

Rutting refers to the longitudinal surface depression that occurs in the wheel path of a road. The severity level of rutting is determined by the mean rut depth. Rut depths between 6 to 13mm are considered low severity, depths between 13 to 25mm are considered medium severity, and depths greater than 25mm are considered high severity. Rutting is measured in terms of the square meters (or square feet) of surface area affected by the depressions

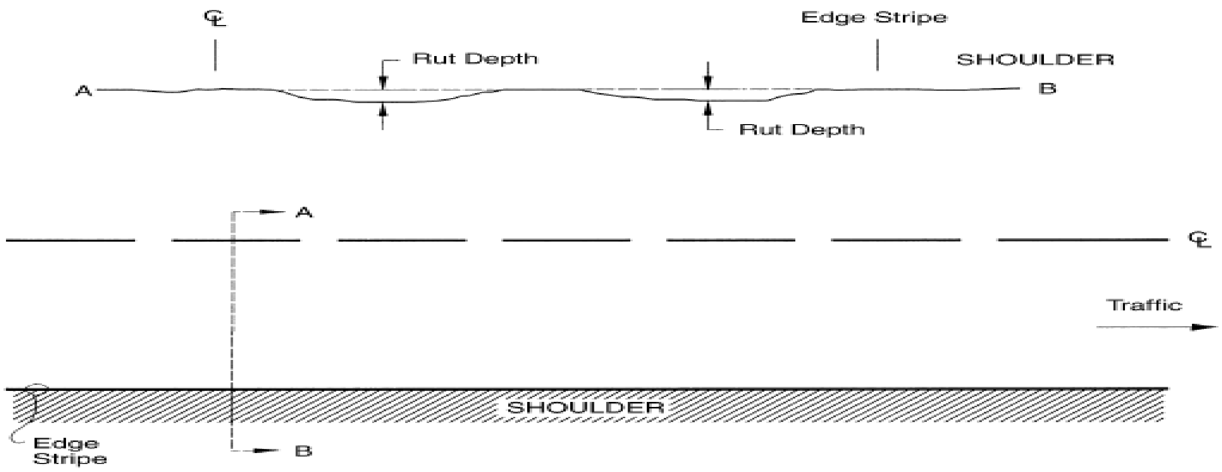


Figure 2-2 Measuring Rut Depth

Source: **-** ASTM D6433

2.5.1.3 Cracking

A. Alligator Cracking(Fatigue)

Alligator or fatigue cracking refers to a pattern of interconnected cracks that occur on the asphalt concrete surface due to fatigue failure caused by repeated traffic loading. The measurement of alligator cracking is based on the square meters (or square feet) of surface area affected by these cracks.

B. Block cracking

Block cracking is a rectangular block cracks on the pavement surface ranges in size from approximately 0.1-10m^2

C. Edge cracking

Edge cracks are crescent-shaped cracks or fairly continuous cracks which intersect the pavement edge and are located within 0.6m of the pavement edge adjacent to the shoulder. Edge cracking is measured in linear meters (feet).

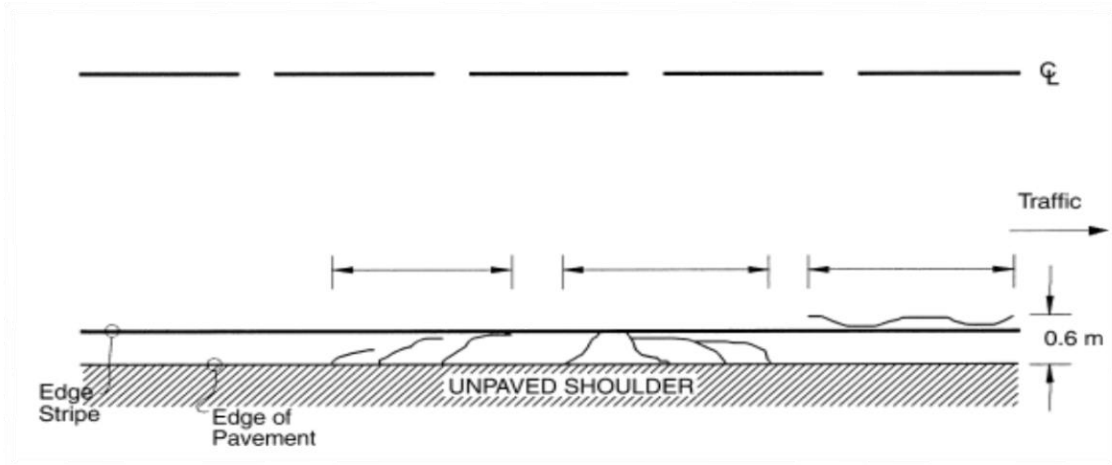


Figure 2-3 Taking Measurement of the cracks

Source :-Distress identification manual for long-Term Pavement performance program (page 7)

D. Longitudinal and transverse cracking

Longitudinal cracks are parallel to the pavement laydown direction and Transverse cracks extend across the pavement at approximately right angles to the pavement direction of laydown and measured in linear meters (feet).

2.5.1.4 Others Distress type

A. Railroad crossing

Railroad crossing defects are depressions or bumps around, or between tracks, or both.

B. Weathering and ravelling

Weathering and ravelling refer to the deterioration of the pavement surface caused by the loss of asphalt or tar binder and the displacement of aggregate particles. The severity of this type of distress can be assessed using ASTM D6433 guidelines, which include visual inspection and may involve capturing images. The extent of the distress is typically measured in terms of the surface area affected, which can be expressed in square meters or square feet.

2.5.2 Pavement condition index

To ensure the performance and safety of pavement and prevent accidents and traffic congestion, various performance indicators are used to assess its health after construction. Among the commonly used indicators are the Pavement Condition Index (PCI), International Roughness Index (IRI), and Present Serviceability Index (PSI). These indicators helps to evaluate the condition and smoothness of the pavement, allowing for effective maintenance and management strategies (Ford, 2012).

The Pavement Condition Index (PCI) is a method used to evaluate the condition of road pavements based on the type and severity of distress. It provides information about the current state of the pavement at the time of the survey, but it does not offer predictive insights into future performance. However, regular condition surveys can be conducted to gather data on pavement conditions which can be valuable for predicting future performance and serving as a more detailed input for measurement purposes (Deni1, 2020).

To calculate the Pavement Condition Index (PCI) for a sample unit, distress quantities measured on-site are converted into distress densities for each severity level. These densities are then used to determine the deduct value. The PCI for each sample unit is obtained by subtracting the deduct value from 100. This calculation allows for a standardized measurement of the pavement's condition, with higher PCI values indicating better pavement conditions (Conshohocken W. , 2011)

A study conducted around the University of Agriculture Makurdi (UAM) Campus in Makurdi town, Nigeria, aimed to assess the pavement conditions of different road segments using the Pavement Condition Index (PCI) method. The researchers visually inspected the pavement and measured it using linear measuring instruments, following the specifications outlined in the ASTM D6433 manual. The results showed varying percentages of fair to good pavement conditions for different routes on the UAM campus road network, with the RR route having a relatively high percentage and the SCV route having the worst pavement condition. (P. T. Adeke1, 2019) .

2.5.2.1 Deduct Value Curves for Asphalt concrete

The deduction values for different types of asphalt distress, which indicate the extent to which pavement condition deteriorates with each distress, can be determined by referring to deduct value curves. These deduct value curves take into account the density and severity level of the distress. In accordance with ASTM D 6433, the deducted values for each type of asphalt distress are as follow

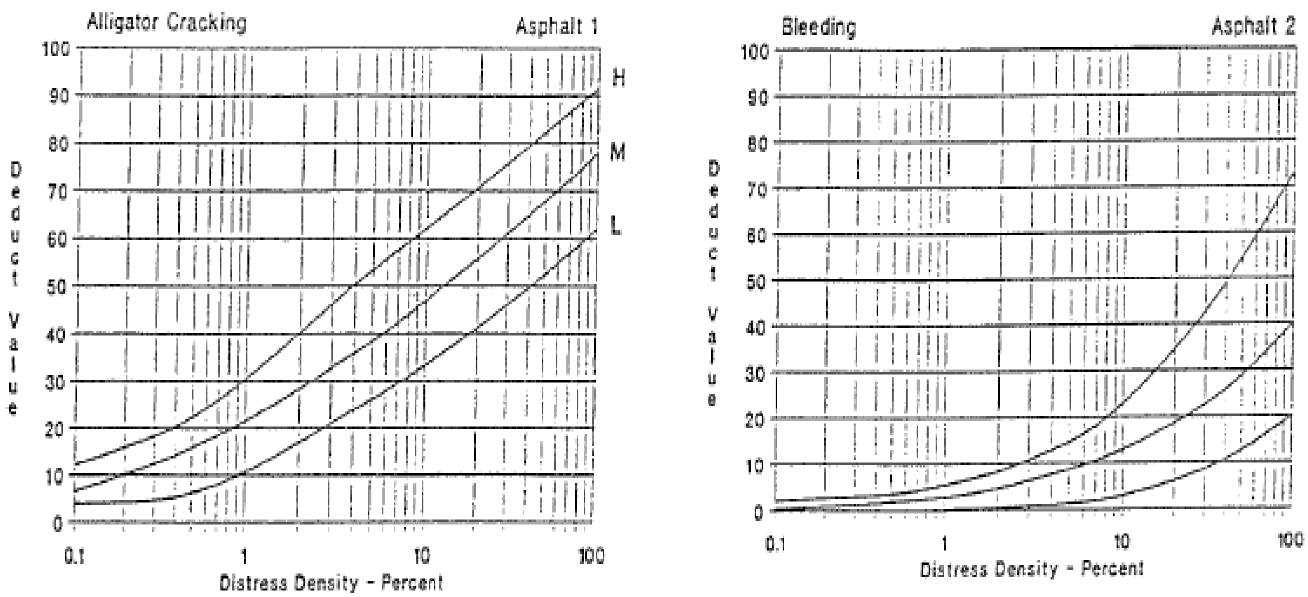


Figure 2-4 Alligator cracking deduct value curve and bleeding deduct value curve

Source: - ASTMD6433

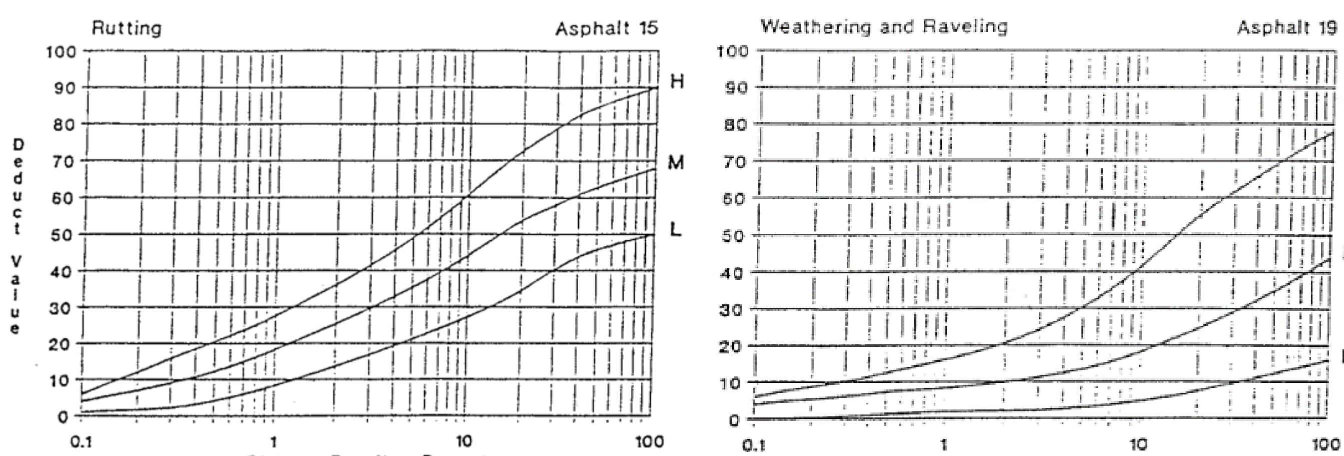


Figure 2-5 Deduct curve for Rutting and weathering and Raveling

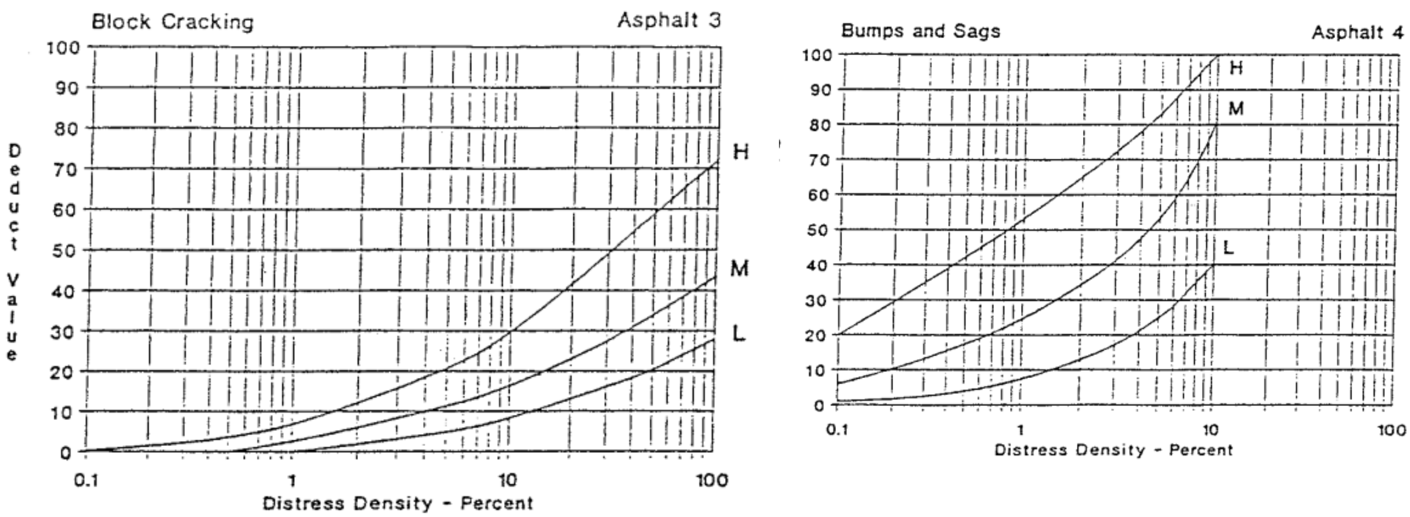


Figure 2-6 Block Cracking and Bumps and sage deduct value curve

Source: - ASTMD6433

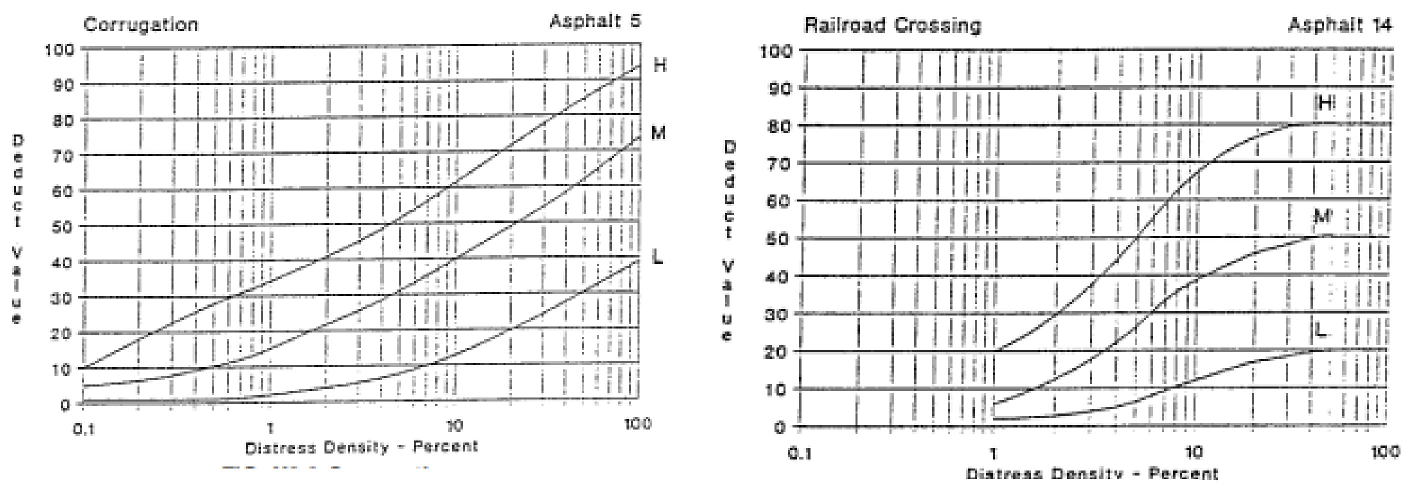


Figure 2-7 corrugation deduct value curve and Railroad deduct value curve

2.5.2.2 Corrected deduct the value (CDV)

The calculation of PCI was simply sum all deducts and subtract this total from 100 as:

PCI=100- ∑All Deducts (Total Deduct Values) ---------------Equation 2-3

The effectiveness of the PCI formula was evaluated using PMS software, including the Carte Graph software installed for the metro. However, when the PCI process was implemented by the Corps of Engineers and agencies for both roads and airfields, it was found that the PCI values obtained from the formula were lower than the ratings provided by field experts, especially when multiple distresses were present in a sample unit. To address this issue, an adjustment procedure was developed to align the PCI with the performance-rated values. This adjustment involved introducing the concept of Corrected Deduct Values (CDV) into the calculation process and implementing a limit on the number of distress types that could be included. These adjustments aimed to improve the accuracy of the PCI calculation and ensure its agreement with expert ratings. (Ostom, 2019).

The 2-point measure is a visual inspection technique used to assess the severity of surface distresses on a scale ranging from 0 to 2. In this method, a rating of 0 indicates the absence of any distress, a rating of 1 represents a mild distress, and a rating of 2 signifies a severe distress. Various types of distresses, such as cracks, potholes, and rutting, can be evaluated using this 2-point measure (E.Pagan-ortiz, May 2014).

The 5-point measure is a comprehensive evaluation method that considers multiple factors, including roughness, cracking, and surface distresses, to assess the overall condition of a pavement surface. It utilizes a scale ranging from 0 to 5, where a rating of 0 indicates a newly constructed or recently resurfaced pavement surface, and a rating of 5 indicates a pavement surface that is severely distressed and in need of immediate repair or replacement. This method provides a more detailed and holistic assessment of the pavement condition.(A.R. Temimi et al., 2021).this one is used for this study.

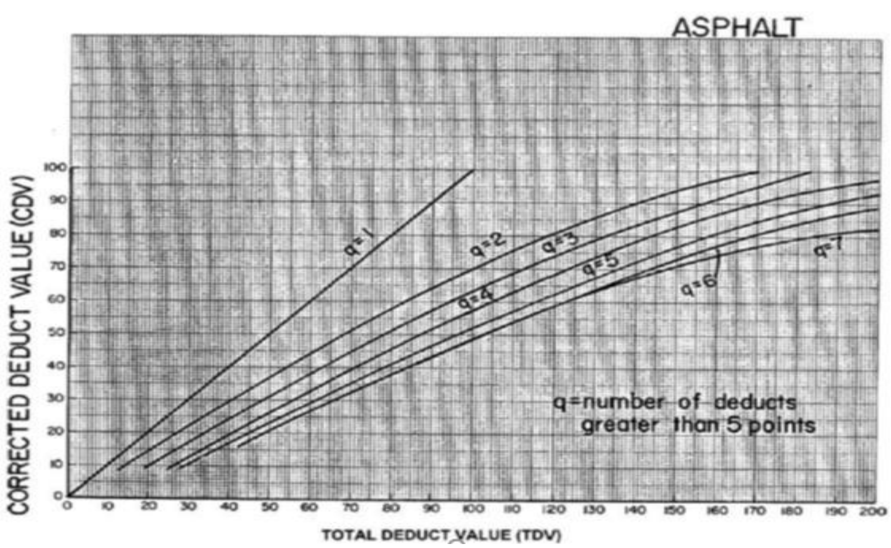


Figure 2-8 Corrected deduct value

Source: - ASTMD6433

2.6 Research gap

This study aims to fill a research gap by conducting a comprehensive analysis of pavement condition and geometric characteristics, with a specific focus on the mid-block section of road segments. Previous studies have often taken an average of parameters across segments, which may not provide accurate results for each segment. Furthermore, some researchers have suggested the need for a larger sample size and consideration of longer segments. In contrast, this study specifically targets the mid-block section and uses a representative length of segments and sample units. By doing so, it seeks to provide valuable insights into the impacts of pavement conditions, geometric characteristics, and peak hour flow on traffic performance.

CHAPTER THREE

3. Research Methodology and Materials

A Desk and field investigation are included in this methodology of the research various methodologies and techniques for data gathering and analysis used. To achieve the stated specific objectives, the study's methodology needed various tools and approaches. As a result, this section of the thesis outlines the technique used and the rationale behind the approach choices made to answer the research-specific objectives.

3.1 Research Approach

The methodologies used in this thesis were created in a way that would appropriately address the research-specific objectives. The study includes both quantitative and qualitative approaches. To assess the impacts of pavement condition and Geometric characteristics on Traffic performance of the chosen Mid-block road segments and show the effects of pavement distress on traffic performance, quantitative data, such as counted traffic volume, road characteristic measurements, Pavement condition survey and speed survey, as well as their analysis is used. Qualitative data on the other hand used to describe the quantitative results. The primary sources of quantitative are data primary data or actual field measurements and secondary data.

3.2 Description of Study Area

Addis Ababa is the capital city of Ethiopia, its area of this city is 1,127,127 km2 and Addis Ababa city has a total road network of 6537 km from which 2,763km of Asphalt 1,675 Gravel and 2,135 km of Coble stone. Generally, this city reached above 20% road network up to June, 2010e.c (Demisa, Speed hump effect on pavement condition for Addis Ababa City roads case study, 2020).

In urban street facility (Interrupted flow) analysis, the street is divided into two types of elements: points and links. Points represent the boundaries between links and are typically intersections or ramp terminals. Links represent the length of roadway between two points and are referred to as segments. A segment includes the link and its boundary intersections. An urban street facility is a continuous length of the roadway that is made up of contiguous urban street segments. These facilities are typically classified as either urban arterials or collector streets based on their function. By dividing the street into these individual elements, analysts can better understand how traffic flows through the system and identify areas where improvements can be made to increase safety and efficiency (National Research Council (U.S.). Transportation Research Board., 2010).

This study specifically focuses on the Mid-block section of urban arterials and collector streets in Addis Ababa to investigate and quantify the impacts of pavement condition and geometric characteristics on traffic performance to insight into different solutions in to mid-block section. To minimize the impact of different obstructions on speed, a site with no or minimal horizontal curves, signals, roundabouts and intersections was selected. Additionally, the study area includes a segment with two sections, one with distressed pavement and one without distressed pavement, to show specifically the impact of pavement condition on traffic performance.

Figure 3-1 Layout of Addis Ababa City Road network (Demisa, Speed hump effect on pavement condition for Addis Ababa City roads case study, 2020).

3.3 Required data for the studies

Both secondary and primary data are used for this study.

The study area for this research was selected using secondary data obtained from the Addis Ababa City Road Authority (AACRA) maintenance office.

Primary data: -refers to data that is collected directly by the researcher on-site, and it can be categorized into two types: dependent data and independent data.

- ✓ **Dependent data: -**Also known as response variables or outcome variables that are being measured or observed for this study.
  - **Average travel speed**: - The average travel speed is calculated by conducting a manual survey at each Sample unit of the pavement condition assessment taken until 100 vehicles have passed.
- ✓ **Independent variables: -** It is the variable that have an effect on the dependent variable, which is the outcome or result being measured. The independent variable for this studies are: -
  - **The pavement condition index (PCI): -** Is measured at a 100-meter sample unit in two sections: one section with distress and other sections without distress, both located in the mid-block of the segment.
  - **Traffic flow: -** The data for this study was collected during working days, specifically during peak hours in the morning and afternoon. The peak day/hour of traffic volume was determined through interviews with traffic police and drivers living in the study area and market day also considered. Furthermore, a survey was conducted at the same location to assess the pavement condition and travel speed.
  - **Road Gradient: -**The road grad of both sections surveyed with total station and leveling
  - **Number of lanes: -** The lane count was conducted on-site by physically walking across the area.
  - **Width of Carriageway: -** The on-site measurement is carried out using a meter for assistance
  - **Presence of walkway and its measurement:** - walkway measurement is taken on- site during carriageway width, presence of median and lane number taken survey taken.

3.3.1 Sample size

According to ASTM D6433, the minimum number of sample Sections(n) must be Surveyed within a given section to obtain a statistically adequate estimate (95 % confidence) of the PCI of the sections calculated using the following formula and rounding n to the next highest whole number.

$$n=\frac{NS2}{e2/_4((N-1)+s2)} \quad \text{..............................Equation 3-1}$$

Where:

e = acceptable error in estimating the section PCI; commonly, e=±5 PCI points;

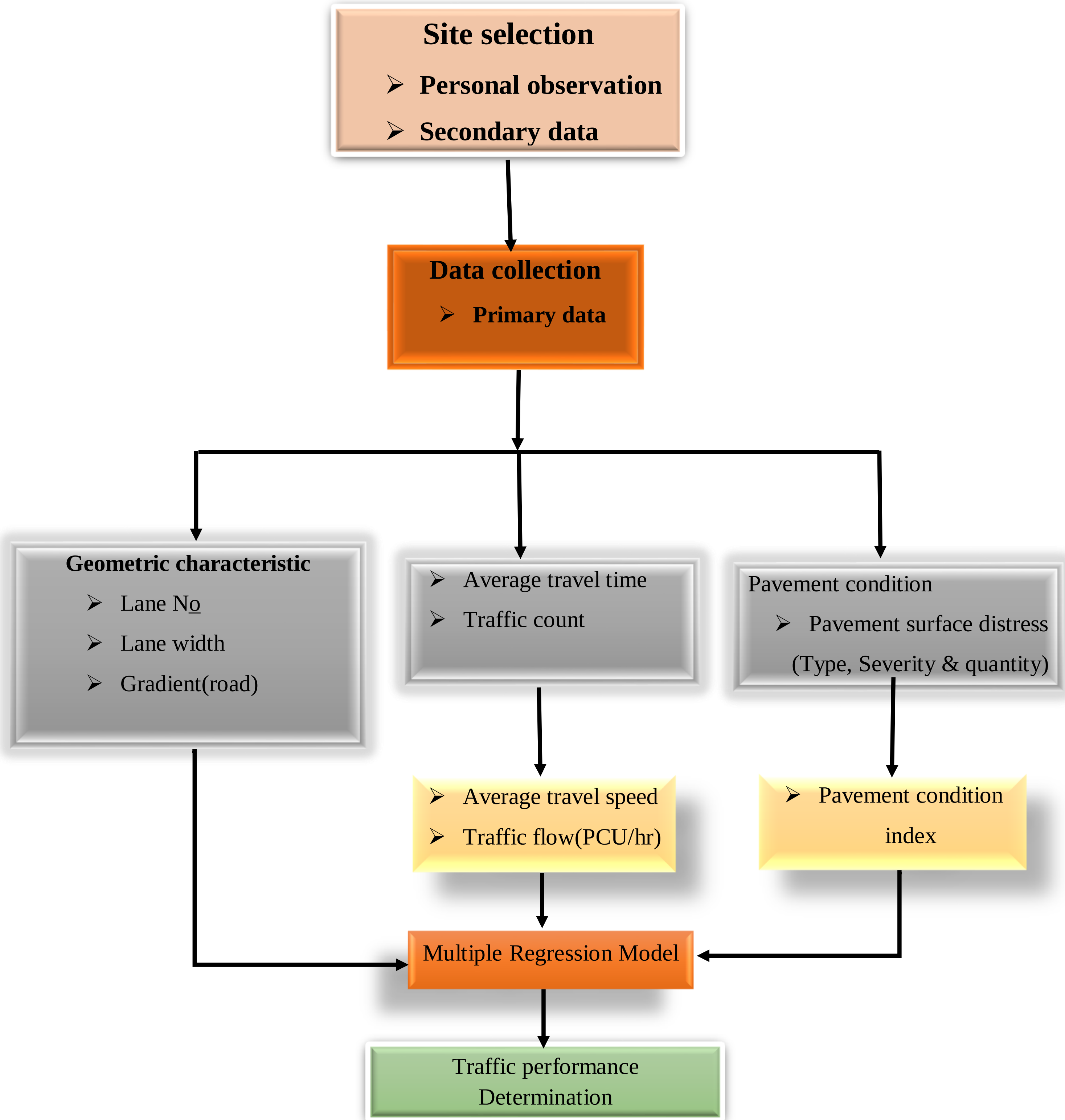
s = standard deviation of the PCI from one sample unit to another within the section. When performing the initial inspection, the standard deviation assumed 10 for AC pavements.

N = the total number of sections from the road segment.

Then, according to Equation 2.1, the minimum number of n inspected are as follows (Demisa, Speed hump effect on pavement condition, 2020)

$n = 11*10^2 / ((52/4)\,(11\text{-}1) + 10^2) = 6$, Where N=11 from Table 3.1 which is the total number of road segments that have been collected from the site.

3.4 Research Design(Procedure)



3.5 Description of Selected Study Area

The selection of the study area was based on a combination of personal observations and data from the AACRA pavement condition survey conducted in 2013 and maintenance data in 2015E.C. Eleven urban street facilities were chosen, with a total segment length of approximately 35.58 kilometers. To ensure a comprehensive analysis each roadway branch was divided into different sections and each section was divided into sample units for further investigation considering factors such as pavement design, traffic composition and road functional classification. This division allows for a more detailed examination of the various conditions and characteristics present in the study area (Materials, 2009)

Table 3-1 Name of street

Serial. No	Name of road		Length(km)	No of lane	Traffic flow direction	Presence of Median
	From	**To**				
1	From Deberezeit road	Glean Condominium	2	3	Two-way	No
2	Mesalemia	Medehanialem Sch.	2.2	3	Two-way	No
3	Medehanialem square	petrous square	1.4	4	Two-way	No
4	petrous square	Autobus Tra	1.3	3	Two-way	No
5	Leburound about	Lafto Betach	1.88	2	Two-way	No
6	Lafto Betach	St. Gofa Geberial	3.5	3	Two-way	No
7	Tikelhaimanot	Mexico square	2.4	3	Two-way	No
8	Dej zewdu aba korant	st.at gojiam beernda	1.7	4	Two-way	No
9	Coca-Cola	Mesalemia	2.8	3	Two-way	yes
10	Hana kelebet	Dama hotel	3	4	Two-way	no
11	Goro	Tuludimtu	13.4	8	Two-way	yes

Source: **-**Addis Ababa city road authority road Network and field measurement

From a total road segment three of them maintained before pavement distress survey taken, Goro to tuludimetu road segment dose not fulfill urban street facilities additionally due to time constraint only six segment selected for further investigation as follow.

Table 3-2 Name of Selected road segment for the Analysis

Serial No	Name of road		Length (km)	No of lane	C.W Width(m)	Traffic flow direction	Presence of Median	Average Walkway width
	From	**To**						
1	From Deberezeit road	Glean Condominium	2	3	10	Two-way	No	0
2	Mesalemia	Medehanialem Sch.	2.2	3	9.5	Two-way	No	0
3	Lafto Betach	Gofa Geberial	3.5	3	10.7	Two-way	No	0
4	Tikelhaimanot	Mexico square	2.4	3	10.5	Two-way	No	2.8
5	Coca-Cola	Mesalemia	2.8	3	10.5	Two-way	No	3.8
6	Hana kelebet	Dama Hotel	3	4	21.2	Two-way	Yes	2.7

Source: **-**Field survey

3.5.1 From Deberezeit road to Glean Condominium

The plan for the Deberezeit road leading to Glean Condominium involves upgrading it to a principal arterial street. However, the current functional classification of this road is a collector and it has been observed that the road pavement is deteriorated.

In 2015 E.C., only 0.74km of the total 2km length of this road segment was maintained. There is a distressed section of 0.9km that requires attention. However, the remaining 0.36km has a different function classification, so it was not included in this study.

To assess the impact of the pavement condition and geometric characteristics on traffic performance, necessary data was collected before and after the maintenance. plan view of the Mid-block is shown in **Figure 3-2.**

Figure 3-2 Deberezeit road to Glean Condominium

Source: -Google Earth

3.5.2 Mesalemia –Medehanialem Square

According to visual inspection, Mesalemia to Medehanialem Square is a deteriorated road pavement that measures 2.2km in length. From Ethio tebieb to Medehanialem Square. 1.06km Maintained on 2014 E.C and 1.14km is distressed section but the maintained section of the segment distresses pavement survey is taken. The pavement condition, average travel speed and Geometric characteristics were surveyed for both the maintained and distressed sections at the mid-block of the road. plain view of the Mid-block is shown in **Figure 3-3.**

Figure 3-3 Mesalemia –Medehanialem School

Source: -Google Earth

3.5.3 Lafto -Gofa Geberial

The mid-block segment from Lafto Betach to Gofa Geberial has a length of 3.5km. Out of this total length, approximately 1.8km is a non-distressed section.

To assess the impact of the pavement condition and geometric characteristics on traffic performance, data was collected at both the distressed and non-distressed sections.

It is important to note that after the maintenance, the segment has retained the same width, number of lanes, and walkway as it had before. This consistency in the physical characteristics of the road will help in evaluating the specific impact of the pavement condition on the road condition and traffic performance. plain view of the mid-block segment is shown in **Figure 3-4.**

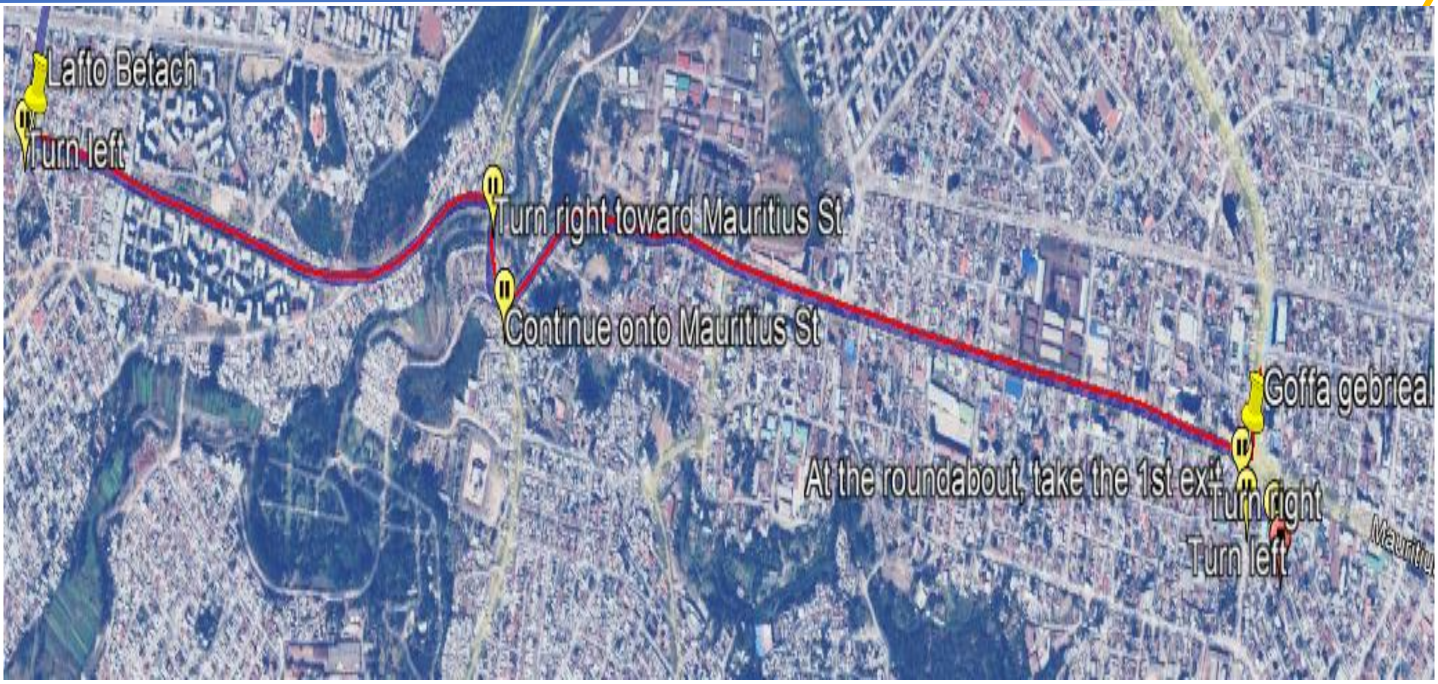


Figure 3-4 Lafto Betach to Gofa Geberial

Source: **-**Google Earth

3.5.4 Tikelhaimanot -Mexico square

The mid-block segment from Tikelhaimanot church through Tibur Anbesa Hospital to Mexico Square consists of both distressed and non-distressed sections. It is worth noting that both sections have the same width, number of lanes and walkway after the maintenance activities.

To comprehensively assess the overall condition of the road and identify areas that may require maintenance or repair, it is crucial to collect data on both the distressed and non-distressed sections.

Figure 3-5 Tikelhaimanot –Tikor Anbesa -Mexico square

Source: **-**Google Earth

3.5.5 Coca-Cola – Mesalemia (Coca-Cola, Building college to Mesalemia)

The plan of this road segment is Principal arterials but the existing segment is Classified as a collector and Only the mid-block segment section is taken for further investigation from Coca-Cola to Mesalemia. All data are taken for distressed(1.78km) and non-distressed sections(1.02km).

Figure 3-6 Coca-Cola To Mesalemia

Source: -Google Earth

3.5.6 Hana kelebet -Dama Hotel(saris)

Hana kelebet to dama Hotel road segment is classified as Sub Arterial street but Only the mid-block segment section is taken for further investigation from Hana Mariam kelebet to Dama Hotel and constructed in 2009E.c. All data are taken for the distressed and Non-distressed sections (1.53km maintained from lafto 58 to dama hotel).

Figure 3-7 Hana kelebet to dama hotel

Source: -Google Earth

3.6 Methods of Data Collection and Equipment

To test the specific objective of the study, data has been collected from primary and secondary sources. For both data sources recommended techniques and steps have been followed to minimize errors.

The primary data are collected using the following techniques:

- ✓ Personal observation
- ✓ Manual traffic volume counts
- ✓ Pavement condition index
- ✓ Manual travel time measure
- ✓ Field measures.

3.6.1 Personal Observation

Personal observation data was used for study area selection. Based on AACRA secondary data personal observation was held to select study areas that fulfill site selection criteria (having two sections distressed and Non-distressed or maintained urban street facility Mid-block).

3.6.2 Pavement condition survey

The visual pavement condition survey is made to measure different types of distress and severities of distress. The measurement includes pavement surface distress (longitudinal and transversal cracks, potholes, reveling, etc.). Permanent deformation such as fatigue crack, and patching.

Procedures of pavement condition survey offer a method for investigating pavement distress types, defining the levels of severity associated with each distress at 100m. The visual survey is made using commonly used recording formats and guidelines for determining pavement condition that involves observing and recording the presence of specific types and distresses on the pavement surface. Data conducted on March 13 and 20/2022, December 11 and 25/2023, May 24/2022, March 29/2023 and February 27 and 20/2022 at the study area

Equipment for this data collection

1. **Data sheet: -** The data sheet gives information about Date, Locations, surveyors, branch, section number, sample unit size, sample area, distress type, severity level quantity, density and deduct value as shown below.
2. Meter and ruler
3. Digital camera
4. Layout plan
5. Safety Equipment

Figure 3-8 Distressed and non-distressed sections of study area

Source:-Own site survey

Table 3-3 Data sheet table for pavement condition survey

Asphalt road surface and parking lots Condition Survey Data Sheet								
	Branch						Sample unit	
	Surveyed by:-						sample area:-	
Sample unit	Rutting		crocodile crack		Bleeding	Raveling		Shoving
	Area(m2)	Depth(mm)	crack width(mm)	Area(m2)	Area(m2)	Raveling depth(mm)	Area(m2)	Area(m2)
1						3	2.52	
						3.5	1.14	
2						4.2	15	
						4	3	
						3	7.5	
3	1*0.8	21						
4								
5			9	2.016	0.89			
6	3.6	25.5	20	3.08		0.8*0.9		
	32.5	26	19.5	3.5712	0.60*0.40	0.3*0.8		
7	4.125*8.253	7	26	4.34636		13	1.331	
	1.162*2.200	13				20		
						39		

Source:-Own site survey

3.6.3 Average travel Time

In the study on the effect of pavement condition on the level of service of the road segment, the travel time for average travel speed was conducted on-site by recording time by using a stopwatch for each vehicle crossing 100m at a visible location along each study area (Changula, 2020) and for this study travel time taken in 2014E.C(distressed section) and 2015E.c (non-distressed section) this record taken until cumulatively 100vechicle pass through each sample unit.

The speed variable is normally distributed and a large sample (≥ 30) was available to calculate the standard deviation, the z-statistic can be used instead of the t-statistic but here is below the most appropriate equation for speed sample size (Daniel, 2018) In this study Passenger Cars, minibuses and Buses will be considered.

$N=(S*K/E)^2$……………Equation 3-2

N=Number of Measured Speeds, S=estimated sample standard deviation, mph, K=constant corresponding to the desired confidence level and E=permitted error in the speed estimate, mph

Standard deviation = 5 mph=8.047 Km/h

Acceptable confidence level = 95%

Permitted error = 1 mph =1.609 Km/.h

The value of K at 95% is 1.96 using this value the sample size where N=100 per segment.

For a speed study at a selected location, a sample size of at least 50 and preferably 100 vehicles is usually obtained (Smith D. , 2002)

Average travel Time is collected manually with a watch and for this methodology, some key steps are used

Steps: -

1. Appropriate length (100m)

   For this study 100m is used since the study areas are cleared.

2. Appropriate locations which fittest to Pavement condition survey area is taken
3. Recorded elapsed observed time with stopwatch

4. Average travel speed calculated

5. Frequency distributed table generated to check the consistency of speed

A data conducted on march 13 and 20/2022, December 11and 25/2023, may24/2022, march 29/2023 and February 27 and 20/2022 at study area

Table 3-4 Average travel speed survey for distressed section sample

Date: 27,02,2022								Start Time:
Name: By Group	Section. 04		Sample unit:-05					End Time:
Location: Tikelhaimanot to Mexico								
Speed Limit: 30 mph								Weather: Clear
		passenger Vehicles		Bus		Trucks		Total frequency
Travel time	KPH for 100m	Record	frequency	Record	frequency	Record	frequency	
47.6	7.6	I	1			II	2	3
81.2	4.4			III	3			3
67.8	5.3	I	1	I	1			2
76.6	4.7	IIIII	5			II	2	7
53.5	6.7	I	1	III	2			3
78.3	4.6	I	1			I	1	2
52.4	6.9			III	2			2
72.4	5.0	II	2			I	1	3
56.0	6.4			I	1			1
43.0	8.4	IIIIIIIIII	10			IIII	4	14
61.5	5.9			II	2			2
74.6	4.8	IIIIIIII	8			I	1	9
58.5	6.2	IIIIIIIIIIII	12	III	2	I	1	15
68.0	5.3	IIIIII	6	IIII	4	III	3	13
58.0	6.2			I	1			1
54.0	6.7					I	1	1
69.7	5.2	IIIIII	6	III	3			9
89.5	4.0	IIIIIIII	7			III	3	10
SUM	1162.5							100
Average(travel time)	11.6							

Source: -Field survey

Table 3-5 Average travel speed survey for Non-distressed section sample

Date: 19,03,2023									Start Time:
Name: By Group	section. 05		Sample unit:-08						End Time:
Location: Coca-Cola to Mesalemia									
Speed Limit: 30 mph									Weather: Clear
		passenger Vehicles		Bus		Trucks			Total frequency
Travel time	KmPH for 100m	Record	frequency	Record	frequency	Record	frequency		
47.6	7.6			II	2	I	1		3
45.0	8.0	IIII	4			II	2		6
43.2	8.3	II	2	I	1				3
45.0	8.0	IIIIIII	6			II	2		8
53.5	6.7	I	1	III	2				3
48.4	7.4	I	1			I	1		2
52.4	6.9			III	2				2
44.5	8.1	II	2			I	1		3
28.0	12.9			I	1				1
43.0	8.4	IIIIIIIIII	10			IIII	4		14
38.0	9.5			II	2				2
41.3	8.7	IIIIIIII	8			I	1		9
48.0	7.5	IIIIIIIIIIII	12	III	2	I	1		15
36.6	9.8	IIIIII	6	IIII	4	III	3		13
42.9	8.4			I	1				1
32.8	11.0					III	3		3
49.7	7.2	II	2	III	3				5
51.4	7.0	IIII	4			III	3		7
Sum(travel time))	791.4								100
Average(travel time)	7.9								

Source: -field survey

3.6.4 Geometric characteristic measurement

To investigate the impacts of geometric characteristics on traffic performance, field measurements of selected geometric characteristics were taken in the study section. These included lane width, number of lanes and grade of the Mid-block. These measurements were taken to determine how these geometric characteristics affect traffic performance in the selected section. Data conducted on March 13 and 20/2022, December 11and 25/2023, May 24/2022, March 29/2023 and February 27 and 20/2022 at the study area.

Table 3-6 Field measurement for distressed section

No	Name of road		Length(km)	No of lane	C.W Width(m)	Median	Average Walkway width
	From	**To**					
1	From Deberezeit road to	Glean Condominium	0.9	3	10.5	No	0
2	Mesalemia	Medehanialem Sch.	1.14	3	10	No	0
3	Lafto Betach	Gofa Geberial	1.8	3	10.7	No	0
4	Tikelhaimanot	Mexico square	1.02	3	10.5	No	2.8
5	Coca-Cola -	Mesalemia	1.78	3	10.5	No	3.8
6	Hana kelebet	Dama Hotel	1.5	4	21.2	Yes	2.7

Source: -field survey

Table 3-7 field measurement for un-distressed section

No	Name of road		Length(km)	No of lane	C.W Width(m)	Median	Average Walkway width
	From	**To**					
1	From Deberezeit road to	Glean Condominium	0.74	3	10.5	No	0
2	Mesalemia	Medehanialem Sch.	1.06	3	10	No	0
3	Lafto Betach	Gofa Geberial	1.7	3	10.7	No	0
4	Tikelhaimanot	Mexico square	1.38	3	10.5	No	2.8
5	Coca-Cola -	Mesalemia	1.02	3	10.5	No	3.8
6	Hana kelebet	Dama Hotel	1.53	4	21.2	Yes	2.7

Source: - own field measurement

Figure 3-9 the boundary of maintained and distress section

Source:-own field measurement

3.6.5 Gradient of the segment

The gradient of a road refers to the slope or incline of the road surface. It is usually expressed as a percentage or a ratio of the vertical rise or fall of the road surface over a given horizontal distance. The gradient of a road can have a significant impact on the performance of vehicles, especially heavy trucks, as it affects their ability to maintain speed and control. Road grades are typically designed to meet certain standards and regulations to ensure safe and efficient travel for all types of vehicles. data conducted on March 13 and 20/2022, December 11and 25/2023, May 24/2022, March 29/2023 and February 27 and 20/2022 at the study area

Table 3-8 Coca cola to Mesalemia survey data at the center

Easting	Northing	Elevation	Description
470316.156	996469.435	2368.761	EX. CL
470316.133	996470.374	2368.737	EX. CL
470298.668	996470.098	2367.364	EX. CL
470298.735	996469.096	2367.31	EX. CL
470280.66	996468.677	2365.887	EX. CL
470280.667	996469.827	2365.849	EX. CL

470268.098	996468.765	2364.964	EX. CL
470268.282	996469.997	2364.994	EX. CL
470260.447	996471.512	2364.402	EX. CL
470259.898	996468.643	2364.383	EX. CL
470256.193	996472.91	2364.119	EX. CL
470255.016	996468.506	2364.044	EX. CL
470251.654	996468.484	2363.854	EX. CL
470250.467	996468.698	2363.789	EX. CL
470253.797	996473.928	2363.98	EX. CL
470250.609	996469.612	2363.787	EX. CL
470252.353	996474.383	2363.877	EX. CL
470194.846	996431.114	2361.289	EX. CL
470194.846	996431.114	2361.289	EX. CL
470213.788	996459.887	2362.562	EX. CL
470212.986	996459.837	2362.531	EX. CL

Source:-EZECO design departement

The survey data for Coca-Cola to Mesalemia and from Deberezeit road to glean condominium road taken from different consultants and contractors and the data conducted with total station at center, Left and right and a final grade conducted by average these three locations elevations divided by the length (100m) but for other section asphalt top reading taken with field survey approximately at the center of the road with leveling machine.

3.6.6 Traffic volume count

Traffic count conducted to execute traffic flow at Sample unit to investigate the effect of traffic flow on Traffic performance. In the study of the influence of pavement condition on headway and average travel speed traffic count conducted for one day to execute traffic flow(Sekhar & Verghese, 2020)

In the study of the influence of pavement distress on travel time 1.2km stretch was taken for assessment and data of pavement condition, travel time and traffic flow were taken. To assess the condition of the road pavement visual assessments were conducted from December 17th to

December 20th, 2012 during good weather conditions. Traffic data was collected on August 6th, 2012 during off-peak hours from 12 noon to 1:00 pm when the road was in bad condition. Another set of traffic data was collected on March 25th, 2013 after the road had been rehabilitated and opened for traffic. These data sets were collected to compare the impact of pavement conditions on traffic performance before and after rehabilitation(Matawal & Aitsebaomo, 2014)

A manual traffic count was held at different time for the study area, a traffic count for Mesalemia to Medehanialem were taken on 2014E.C at the distressed section and also for Tikelhaimanot to Mexico section but other section coca- cola to Mesalemia, lafto to St. Geberial, Hana kelebet to Dama hotel and from Deberezeit road to Glean condominium traffic count taken at different time in 2014 and 2015E.c.

Based on market day and information from traffic police and driver's data conducted at the study area on March 22/2022, May 24/2022, February 27/2022, December 11 and 25/2023, March 23/2023 and March 29/2023 is taken.

Table 3-9 Traffic count for from Deberezeit road to glean Condominium

From Deberezeit road to glean Condominium

Distressed section

Roads and highways Department Traffic count sheet Sheet 01

Name of Roads From Deberezeit road to glean Condominium Road Numbers :- Section 01 Date 13/07/2014

Enumerator :-Hewn supervisor Yematawork

Sample unit 01 megabit

	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajaj	motor cycle	bicycle	Gari	
sample unit 01	8:30-8:45	4	3		4	16	11	42	20	1	1	1	
	8:45-9:00	*1*		*3*	*7*	*11*	*22*	*32*	*32*	*2*		*3*	
	9:00-9:15	3		1	4	21	17	30	25		1		
	9:15-9:30	3	1	4	8	23	14	35	20	1	2		
	PCU multiple	11	4	8	23	71	64	139	97	4	4	4	
	Total	22	8	16	46	142	64	139	39	1	1	3	480

Roads and highways Department Traffic count sheet Sheet 02

Name of Roads From Deberezeit road to glean Condominium Road Numbers :- Section 01 date 12/07/2014

Enumerator :-sosi supervisor Yematawork

	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajaj	motor cycle	bicycle	Gari	
sample unit 02	8:30-8:45	2	3	2	1	8	12	25	15	1	1		
	8:45-9:00	*1*		*1*	*3*	*10*	*20*	*44*	*28*	*2*		*2*	
	9:00-9:15	2	1		1	22	15	24	25		1		
	9:15-9:30			4		4	15	32	26	1	2		
	PCU multiple	5	4	7	2	44	62	125	94	4	4	2	
	Total	10	8	14	4	88	62	125	38	1	1	1	352

Roads and highways Department Traffic count sheet Sheet 03

Name of Roads From Deberezeit road to glean Condominium Road Numbers :- Section 01 date 13/07/2014

Enumerator :-Hewn supervisor Yematawork

	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajaj	motor cycle	bicycle	Gari	
sample unit 03	11:00-11:15	1	1		2	5	2	11	5		1		
	11:15-11:30	*1*		*3*	*4*	*3*	*1*	*6*	*7*	*1*		*1*	
	11:30-11:45		2			4	10	1	9		1		
	11:45-12:00			4		3	5	4	8	1			
	PCU multiple	2	3	7	6	15	18	22	29	2	2	1	
	Total	4	6	14	12	30	18	22	12	1	0	1	119

Source:-own field measurement

Table 3-10 Hana kelebet to Dama hotel Traffic volume

Hana Kelebet to Dama hotel

Distressed section

Roads and highways Department Traffic count sheet Sheet 01

Name of Roads Hana Kelebet to Dama Hotel Road Numbers :- Section 06 Date 18/04/2015

Enumerator :-Hiwet supervisor Yematawork

	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajaj	motor cycle	bicycle	Gary	
sample unit 01	8:30-8:45	2	1		6	28	32	56	23	4	1	1	
	8:45-9:00	*5*	*3*	*3*	*8*	*21*	*25*	*50*	*32*	*5*		*3*	
	9:00-9:15	4		1	11	32	32	33	25		6		
	9:15-9:30		1	4	8	35	28	21	24	1	2		
	PCU multiple	11	5	8	33	116	117	160	104	10	9	4	
	Total	22	10	16	66	232	234	320	104	3	2	3	1011

Hana Kelebe to Dama hotel

Distressed section

Roads and highways Department Traffic count sheet Sheet 02

Name of Roads Hana Kelebet to Dama Hotel Road Numbers :- Section 06 date 18/04/2015

Enumerator :-Dawit supervisor Yematawork

	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajaj	motor cycle	bicycle	Gari	
sample unit 02	8:30-8:45	4	3		4	16	32	65	2	1	1	1	
	8:45-9:00	*1*		*3*	*7*	*11*	*26*	*56*	*8*	*2*		*3*	
	9:00-9:15	3		1	4	21	20	45	25		1		
	9:15-9:30	3	1	4	8	23	34	66	20	1	2		
	PCU multiple	11	4	8	23	71	112	232	55	4	4	4	
	Total	22	8	16	46	142	112	464	22	1	1	3	837

Source:-own field measurement

3.7 Methods of Analysis

3.7.1 Pavement condition index

A pavement condition index (PCI) is a numerical value between 0 and 100 used to grade the conditions of pavement surface which is developed by experienced engineers, based on a user-defined scale.

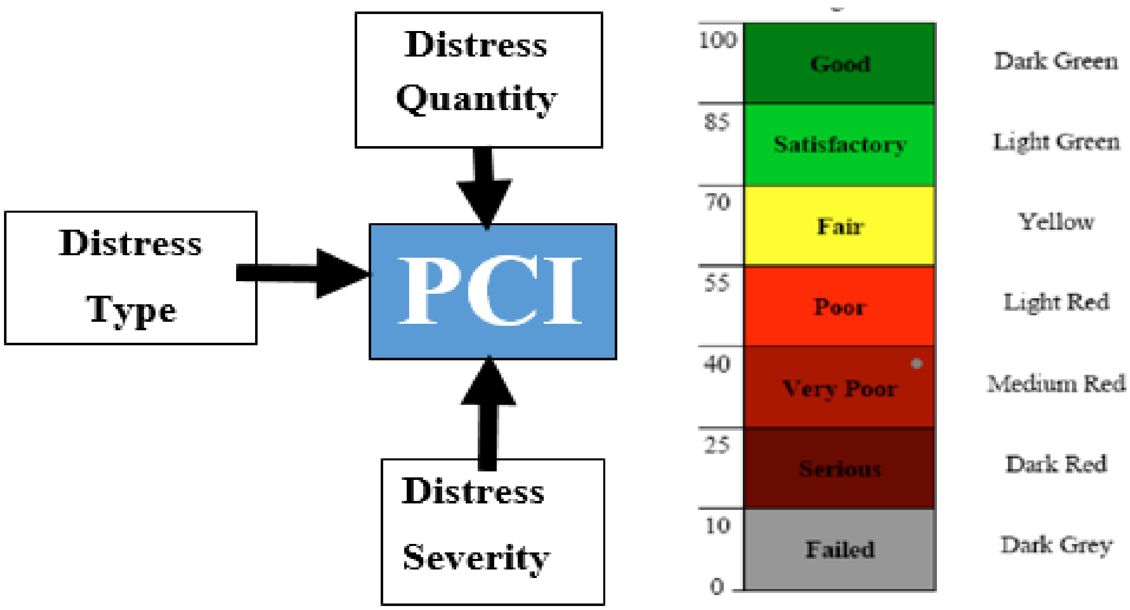


Figure 3-10 Pavement condition index Procedures (ASTMD6433)

Source: - ASTMD6433

During pavement condition surveyor walks over each sample unit of the sections records distress type and measures each distress extent, by using the equipment mentioned above.

PCI calculation is done based on ASTMD6433 which involves the following steps:

1. Inspecting each sample unit and record distress
2. Determining Densities of the distress and add up
3. Determine Deduct values

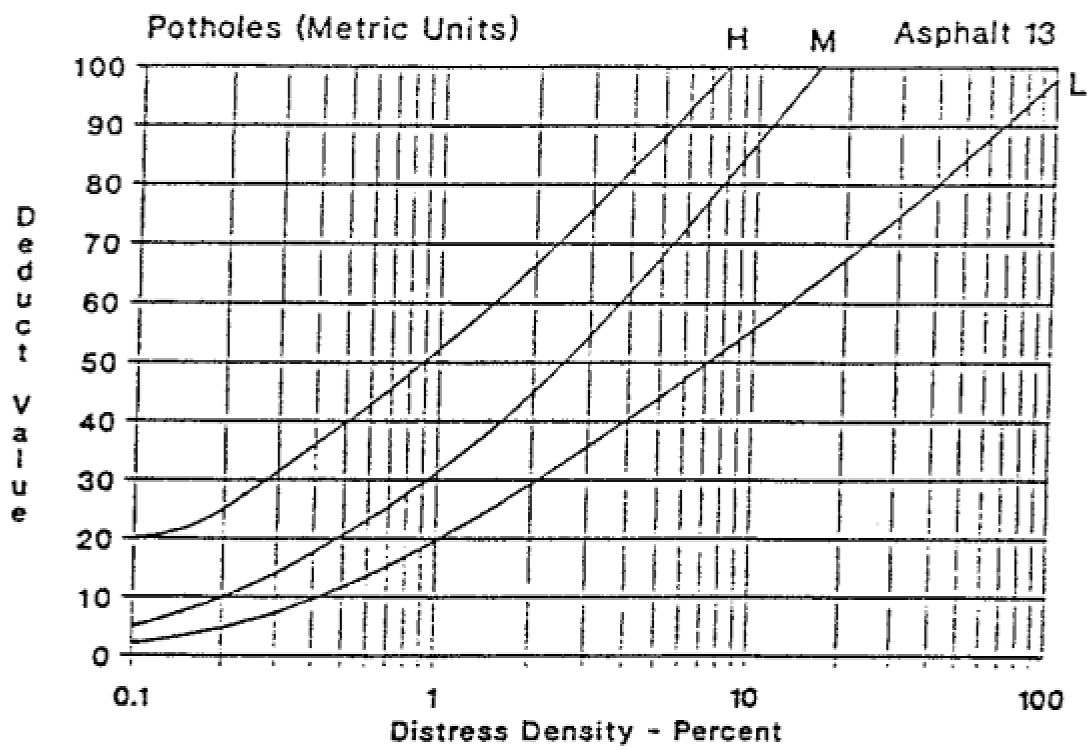


Figure 3-11 Deduct values for Potholes (ASTM standard D6433)

Source: - ASTM standard D6433

4. Determine Total deduct value (TDV)

The total deduct value is a sum of deduct values based on deduct numbers (q) and this value is used to determine the corrected deduct value (CDV).

5. Computing Corrected Deduct values(CDV)

This value is taken from the corrections curve and the procedures for computing CDV is as follow

- If none or only one individual deduct value is greater than two, sum all DV and use in the place of maximum CDV to determine PCI value, else maximum CDV must be determined using the following procedures
    a) List the individual deduct values in descending order
    b) Determine the allowable number of deducts

$m = 1\frac{9}{98}(100 - HDV) \leq 10$……...Equation 3-3

Where; m= is allowable number of deduct value including fractions (but must or equal to 10)

HDV=Highest deduct value

c) The number of deduct values reduced to m including fractions if less than (m) deduct value presents all of the deduct value used.

d) Iteratively determine the maximum corrected deduct value

To determine this maximum corrected, deduct value from correction curve Total deduct value and deduct number is used. During iteration Reduce the smallest individual deduct value greater than 2.0 to 2.0

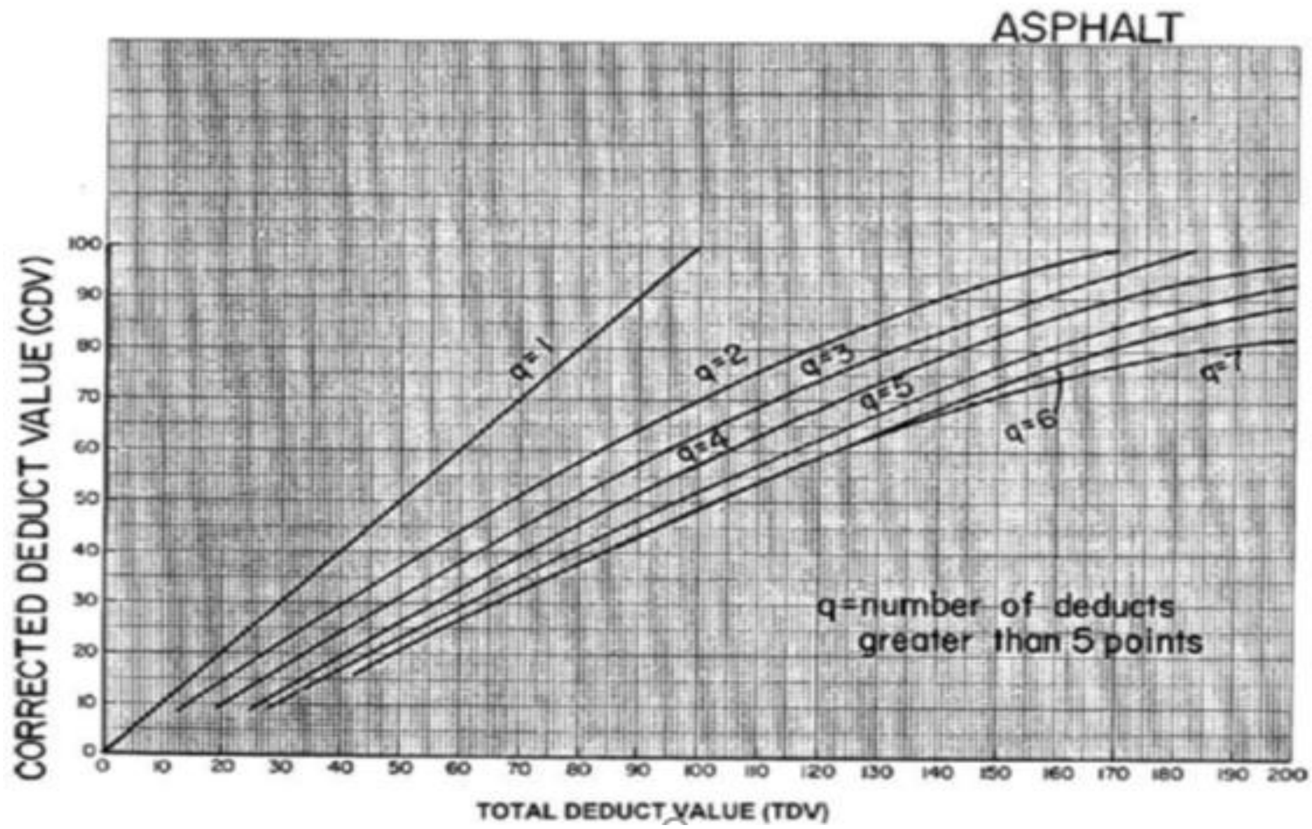


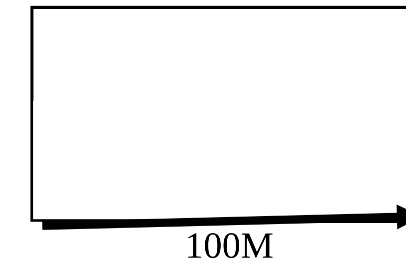
Figure 3-12 Total deduct value(ASTM standard D 6433)

Source: - ASTM standard D6433

Table 3-11 PCI determination with 100m block at Mesalemia to Medehanialem Square

Asphalt road surface and parking lots
Condition survey data sheet
For Sample unit

Sketch



100M

Survey Direction

Branch:- Mesalemia to Medehanialem square **section :- 09** **sample unit:-**

Surveyed by: Group **date:-___________** **sample area:-210m2**

1.Alligator cracking(m2)	6.Depression(m2)	11.paching/utility cut patching(m2)	16.Shoving(m2)
2.Bleeding(ml)	7.Edge cracking(ml)	12.polishing Aggregate(m2)	17.Silppage cracking
3.Block cracking(ml)	8.Reflection cracking	13.potholes	18.Swell
4.Bump or sag	9.Lane/shoulder drop off	14.Rail road crossing(mL)	19.Weathering and Raveling(m2)
5.Corrugation(m2)	10.long or trans cracking(ml)	15.Rutting(m2)	

sample unit No.	Distress severity	Quantity							Total	Density	Deduct
13	13M	6	2.5088	11.6162					20.1	9.6	84
	15M	2.1							2.1	1.0	29
	15L	2.34							2.34	1.1	9

m=1+(9/98)*(100-HDV)
m=1+(9/98)*(100-84)=2.47
Use highest 2 deducts and 0.47 of Three deduct
5.4

Iteration No	DV			q	TDV	CDV
1	84	29	2	2	115	78
2	84	2	2	1	88	86

14

Max CDV =86
PCI = 100- Max CDV =14

Rating =Serious

3.7.2 Average travel speed

Speed is an important consideration in transportation since it relates to safety, time, comfort, convenience, traffic conditions and economics (Smith D. , 2002).

The average travel speeds or median speed of vehicles will be computed as 50 percentiles from the cumulative frequency-speed curve (Smith D. , 2002)

There is steps to find 50^{th} percentile speed

- ✓ Obtaining Average travel speed at each sample units for each vehicle type
- ✓ Add up each number of vehicles
- ✓ Placing a speed in ascending order
- ✓ Finding vehicle number cumulative
- ✓ Finding frequency cumulative percent

$$S_D = \frac{P_D - P_{min}}{P_{max} - P_{min}}(S_{max} - S_{min}) + S_{min}$$ ----------------Equation 3-4

And 50^{th} percentile speed calculated by using this formula.

3.7.3 Traffic flow

To analyze manually counted traffic volume a passenger car unit (PCU) and peak hour volume are used. This is a numerical value for different types of vehicles based on their impact on traffic flow compared to a standard passenger car. From this analysis peak- hour traffic flow is obtained.

3.7.4 Gradient of the segment

A survey data was conducted using leveling techniques to determine the elevation difference along a segment. The elevation difference was divided by a distance of 100 meters and then multiplied by the 100, to be expressed as a percentage. This process allowed for the calculation of the gradient of the segment, which indicates the steepness or slope of the road.

3.7.5 Statistical Analysis and Model development

To assess the effects of pavement condition and geometric characteristics on traffic performance, a multiple regression analysis was conducted.

In addition, a comparison of travel speeds was conducted between the distress and non-distress sections of the segment. This comparison aimed to examine the impact of pavement conditions on travel speed. By analyzing these factors, the study aimed to understand how pavement conditions and geometric characteristics influence traffic performance, providing valuable insights for transportation planning and management.

CHAPTER FOUR

4. Result and Discussion

The collected data was analyzed using the appropriate and most effective method for the selected mid-block or link of the road segment. The results of the analysis are presented in the following sections along with a brief explanation

4.3 Data composition

The composing of the data to maximize sample size and while the size of the sample becomes higher the model becomes more accurate. There are six mid-blocks for this study and from those based on Geometric characteristics and traffic composition four (Mesalemia-Medehanialem Sch. And Lafto Betach –Gofa Geberial and Coca-Cola to Mesalemia and Tikelhaimanot –Mexico Square) segments are composed for further investigation

Table 4-1 Table of Comparison segments for data composing

No	Name of road		Functional Classification		Length (km)	No of lane	C.W Width (m)	Median	Average Walkway width	Traffic Compostion	**Road Gradeint**
	Fom	To	AACRA	Existing							
1	From Deberezeit road	Glean Condominium	P.A.S	Collector	2	3	10.5	No	0	Truck %higher	
2	Mesalemia	Medehanialem Sch.	P.A.S	Collector	2.2	Similar	Similar	Similar	Similar	Similar	Similar
3	Lafto Betach	Gofa Geberial	P.A.S	Collector	3.5						
4	Tikelhayimanut	mixco square	P.A.S	Collector	2.4	Similar	Similar	Similar	Similar	Similar	Similar
5	Coca-Cola	Mesalemiya	P.A.S	Collector	2.8						
6	Hana kelebet	Dama Hote	S.A.S	S.A.S	3	4	21.2	Yes	2.7		
Total Length(Km)			**16**								

Where: -P.A. S-Principal Arterial Street, S.A.S-Sub Arterial street

From the above summary, Deberezeit road to Glean condominium due to high heavy truck flow this mid-block analysis was executed individually since traffic composition affects travel speed but Mesalemia- Medehanialem to Medehanialem square and Lafto Betach to St. Geberial has similar Geometric characteristic, traffic composition and Grade of road and also Tikelhaimanot-Mexico square and Coca-Cola to Mesalemia has similar Geometric characteristic with a tolerable walkway width, traffic composition and Grade difference the data composed for a better analysis However, the functional classification of Hana kelebet to dama hotel is difference and this segment analysis alone.

4.4 Detailed data analysis Result

4.4.1 Distress distribution

A pavement condition survey is a process of evaluating the condition of a road pavement surface. It involves the collection of data on the pavement surface distresses, roughness and other factors that affect its performance. The survey is conducted to determine the current condition of the pavement and to identify the impacts of pavement conditions on traffic performance.

After conducting a pavement condition survey on the Deberezeit road to Glean Condominium mid-block, it was found that the road had several surface distresses. The survey identified potholes and alligator cracking as the most dominant surface distress, accounting for 64.1% and 8% of the total surface distress, respectively. On the other hand, the smallest surface defect relative to the others was the railroad crossing, accounting for only 0.5% of the total surface distress.

The pavement condition survey conducted on the Mesalemia-Medehanialem Sch. Mid-block revealed the presence of multiple surface distresses. The survey found that corrugation and alligator cracking were the most prevalent surface distresses, accounting for 16.7% and 14% of the total surface distress, respectively. In contrast, the bump or sag had the smallest surface defect relative to the other distresses, accounting for only 0.5% of the total surface distress.

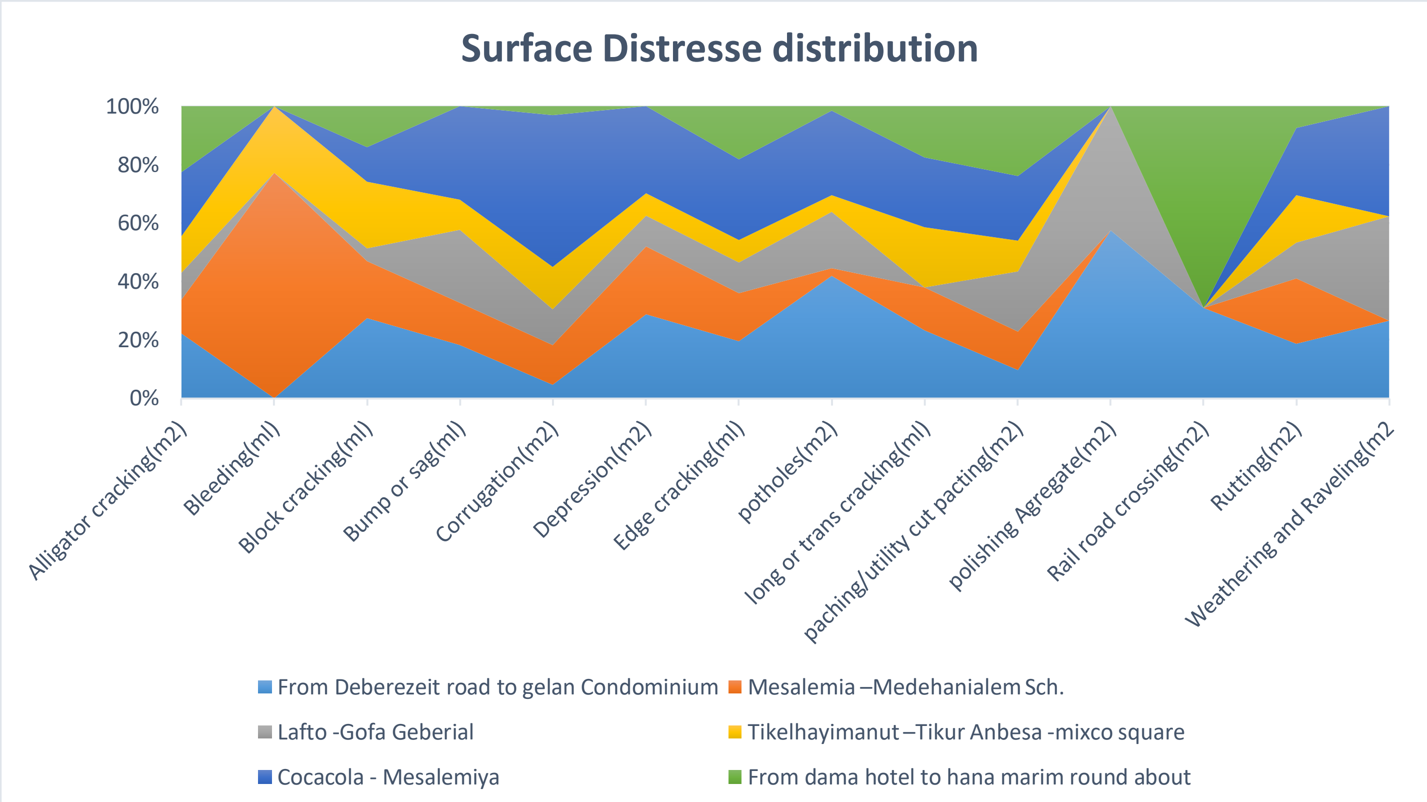


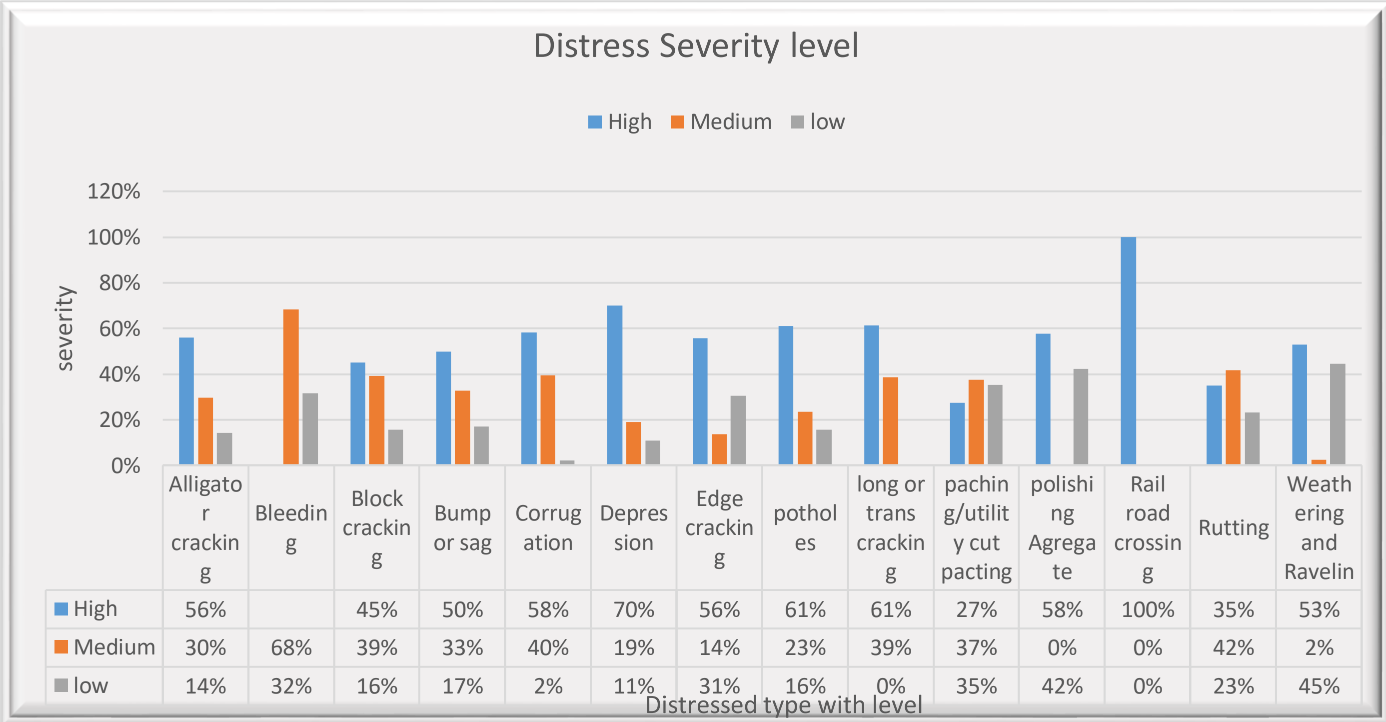
Figure 4-1 Surface distress distribution in each section of the study area

After conducting a pavement condition survey on the lafto to Gofa Geberial mid-block, it was discovered that several surface distresses were present. The survey revealed that the most common surface distresses were potholes and corrugation, accounting for 54.4% and 8.2% of the total surface distress, respectively. Conversely, the depression was the smallest surface defect in comparison to the other distresses, accounting for only 0.5% of the total surface distress.

For the other sections, such as Coca-Cola to Mesalemia and Tikelhaimanot to Mexico, potholes were the dominant surface distress. However, for the section from Hana kelebet to Dama Hotel, alligator cracking was the most prevalent surface distress. It is important to note that the type and severity of surface distress can vary depending on the location and conditions of the road.

4.4.2 Distressed severity level

Distress severity level in pavement condition refers to the degree of severity or extent of damage or distress on the study area's pavement surface. It is determined by evaluating the type, size, and extent of the distress. The severity level is classified into low, medium, and high, depending on the extent and severity of the distress. The severity level is an important factor in determining the overall condition of the pavement surface and showing the impacts of pavement condition on traffic performance.



	Alligator cracking	Bleeding	Block cracking	Bump or sag	Corrugation	Depression	Edge cracking	potholes	long or trans cracking	pachin g/utility cut pacting	polishing Agregate	Rail road crossing	Rutting	Weathering and Ravelin
High	56%		45%	50%	58%	70%	56%	61%	61%	27%	58%	100%	35%	53%
Medium	30%	68%	39%	33%	40%	19%	14%	23%	39%	37%	0%	0%	42%	2%
low	14%	32%	16%	17%	2%	11%	31%	16%	0%	35%	42%	0%	23%	45%

Figure 4-2 Severity Level

Figure 4-2 displays the percentage of different types of distress, including alligator cracking, railroad crossings, potholes, and depression, observed in the study area. The data reveals that 56% of the observed alligator cracking is classified as high severity, 30% as medium severity, and 14% as low severity; 100% of the observed railroad crossing is classified as high severity; 61% of the observed pothole is classified as high severity, 23% as medium severity, and 16% as low severity; and 70% of the observed depression is classified as high severity, 19% as medium severity, and 11% as low severity.

4.4.3 Pavement condition index

A visual inspection of the pavement surface and evaluation of the type, severity and extent of any surface distresses, such as cracks, potholes and rutting, are conducted. The data collected during the inspection is then used to calculate the PCI value for the pavement surface. The PCI value is used to show the impacts of pavement condition on traffic performance by taking traffic performance indictor Average travel speed at distressed and non-distressed sections of each segment.

Table 4-2 pavement condition index value of each section in every sample unit

Hana kelebet to Dama hotel

Distress section — Non-Distresses

Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Distressed	48	47	41	22	43	37	29	37	33	29	19.5	24	31	36	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Suggested color																												

Mesalemia to Medehanialem square and Lafto -St. Geberial

Sample unit	1	2	3	4	5	6	7	8	9	10	1	2	3	4	6	8	12	13	14	15	16						
Distressed Rating	40.2	50	34	51	24	25	38	42	14	28	30	35	32	24.7	33.7	28	29.4	32	33	19	31						
Suggested color																											
Sample unit	11	12	13	14	15	16	17	18	19	20	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
maintained	100	100	100	100	100	100	100	100	100	100	100	99	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Suggested color																											

From Deberezeit road to Glean condominium

Distress section — Un-distress section

Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Distressed Rating	46	42	4	6	24	26	23	100	100	100	100	100	100	100
Suggested color														

Coca-Cola to Mesalemia and Tikelhaimanot to Mexico

Sample unit	1	2	3	4	5	6	7	18	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Distressed	45	34	42	33	23	26	29	37	18	16	21	24	19	34	22	43	37.4	51	47	38	36.4	37.6	20	36.9	34	28.5	33
Suggested color																											
Sample unit	8	19	20	21	22	23	24	25	14	15	17	18	22	24	25	26	27	28									
maintained	98	97	99	97	98	97	99	95	95	100	100	100	100	100	98	100	100	99									
Suggested color																											

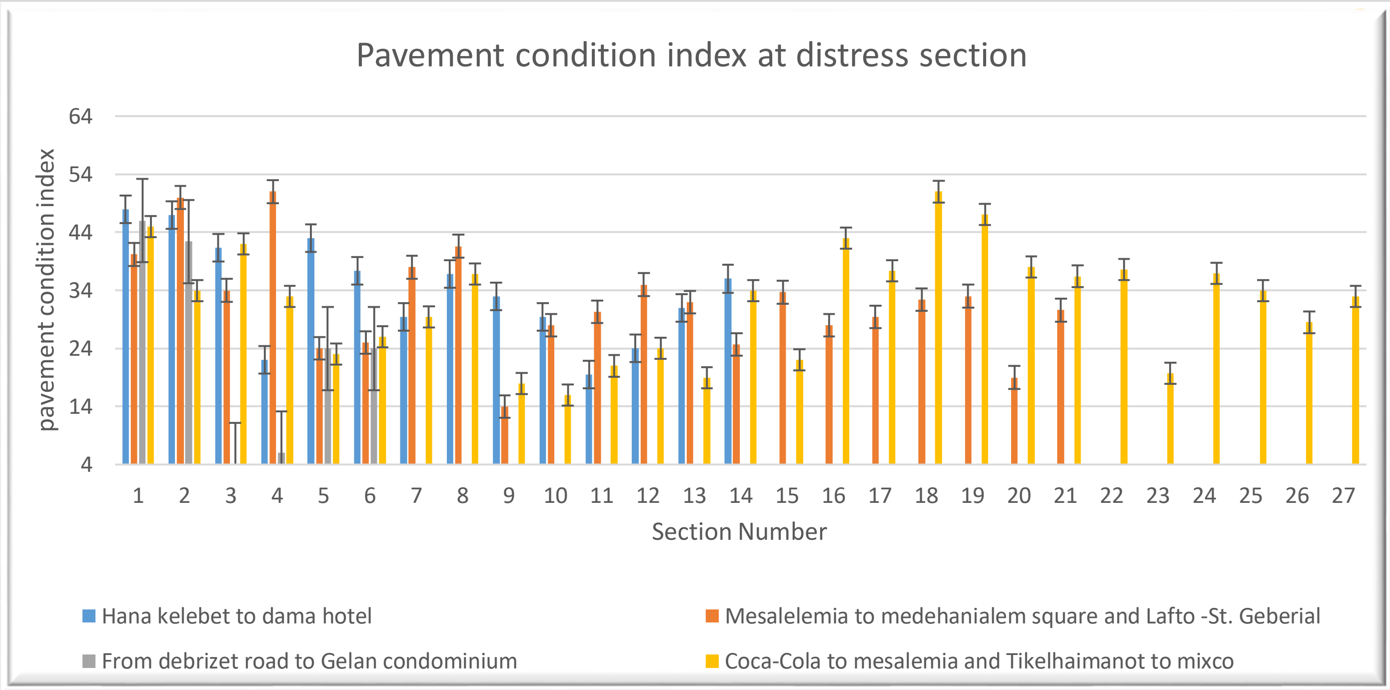


Figure 4-3 Pavement condition index at distressed section

Hana Kelebet to Dama Hotel Road Segment: The minimum PCI value is 19.5 at sample unit 11, and the maximum PCI value is 48 at sample unit 1, but the average PCI value on this road is 34.13. The average rating scale represents the pavement's condition as being in very poor condition.

The section from Mesalemia to Medehanialem Square and Lafto-St. Geberial has a range of distressed ratings from 14 to 51, with an average rating of approximately 32.09. The middle value, or median, of the ratings is 35. This means that the distress levels vary significantly along this section, with the highest rating recorded at 51 and the lowest at 14.

The pavement condition index value of the section from Deberezeit road to Glean condominium road is more distressed; the minimum PCI value is 4 and 6 at sample units 03 and 04, respectively, but the maximum PCI value is 46 at sample unit 01; however, the average PCI value in this road is 24.4 as per ASTMD 6433, which represents dark red (the distress is serious). Relatively, this road segment is more distressed due to different reasons.

Coca-Cola - Mesalemia and Tikelhaimanot - Mexico square road segments' minimum PCI value is 16 at sample unit 10, but the maximum PCI value is 51 at sample unit 18. However, the average

PCI value on this road is 32.06, it is medium red, and the pavement condition is very poor. Averagely road segment pavement condition index shows that, the pavement condition is very poor due to different reasons.

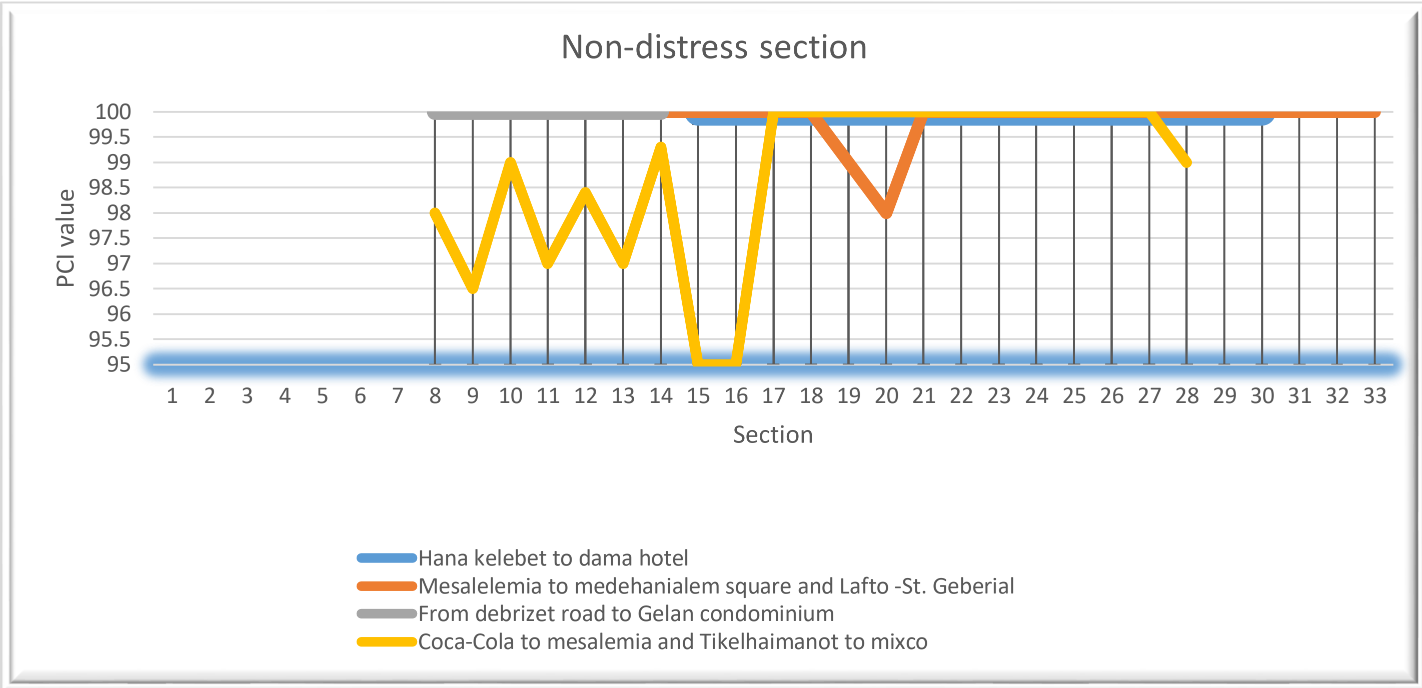


Figure 4-4 pavement condition index for maintain and non-distressed section

From the conducted data, Deberezeit Road to Glen Condominium, Mesalemia-Medehanialem Square, and Hana kelebet to Dama Hotel Road sections were maintained and had a pavement condition index rating scale of 100, which is excellent, but for the other sections, Coca-Cola-Mesalemia, lafto Betach-St. Geberial Ch. and Tikelhaimanot-Mexico segment is non-distressed, or a section that has a small defect but still rating excellent as per ASTMD6433.

4.4.4 Average travel speed

Travel time is conducted at free time for each section as per the number of segments, and to find the average travel speed, the average travel time is divided by each sample unit length converted into km/hr., and the 50th percentile is taken.

The 50th percentile is the average or median speed of the observed data set. This percentile represents the speed at which half of the observed vehicles are below and half of the observed vehicles are above a limited speed.(Moreau, 2002).

Table 4-3 Average travel speed data

Hana kelebet to dama hotel ATS(km/hr.)																													
	Distress section														**Un-Distrsess**														
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
D.ATS(Km/hr.)	41.9	37	28	21	36	32	26	27	20	21	14.6	19	20	28	45	44	46	44	48	50	55	48	56	46.7	53	57	56.4	52	
Mesalemia to Medehanialem square and Lafto -St. Geberial ATS(km/hr)																													
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21								
D.ATS(Km/hr.)	34	44	24	46	16	29	30	31	11	23	32	36	30	20.5	36	21	24	27	25	20	15								
Sample unit	11	12	13	14	15	16	17	18	19	20	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
Un.D.ATS(Km/hr.)	45	39	42	40	38	46	47	45	48	51	33	35	40	35.4	32	36	38	41	36	38	34	44	39	36.4	37	42	35.03		
From Deberezeit road to Glean condominium(km/hr.)																													
Distress section								**Un-distress section**																					
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14															
ATS(Km/hr.)	34	28	10	12	21	20	23	30	31	34	29	38	41	36															
Coca-Cola to Mesalemia and Tikelhaimanot to Mexico ATS(km/hr)																													
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
D.ATS(Km/hr.)	30.5	26	27	24	20	21	26	27	20	16	15	19	20	29.8	20.6	34	31.8	39	36	30	27.9	30	23	28.3	23	21.9	18.5		
Sample unit	8	19	20	21	22	23	24	25	14	15	17	18	22	24	25	26	27	28											
Un.DATS(Km/hr.)	35.1	37	42	45	38	41	36	44	43	31	32	36	41	34	38	42	37	38											

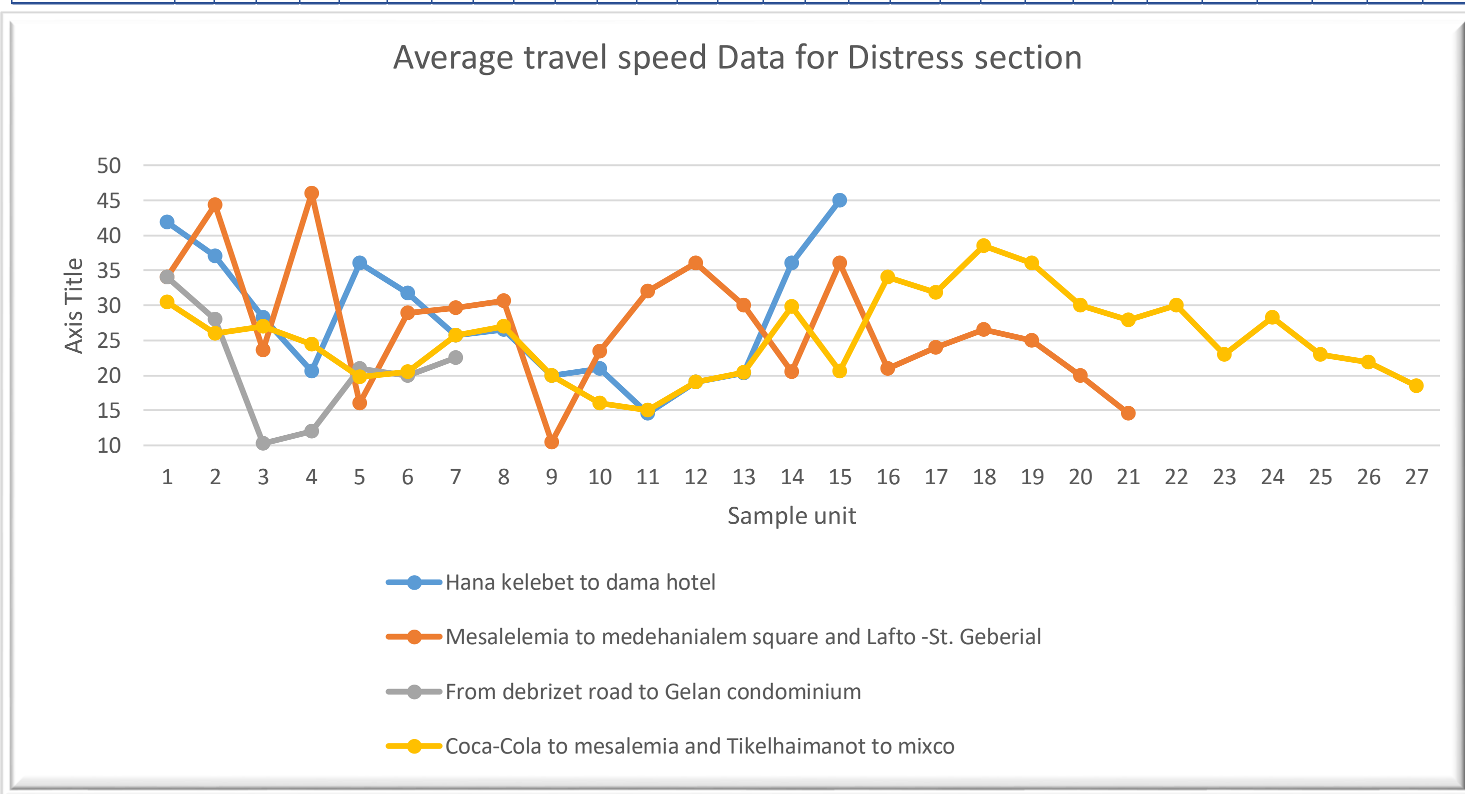


Figure 4 5 Average travel sped data distribution

The conducted data on average travel speed from Deberezeit to Glean Condominium indicates that the pavement condition is serious and the mean average travel speed is 21.114 km/hr, but other sections, such as Coca-Cola to Mesalemia and Tikelhaimanot-Mexico Square, Mesalemia-Medehanialem Square and Lafto Betach to St. Geberial Ch., indicate that the pavement condition of these sections is categorized as very poor. Despite this, the mean ATS value of these sections is better than that of the other section. The mean average travel speed for Coca-Cola to Mesalemia and Tikelhaimanot to Mexico Square is 25.35 km/hr, for Mesalemia-Medehanialem Square and Lafto Betach to St. Geberial Ch. is 27.26 km/hr, and Hana kelebet to Dama Hotel is 28.23 km/hr. This suggests that due to the pavement condition, Status has a relatively good travel speed compared to pavement that is in serious condition.

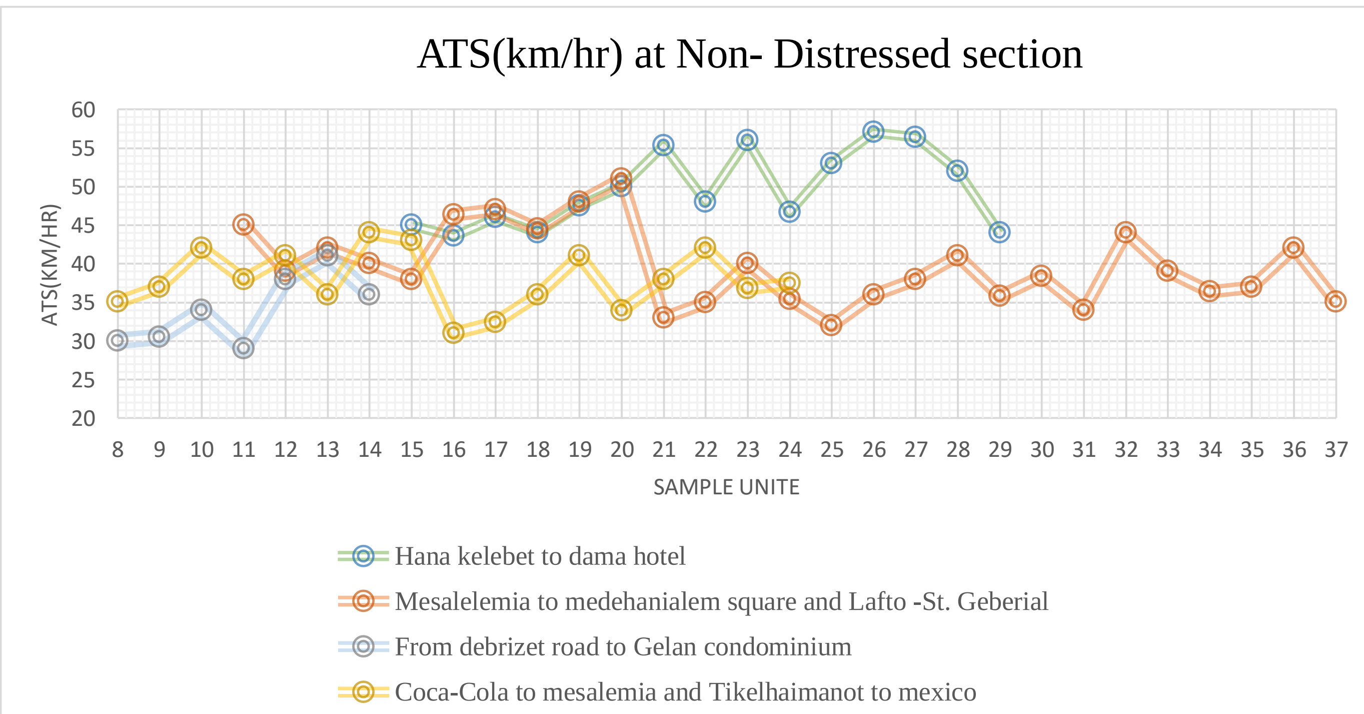


Figure 4-5 Average travel speed for Non-distressed section

The mean travel speed for four different routes on the non-distressed section has been calculated. The speed for Deberezeit Road to Glean Condominium is 34.1 km/hr, while the speed for Mesalemia to Medehanialem Square and Lafto Betach-St. Geberial Ch. Is 39.74km/hr. The speed for Coca-Cola to Mesalemia and Tikelhaimanot-Mexico Square is 37.92 km/hr, and the speed for Hana Kelebet to Dama Hotel is 49.64 km/hr.

4.4.5 Traffic flow

To minimize the impacts of cars, the peak-hour traffic flow data was adjusted by multiplying it by a factor known as the passenger car unit (PCU). This adjustment allows for a standardized measure of traffic flow that takes into account the varying sizes of different types of vehicles.

Table 4-4 Peak-hour Traffic flow at each section for every sample unit

Traffic flow (PCU/hr.) for Distress Sample unit																													
Hana kelebet to Dama hotel Traffic flow (PCU/hr)																													
	Distressed														**Un-Distrsess**														
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
(PCU/hr)	1011	837	327	154	743	654	453	148	129	121	98	120	104	543	1045	1004	145	345	546	287	534	1123	652	983	978	704	704	425	
Mesalelemia to medehanialem square and Lafto -St. Geberial Traffic flow (PCU/hr)																													
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21								
Distress(PCU/hr)	406	534	214	657	123	643	354	400	104	277	214	400	345	102	432	456	453	148	254	325	435								
Sample unit	11	12	13	14	15	16	17	18	19	20	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
un-Distress(PCU/hr)	567	1008	923	2351	456	1011	1011	1011	1011	1011	175	123	113	132	114	119	131	140	110	124	124	124	200	122	132	132	132		
From debrizet road to Gelan condominium Traffic flow (PCU/hr)																													
	Distressed							**Un-Distrsess**																					
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14															
(PCU/hr)	480	352	119	123	200	234	298	112	165	351	1021	130	145	234															
Coca-Cola to mesalemia and Tikelhaimanot to mixco Traffic flow (PCU/hr)																													
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Distress(PCU/hr)	213	213	145	123	142	234	298	343	187	135	112	236	246	657	255	765	645	1105	897	765	534	610	453	498	200	143	123		
Sample unit	8	19	20	21	22	23	24	25	14	15	17	18	22	24	25	26	27	28											
un-Distress(PCU/hr)	100	125	1021	1021	1021	1021	109	122	122	96	96	102	132	108	197	953	756	756											

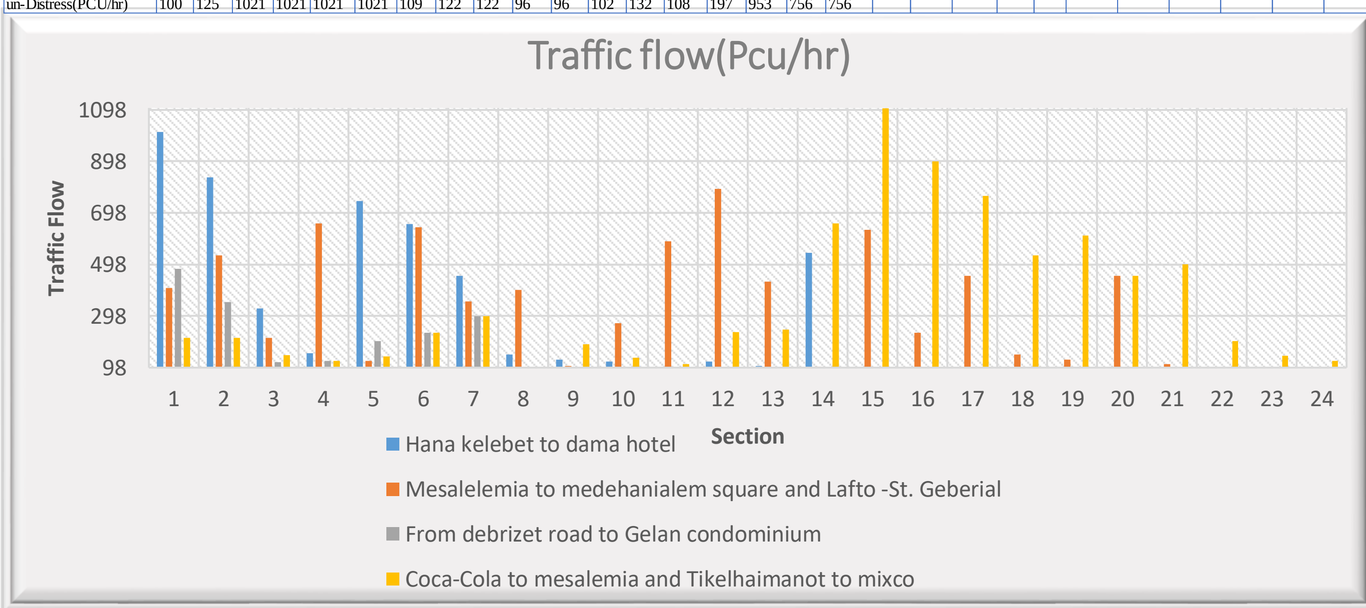


Figure 4-6 Data distribution for hourly Traffic flow

From the provided data, Hana kelebet to Dama Hotel, Mesalemia to Medehanialem and Tikelhaimanot to Mexico, which have pavement condition rating scales that are very poor, averagely have better traffic flow than the remaining study area sections. The average hourly traffic flow of Hana kelebet to Dama Hotel is 388.714, Mesalemia to Medehanialem and Lafto Betach-St. Geberial is 346.476 and Coca-Cola to Mesalemia and Tikelhaimanot to Mexico is 380.63PCU/hr.

4.4.6 Road Grade

The result of this road grade is taken by taking the average of center, left and right for two segments from Deberezeit Road to glean Condominium and Coca-Cola to Mesalemia but for other sections, due to time and budget constraints, approximately 100 meters of elevation at the center within 100 meters is taken.

Table 4-5 Study section Road Gradient

Segment road gradient Distress sample unit																												
Hana kelebet to dama hotel Gradient (%)																												
Distressed															**Un-Distrsess**													
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Gradient (%)	5.10	5.03	2.90	1.03	1.00	3.00	2.00	0.00	1.00	1.00	6.00	4.00	4.00	4.00	5.00	5.00	2.00	1.00	1.00	3.00	2.00	0.00	1.00	1.00	6.00	4.00	4.00	4.00
Mesalelemia to medehanialem square and Lafto -St. Geberial Gradient (%)																												
Distress section																												
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21							
D.Gradient (%)	3.00	2.90	2.60	3.40	2.00	2.40	3.00	3.30	1.00	1.70	0.00	1.00	1.00	1.00	1.00	4.00	3.00	1.00	2.00	1.00	6.00							
Sample unit	11	12	13	14	15	16	17	18	19	20	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
Un-D.Gradient (%)	2.50	1.40	1.00	1.00	2.00	1.60	1.00	3.00	3.01	2.90	5.00	4.00	3.50	1.40	2.20	1.02	1.00	1.00	1.00	1.10	1.30	2.30	1.50	1.00	6.00	5.40	3.80	
From debrizet road to Gelan condominium Gradient (%)																												
Distress section									Un-Distrsess																			
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14														
Gradient (%)	2.00	2.00	1.00	1.00	1.00	2.00	2.00	6.00	1.00	4.00	6.00	2.20	2.00	5.10														
Coca-Cola to mesalemia and Tikelhaimanot to mixcoGradient (%)																												
Sample unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
D.Gradient (%)	1.00	0.50	2.10	0.50	2.00	3.20	1.40	3.80	0.50	2.10	5.70	3.00	0.50	1.90	0.50	2.10	2.30	7.00	4.00	5.00	3.00	4.00	1.00	3.00	4.00	1.00	8.00	
Sample unit	8	19	20	21	22	23	24	25	14	15	17	18	22	24	25	26	27	28										
Un-D.Gradient (%)	2.2	3.00	1.00	1.00	0.50	0.60	1.00	9.00	8.30	1.70	1.00	2.70	3.20	2.80	2.00	2.90	1.00	1.80										

In this context, the minimum slope represents the least steep section of the road, while the maximum slope indicates the steepest section. The mean slope provides an average slope value across the sections of each road segment.

For example, on the Deberezeit Road to Glean Condominium (Section 01), the slope ranges from 0.5% to 2.3%, with a mean slope of 1.2%. This suggests that the majority of samples in this section have a relatively moderate slope. On the other hand, in the Coca-Cola to Mesalemia and

Tikelhaimanot to Mexico sections, the slope ranges from 0.5% to 7%, with a higher mean slope of 2.504%. This indicates a higher overall steepness in this section compared to others.

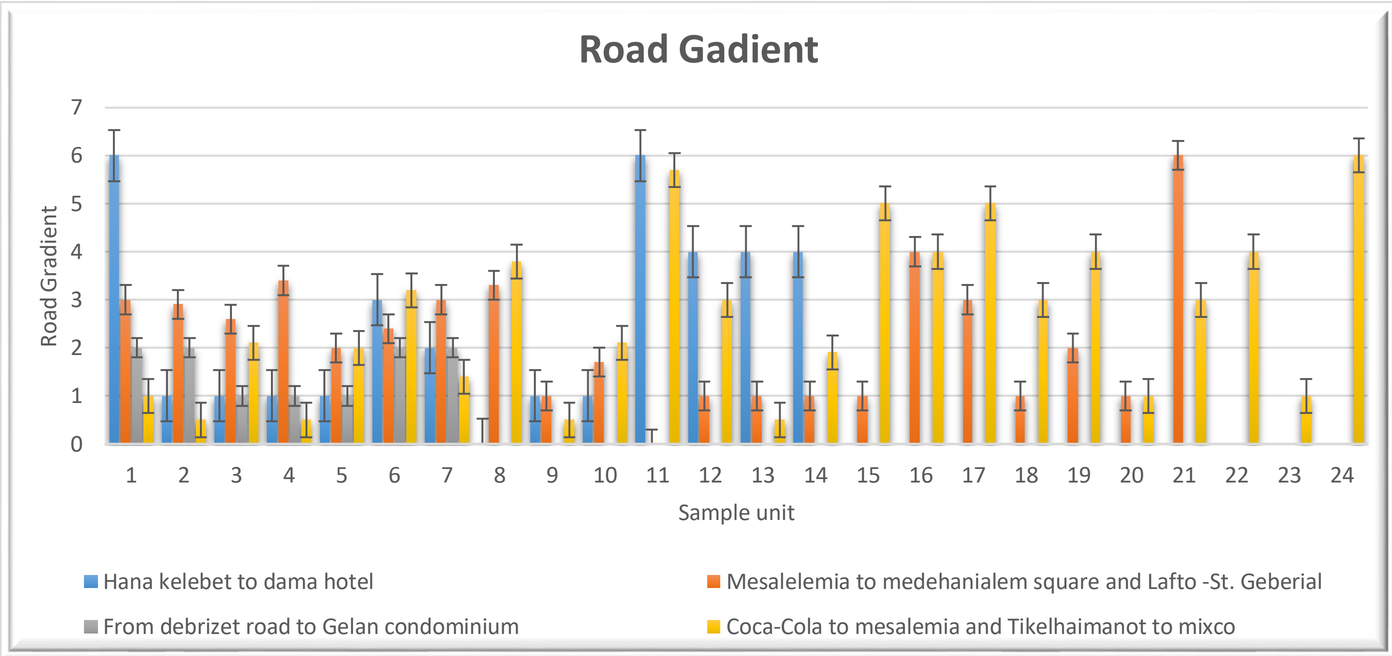


Figure 4-9 Road Gradient Data distribution for study area

The provided chart below shows the comparison of average pavement condition index, average travel speed, and geometric characteristics of different segments to show the consistency of the parameters and grade of the road at distressed sections and non-distressed sections.

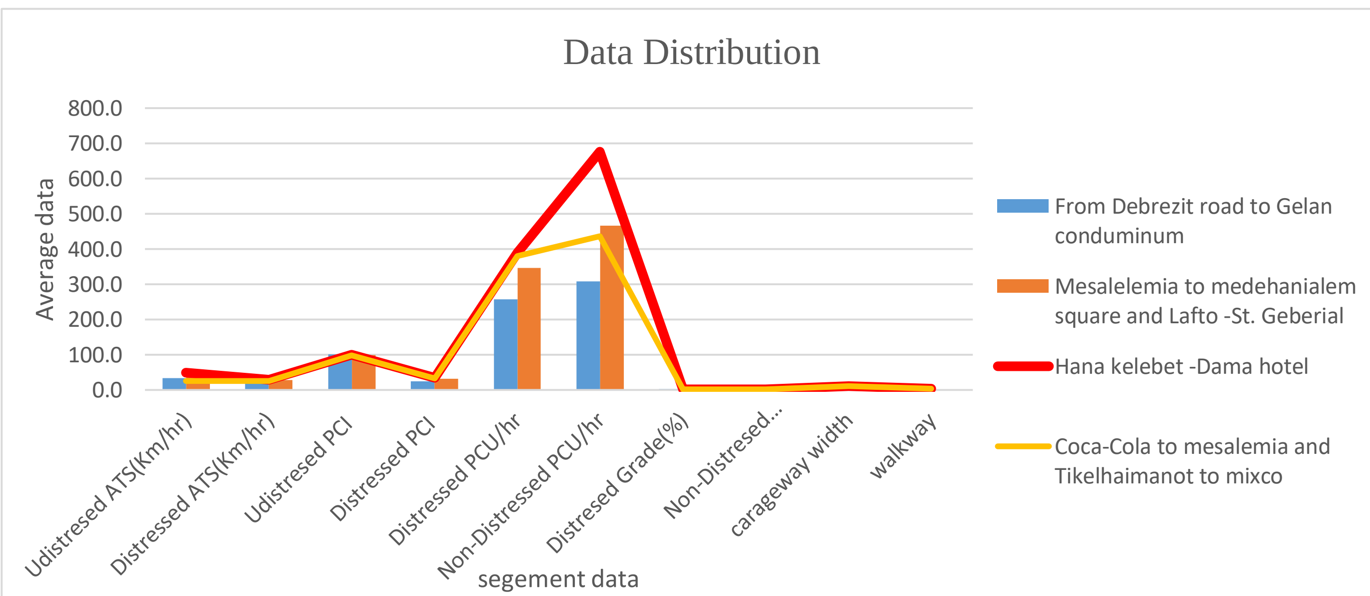


Figure 4-7 Data distribution to comparison of Variable at distressed and non-distressed section

4.5 Statistical Analysis and Model Development

4.5.1 Statistical Analysis

In this study, various statistical analyses were conducted to assess the reliability of the data and examine the effects of pavement condition and geometric characteristics on traffic performance in urban streets. The predictor variables used in the analysis included the following factors.

- Dependent variable
  - ✓ Average travel speed
- Independent variables
  - ✓ Pavement condition index
  - ✓ Traffic flow
  - ✓ Grade of the road
  - ✓ Number of lane
  - ✓ Width of carriageway
  - ✓ Walkway width

All conducted data were checked for outliers, normality, multi-collinearity, and homoscedasticity

Data Outlier

From conducted data Coca-Cola to mesalemia sample unit 16 and 17 hourly traffic flow data which is outlier (too much larger or smaller) is removed from a dataset.

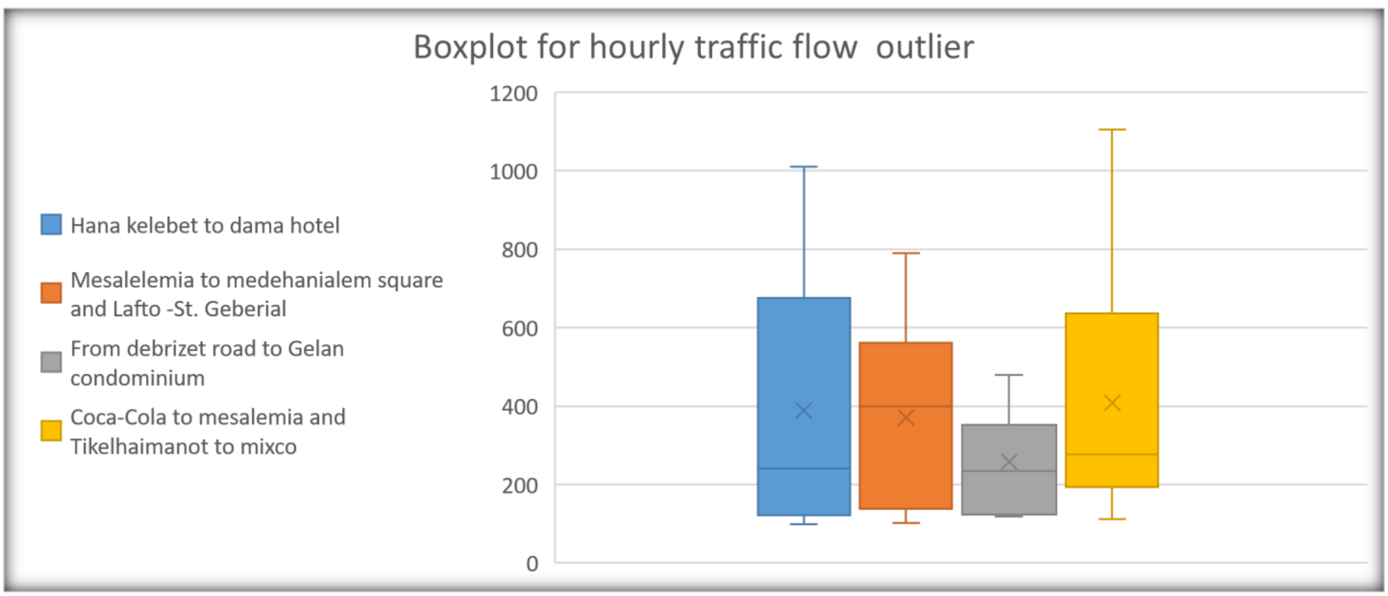


Figure 4-8 Boxplot Traffic flow data for outlier data checking

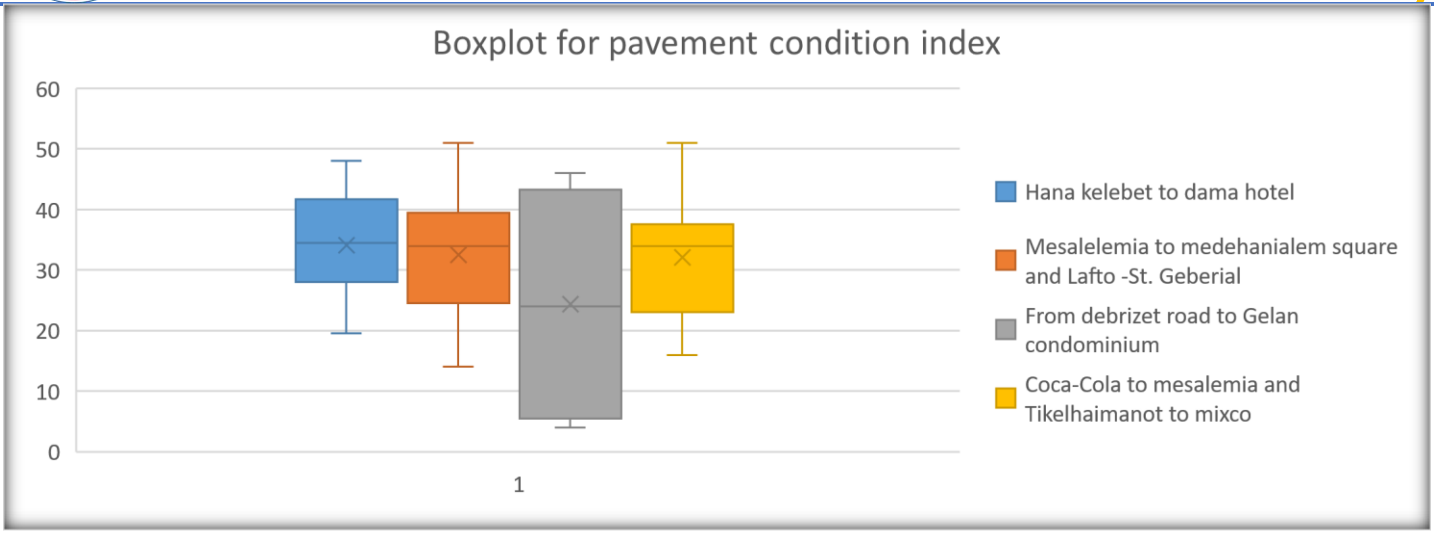


Figure 4-9 Boxplot Pavement condition index data for outlier data checking

- **Data outlier Using the Quartile Functions**

Table 4-6 checking data outlier by using the Quartile Functions at Hana kelebt to Dama Hotel

Hana kelebt to Dama hotel

Sample unit	Grade	Outlier		
1	0	FALSE	QTL1	1.01
2	1	FALSE	QTL3	4.00
3	1	FALSE	IQRS	2.99
4	1	FALSE	Lower Limit	-3.48
5	1.03	FALSE	Upper Limit	8.49
6	2	FALSE		
7	2.9	FALSE		
8	3	FALSE		
9	4	FALSE		
10	4	FALSE		
11	4	FALSE		
12	5.03	FALSE		
13	5.1	FALSE		
14	6	FALSE		

Table 4-7 checking data outlier by using the Quartile Functions at Coca-Cola to mesalemia and Tikelhaimanot to Mexico Gradient (%)

Coca-Cola to mesalemia and Tikelhaimanot to Mexico Gradient (%)

Sample unit	Grade(%)	Outlier	Sample unit	Grade(%)	Outlier
1	0.5	FALSE	23	2.1	FALSE
2	0.5	FALSE	24	2.1	FALSE
3	0.5	FALSE	25	2.2	FALSE
4	0.5	FALSE	26	2.3	FALSE
5	0.5	FALSE	27	2.7	FALSE
6	0.5	FALSE	28	2.8	FALSE
7	0.6	FALSE	29	2.9	FALSE
8	1	FALSE	30	3	FALSE
9	1	FALSE	31	3	FALSE
10	1	FALSE	32	3	FALSE
11	1	FALSE	33	3	FALSE
12	1	FALSE	34	3.2	FALSE
13	1	FALSE	35	3.2	FALSE
14	1	FALSE	36	3.8	FALSE
15	1	FALSE	37	4	FALSE
16	1.4	FALSE	38	4	FALSE
17	1.7	FALSE	39	4	FALSE
18	1.8	FALSE	40	5	FALSE
19	1.9	FALSE	41	5.7	FALSE
20	2	FALSE	42	7	TRUE
21	2	FALSE	43	8	TRUE
22	2.1	FALSE	44	8.3	TRUE
			45	9	TRUE

QTL1	1.00
QTL3	3.20
IQRS	2.20
Lower Limit	-2.30
Upper Limit	6.50

From this section sample unit 14,18,25 and 27 Grade of the road are data outlier and removed from the Analysis.

❖ **Normality**

To check the normality of the data, skewness and kurtosis were calculated using SPSS. The skewness and kurtosis values were then divided by their respective standard errors to obtain the Z-value. If the Z-value falls within the range of -1.96 to 1.96, it indicates that the data follows a normal distribution.

Table 4-8 Statistical data for study areas

Statically test	Hana kelebet to dama hotel	Mesalemia to Medehanialem square and Lafto - St. Geberial	From Deberezeit road to Glean condominium	Coca-Cola to Mesalemia and Tikelhaimanot to Mexico
Mean	34.1	32.6	24.4	32.1
Standard Error	2.4	2.2	7.2	1.8
Median	34.5	34	24	34
Mode	29.4	28	24	34
Standard Deviation	8.9	10.0	17.6	9.5
Sample Variance	79.2	100.8	309.1	90.3
Kurtosis	-0.9	-0.5	-1.8	-0.8
Skewness	-0.03	-0.03	0.07	0.02
Range	28.5	37	42	35
Minimum	19.5	14	4	16
Maximum	48	51	46	51
Sum	477.8	684	146.4	865.78
Count	14	21	6	27
Z-value = Kurtosis/std error	-0.362	-0.244	-0.248	-0.446
Z-value -=skewness/Std error	-0.014	-0.012	0.009	0.013

Based on these values, it appears that the data for all road sections deviates slightly from a perfectly normal distribution. The kurtosis values range from -0.5619 to -1.8, indicating a mild departure from normality. Similarly, the skewness values range from -0.03 to 0.0796, suggesting a slight asymmetry in the data. While these deviations from normality are relatively small, it is important to consider them when analyzing the data and making any statistical inferences. However, given the sample sizes and the fact that the deviations are not extreme, the data can still be considered approximately normally distributed for practical purposes.

❖ Multi collinearity

Multi-collinearity refers to a situation where there is a high degree of correlation or association among the independent or explanatory variables in a multiple regression model. This can lead to problems in the estimation of the regression coefficients and affect the accuracy and reliability of the results. Therefore, it is important to identify and address multi-collinearity in order to obtain valid and meaningful results from a multiple regression analysis. (Adefemi, 2019).

❖ **Test for detecting multi collinearity**

One common technique for detecting multi collinearity is to construct a correlation matrix of the data if the correlation number exactly one there is a high correlation between variables (Adefemi, 2019).

Table 4-9Normality Test with correlation

Pearson Correlation	ATS(Kph)	PCI	Traffic flow	Road grade	Walkway Width(m)	Median presence	Width of Lane(m)	No of lane
ATS(Kph)	1.000	.990	.951	.980	-.304	.	.	.
PCI	.990	1.000	.641	.349	-.341	.	.	.
Traffic flow	.951	.641	1.000	.335	-.432	.	.	.
Road grade	.980	.349	.335	1.000	-.498	.	.	.
Walkway width(m)	-.304	-.341	-.432	-.498	1.000	.	.	.
Median presences	.	.	.	.	.	1.000	.	.
Width of Lane(m)	.	.	.	.	.	.	1.000	.
No of lane	.	.	.	.	.	.	.	1.000

The variable walkway width has a weak negative correlation with average travel speed (ATS). This suggests that it does not have a significant impact on ATS and can be removed from the regression analysis. Removing this variable can simplify the model and potentially improve its predictive power by focusing on the variables that have stronger correlations with ATS.

❖ **Homoscedasticity**

The analysis of the data in this study involved checking the distribution of each variable using histograms. The histograms provide a visual representation of the data distribution, allowing for a better understanding of its shape and characteristics.

Based on the results obtained from the histograms, it observed that the data followed an approximately bell-shaped graph. This shape is often referred to as a normal distribution or Gaussian distribution

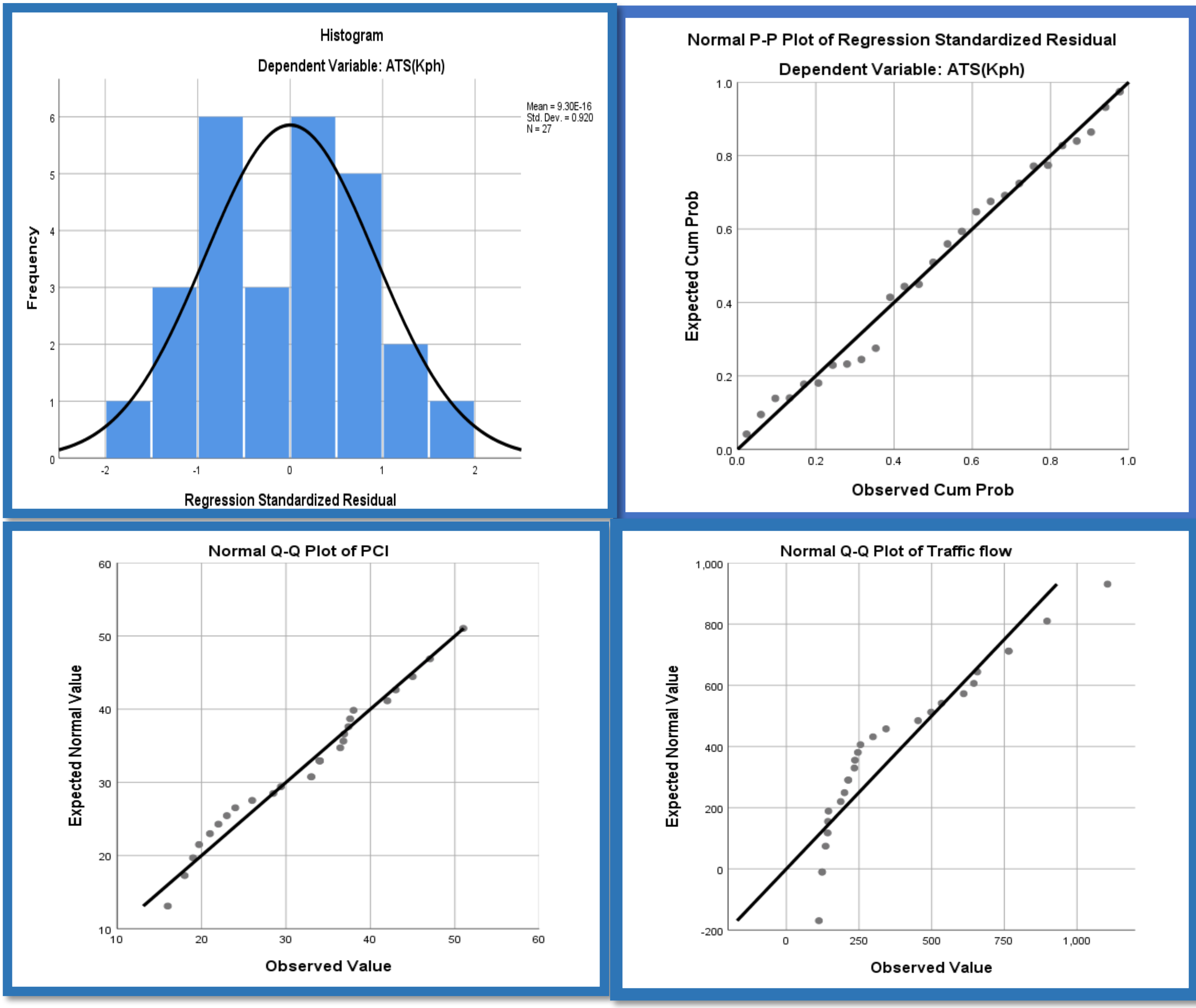


Figure 4-10 Coca-Cola to Mesalemia and Tikelhaimanot -Mexico road segment

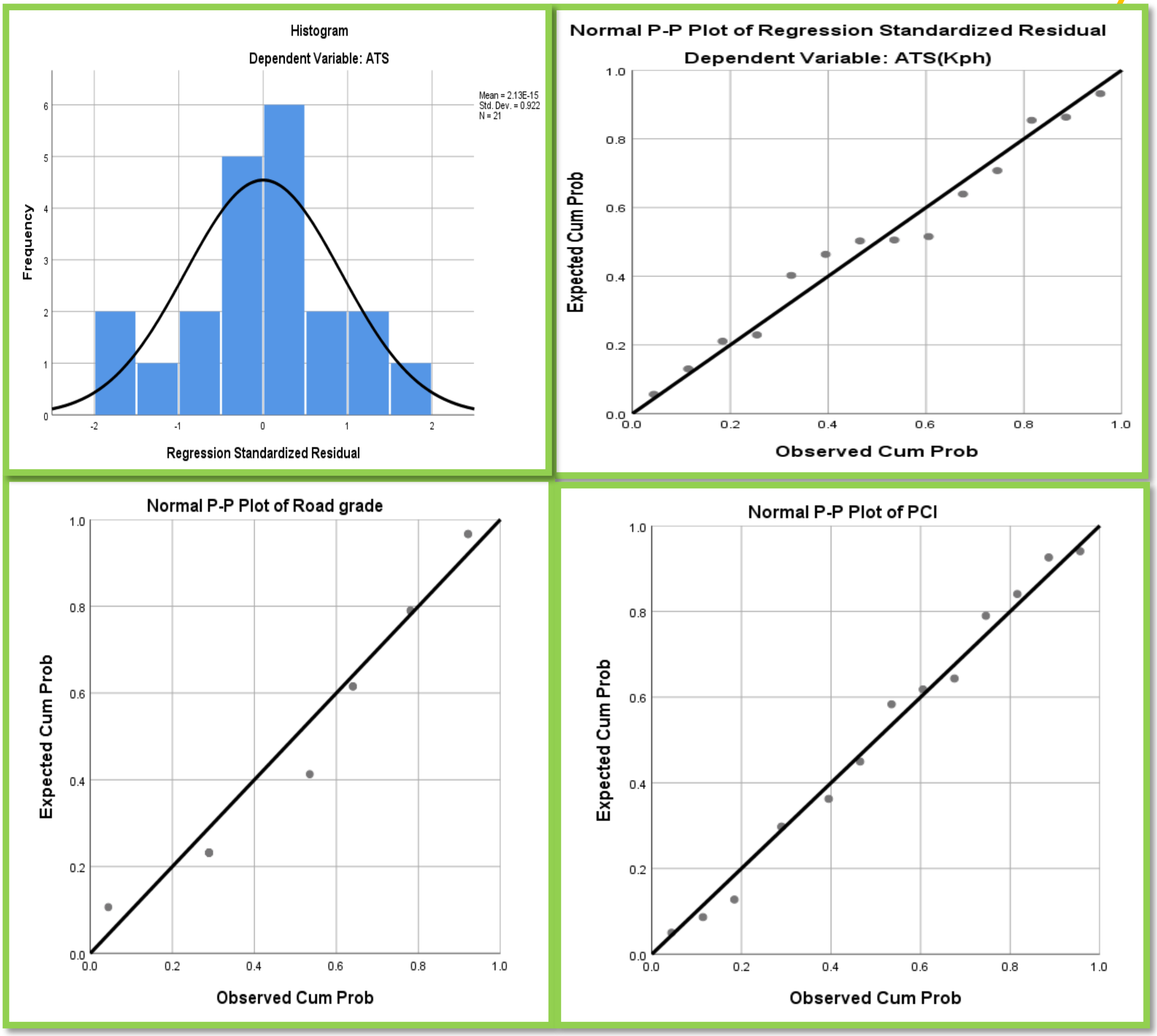


Figure 4-11 Hana kelebet to Dama hotel

The histogram of the mentioned road segment and the remaining study area indicates that the data is distributed in a manner that closely resembles a normal distribution.

4.6 Regression model

4.6.1 Parameter selections for model

After analyzing the correlation results from table 4-6, it was observed that certain parameters have a strong correlation with the dependent variable (average travel speed), while having minimal or no correlation with each other (independent variables). As a result, the variables selected for further analysis are pavement condition index, traffic flow and road gradient. On the other hand, parameters such as the presence of a median, lane width and lane number remain constant throughout the study area and do not have a significant impact on average travel speed. Therefore, these variables are disregarded in the model.

4.6.2 Regression Analysis and Sensitivity Analysis

In this study, a multiple regression analysis is employed to investigate the association between a continuous dependent variable and a true independent variable. The analysis takes into account data collected from a specific site. Multiple regression models are particularly useful when there are multiple independent variables that could potentially impact the dependent variable. At a 95% confidence level, the hypothesis that each of the coefficients is equal to zero is rejected. This is supported by the t-values, which exceed ±1.96 (Demisa, Speed hump effect on pavement condition, 2020).

Table 4-10 From Deberezeit road to Glean Condominium

1) From Deberezeit road to Glean condominium							
Model	Unstandardized	Coefficients		T-value	sig	95% Confidence Interval for B	
	B	std. error	Beta			Lower Bound	Upper Bound
Constant	7.854	1.533		5.123	.014	2.975	12.733
PCI	0.306	0.085	0.590	3.612	.036	.036	0.576
Traffic flow	0.032	0.011	0.503	2.917	.022	0.003	0.068
Road grad	-164.831	14.367	0.106	-1.766	.028	-614.723	285.061

Model Summary

R	R^2	$AdjR^2$	Std. Error	R^2 change	F change	Sig F change
0.996	0.991	0.982	1.11258	0.991	111.199	0.001

The regression model for the road section from Deberezeit Road to Glean Condominium shows a high level of goodness of fit, with an R-squared value of 0.991. This means that approximately 99.1% of the variation in the average travel speed can be explained by the independent variables included in the model (PCI, traffic flow, and road gradient).

ATS(Km/hr)=0.306PCI+0.032TF-164.831RG+7.854 Equation 4-1

ATS (Km/hr)=0.306×PCI+0.032×TF−164.831×RG+7.854ATS (Km/hr)=0.306×PCI+0.032×TF−164.831×RG+7.854 represents a model for calculating Average Travel Speed (ATS) in kilometers per hour based on three variables: Pavement Condition Index (PCI), Traffic Flow (TF), and Road Gradient (RG). The coefficients provide insights into the impact of each variable on ATS. The positive coefficient of 0.306 for PCI suggests that an improvement in pavement condition leads to an increase in average travel speed, while the positive coefficient of 0.032 for TF indicates a similar positive relationship with traffic flow. Conversely, the negative coefficient of -164.831 for RG implies that as the road gradient increases, the average travel speed tends to decrease. The constant term of 7.854 represents an additional factor influencing ATS. This equation assumes a linear relationship between the variables and ATS, providing a quantitative understanding of their respective contributions to average travel speed in the specified context.

Table 4-11 Coca-Cola to Mesalemia and Tikelhaimanot to Mexico

2) Coca-Cola to Mesalemia and Tikelhaimanot –Mexico

Model	Unstandardized	Coefficients		T-value	sig	95% Confidence interval for B	
	B	std. Error	Beta			Lower Bound	Upper Bound
Constant	9.449	1.481		6.381	.000	6.360	12.537
PCI	.411	.020	.676	21.00	.000	0.370	.451
Traffic flow	.012	.001	.500	14.367	.000	.010	.013
Road grad	-81.520	10.309	-.229	-7.908	.013	-103.025	-60.016
Walkway	0.156	0.351	0.013	0.444	0.662	-0.577	0.889

Model Summary

R	R^2	AdjR^2	Std. Error	R^2 change	F change	Sig F change
0.993	0.986	0.984	0.710	0.986	355.30	0.000

The regression model for the road section from Coca-Cola to Mesalemia and Tikelhaimanot-Mexico Square suggests that the pavement condition index (PCI), traffic flow, and road gradient are significant factors in determining the average travel speed (p-value<0.05) but walkways do not affect the average travel speed (p-value>0.05).

ATS(Km/hr.)=0.411PCI+0.012TF-81.52RG+9.449 Equation 4-2

In the context of a three-variable model involving Pavement Condition Index (PCI), Traffic Flow (TF), and Road Gradient (RG), the coefficients shed light on the influence of each factor on Average Travel Speed (ATS). The positive coefficient of 0.411 associated with PCI implies that an enhancement in pavement condition is linked to an upsurge in average travel speed. Additionally, the small positive coefficient of 0.012 for TF suggests a marginal positive correlation with traffic flow. Conversely, the negative coefficient of -81.52 for RG indicates that higher road gradients are associated with a decline in average travel speed. The constant term of 9.449

represents an inherent factor affecting ATS. This model assumes a linear relationship between the variables and ATS, offering a quantitative depiction of their effects on average travel speed.

In summary, the regression analysis suggests that the predictor variables (PCI, traffic flow and road gradient) have statistically significant effects on the outcome variable, but Walkway does not. The coefficients provide estimates of the magnitude and direction of these effects, while the t-values and p-values indicate their statistical significance.

Table 4-12 Hana Kelebet to Dama hotel

3) Hana kelebet to Dama hotel							
Model	Unstandardized	Coefficients		T-value	Sig	95% Confidence interval for B	
	B	std. Error	Beta			Lower Bound	Upper Bound
Constant	9.195	2.681		3.429	.006	3.221	15.169
PCI	.345	.091	.386	3.792	.004	0.142	0.548
Traffic flow	0.016	0.03	0.647	6.393	0.000	0.022	0.263
Road grad	-51.662	21.336	-0.123	-2.421	0.036	-99.201	-4.123

Model Summary						
R	R^2	AdjR^2	Std. Error	R^2 change	F change	Sig F change
0.990	0.983	0.975	1.26889	0.980	166.65	0.000

The regression model for the average travel speed (ATS) on the road section indicates that the pavement condition index (PCI), traffic flow, and grade of the road are significant factors in determining the average travel speed.

ATS(Km/hr.)=0.345PCI+0.016TF-51.662RG+9.195 Equation 4-3

the coefficients provide valuable insights into the interplay of Pavement Condition Index (PCI), Traffic Flow (TF), and Road Gradient (RG) on Average Travel Speed (ATS). The positive coefficient of 0.345 for PCI suggests that an improvement in pavement condition contributes to an increase in average travel speed. The small positive coefficient of 0.016 for TF indicates a slight positive relationship with traffic flow. Conversely, the negative coefficient of -51.662 for RG implies that as the road gradient increases, there is a tendency for the average travel speed to decrease. The constant term of 9.195 represents an additional factor influencing ATS.

In conclusion, the regression analysis indicates that the pavement condition index, traffic flow, and road gradient are important factors in determining the average travel speed on the road section. The model provides valuable insights into the relationship between these variables and average travel speed.

Table 4-13 Mesalemia –Medehanialem square and Lafto-St. Geberial

4) Mesalemia –Medehanialem Square and Lafto-St. Geberial							
Model	Unstandardized	Coefficients		t	sig	95% Confidence interval for B	
	B	std. Error	Beta			Lower Bound	Upper Bound
Constant	0.557	0.840		0.663	.000	-1.215	2.329
PCI	.0.806	.030	.795	26.552	.000	0.742	0.870
Traffic flow	0.026	0.002	0.472	14.459	0.00	0.023	0.030
Road grad	-375.863	19.138	-0.573	-19.64	0.002	-416.24	-335.49

Model Summary						
R	R^2	AdjR^2	Std. Error	R^2 change	F change	Sig F change
0.995	0.990	0.988	1.00642	0.990	535.875	0.000

ATS(km/hr.) =0.806PCI+0.026TF-375.863RG+0.557 Equation 4-4

Pavement Condition Index (PCI), Traffic Flow (TF) and Road Gradient (RG). The coefficients provide key insights into the influence of each factor on ATS. The substantial positive coefficient of 0.806 for PCI indicates that an improvement in pavement condition significantly contributes to an increase in average travel speed. The smaller positive coefficient of 0.026 for TF suggests a minor positive correlation with traffic flow. Notably, the considerably negative coefficient of -

375.863 for RG implies a substantial impact, signifying that as the road gradient increases, there is a substantial decrease in average travel speed. The constant term of 0.557 represents an additional factor affecting ATS. This equation assumes a linear relationship between the variables and ATS, offering a quantitative understanding of their effects on average travel speed within the specified context.

In summary, the regression analysis suggests that the predictor variables (PCI, traffic flow and road gradient) have statistically significant effects on the average travel speed. The coefficients provide estimates of the magnitude and direction of these effects, while the t-values and p-values indicate their statistical significance. The confidence intervals provide a range of plausible values for each coefficient.

Table 4-14 Model summary

Sr. No	**Section Name**	**Multiple Regression model**	**Sig**	**R^2**	**AdjR^2**
1	From Deberezeit road to Glean condominium	ATS(km/hr.) =0.306PCI+0.032TF -164.831RG+7.854	0.00	0.991	0.981
2	Mesalemia to Medehanialem square and Lafto Betach to St. Geberial church	ATS(km/hr.) =0.806PCI+0.026TF -375.863RG+0.557	0.00	0.990	0.988
3	Coca-Cola to Mesalemia and Tikelhaimanot to Mexico Square	ATS(Km/hr.)=0.411PCI+0.012TF -81.52RG+9.449	0.00	0.986	0.984
4	Hana kelebet to Dama hotel	ATS(Km/hr.)=0.345PCI+0.016TF -51.662RG+9.195	0.00	0.983	0.975

The multiple regression models presented for the different sections provide a generalized understanding of the factors influencing travel speeds in the studied areas. These models demonstrate the importance of considering variables such as pavement condition index (PCI), traffic flow (TF) and road grade (RG) when analyzing travel speeds.

Across all sections, the models consistently show that higher PCI and TF values are associated with increased travel speeds. This suggests that better pavement conditions and lower traffic congestion contribute to faster travel times. On the other hand, the negative coefficients for RG indicate that steeper road grades have a negative impact on travel speeds. This finding highlights the significance of road gradients in determining the efficiency of travel in these areas.

Furthermore, the high levels of significance and strong goodness of fit observed in the models indicate that they effectively explain a substantial portion of the variability in travel speeds. This suggests that the selected predictors (PCI, TF and RG) are reliable indicators of the factors influencing travel speeds in these sections.

If the calculated t-statistic for an individual variable in a multiple linear regression model is higher than the corresponding t-critical value at a certain level of significance, it provides evidence to reject the null hypothesis. The null hypothesis assumes that the variable has no effect on the outcome. By rejecting the null hypothesis, can conclude that the individual variable does have a significant effect on the outcome, based on the observed data and the chosen level of significance. (Demisa, Speed hump effect on pavement condition, 2020)

In this study, the Pavement Condition Index is the most sensitive variable among all the independent variables, as it has the highest T-value. This indicates that the condition of the pavement is most strongly associated with the outcome of interest. However, for the Hana Kelebet to Dama Hotel route, the sensitive variable is the traffic flow, suggesting that the level of traffic on that particular route is the most influential factor in determining the outcome.

In conclusion, the multiple regression models provide a generalized understanding of the relationship between PCI, TF, RG, and travel speeds in the studied areas. These models highlight the importance of considering these variables when analyzing travel speeds, provide valuable insights and provide a basis for decision-making and prioritizing interventions to improve the identified sections and optimize travel speeds for the benefit of road users.

Table 4-15 Average Travel speed at Distressed and Non-Distressed section

SR. No	Section Name	ATS(km/hr.) at Distressed Section	ATS(km/hr.) at Non-Distressed Section	Decrement in %
1	From Deberezeit road to Glean condominium	21.14	34.1429	0.620
2	Mesalemia to Medehanialem square and Lafto Betach to St. Geberial	27.357	39.734	0.686
3	Coca-Cola to Mesalemia and Tikelhaimanot to Mexico	25.381	38.339	0.6620
4	Hana kelebet to dama hotel	26.5357	49.673	0.5342

In the given table, there is information about the average travel speed (ATS) in kilometers per hour (km/hr.) at distressed and non-distressed sections, along with the percentage decrease in speed.

When comparing the average travel speeds (ATS) at distressed and non-distressed sections, a significant decrease in speed was observed in all four sections. For instance, in the first section from Deberezeit Road to Glean Condominium, the ATS at the distressed section was 21.14 km/hr., while it was 34.143 km/hr. at the non-distressed section. This represents a decrease of 0.620, or 62.0%. Similar patterns of decreased speeds were observed in the other sections. This suggests that factors related to the pavement condition or geometric characteristics are likely contributing to the reduction in travel speeds. But it is worth noting that the road gradient has a tolerable difference, especially at the section from Hana Kelebet to Dama Hotel, where the grade of the road is the same. The data was collected before and after maintenance at the same location, and the average travel speed was measured during peak off-time traffic flow, indicating that traffic flow is not the primary cause of the reduction in travel speed.

The percentage decrease in speed provides an indication of the severity of the decrease in each section. Looking at the percentages, the highest decrease is observed in the second section, Mesalemia to Medehanialem Square and Lafto Betach to St. Geberial, with a decrease of 0.6885, or 68.85%. This indicates that this section has the most significant impact on reducing travel speed compared to the other sections. The other sections also show substantial decreases, ranging from 53.42% to 66.2%.

In summary, the provided data shows a consistent decrease in average travel speeds in all four sections. The percentage decrease in speed provides insights into the severity of the reduction, with the second section showing the highest decrease. These findings suggest the presence of distress and an improper grade of road are having a significant impact on travel speeds in these areas.

4.6.3 Economic Analysis for pavement condition Rate

Economic analysis for Pavement Condition Index (PCI) ratings involves assessing the cost-effectiveness of various strategies for maintaining and rehabilitating road pavements based on their condition. The PCI is a numerical index that quantifies the condition of a pavement, reflecting distresses such as cracks, potholes, and surface deterioration. Conducting an economic analysis for PCI ratings is crucial for transportation agencies and decision-makers to allocate resources efficiently. In this study maintenance cost investigating for 3486.11m^2 from failed to Good rating to show severity impact on maintenance cost and a rate is taken from kality Ring road to tuludimtu Roundabout.

Table 4-16 unit rate for maintenance

EMPLOYER			**CONSULTANT**		
Addis Ababa City Roads Authority			**Engineer Zewdie Eskinder & Co.Plc**		
BILL-2 and Bill -3	**Description**	**Unit**	**Contract**		
			Quantities	**Rate**	**Amount**
				ETB	**ETB**
2	**Bill No. II**				
	Earthworks				
205 P5	Capping Layer under the subbase layer with maximum compacted layer thickness 300mm,and as specified on the agreement and irrespective of the hauling distance	m3		245.10	-
	Total BILL-2 Carried Forward to Summary				**0.00**

3	**Bill No. III Pavements**			
	a. Carriageway			
301 P3.4 (ii)	30cm thick Gravel Subbase Compaction to 96% of AACRA Test S-11 Test S-11 Density (Compacted layer thickness of maximum 150mm)	m3	476.38	-
302 P1.2 (i)	25cm thick Crushed Stone Base Compaction to 98% of AACRA Test S-11 density (maximum compacted layer thickness 150mm)	m3	515.93	-
401 P1.1	Supply and spray MC- 30 Cut Back Asphalt Prime Coat application at a Rate of 1lit/m^2 between asphalt concrete and Base Course.	Lit	31.81	-
403 P1	Supply and apply RC-70 Tack Coat application at a Rate of 0.3 lit/m^2 on every layer of Asphalt Concrete.	Lit	37.18	-
403 P4	Dense Graded Asphaltic Concrete (AC) Wearing Course Compacted thickness of 70mm	m2	427.56	-
403 P3 (b)	Dense Graded Asphaltic Concrete (AC) in intermediate Courses for bottom layer Compacted thickness of 80mm	m2	472.88	-

Table 4-17 Maintenances cost based on severity rating

Severity rating	**Failed**	**Serious**	**very poor**	**poor**	**Fair**	**Satisfactory**	**Good**
Maintenance cost ETB(3486.11m2)	4,840,068.06	4,840,068.06	4,414,959.14	3,872,625.75			

The provided table establishes a clear correlation between Pavement Condition Index (PCI) severity ratings and their corresponding maintenance costs for a specific area of 3486.11 square meters. Notably, both "Failed" and "Serious" ratings incur identical maintenance costs, suggesting a uniform need for substantial repairs in these severe conditions. As the severity diminishes from "Very Poor" to "Fair," a consistent decrease in maintenance costs is observed, indicating a proportional relationship between pavement condition improvement and reduced maintenance expenses. However, the absence of specified costs for the Satisfactory and Good the associated costs are negligible in comparison to more deteriorated states. This table underscores the importance of proactive maintenance measures, as it highlights the potential cost savings associated with improving and sustaining better pavement conditions.

CHAPTER FIVE

5. Conclusions and recommendations

5.1 Conclusions

The aim of this study was to examine the influence of pavement condition and geometric characteristics on traffic performance, specifically focusing on average travel speed as an indicator for urban street facility traffic performance. The study utilized the Pavement Condition Index (PCI) as a measure of pavement condition and considered various geometric characteristics such as lane width, lane number, existence of a median, road grade and walkway width. Multiple regression analysis was conducted to assess the relationship between these variables and average travel speed, providing insights into the impact of pavement condition and geometric characteristics on traffic performance in urban street facilities. The model result's conclusion is as follows:

- ❖ The impacts of geometric characteristics (road gradient) on traffic performance are significant but lane width and lane number is constant throughout sections and do not have a significant impact on average travel speed for this study area.
- ❖ Based on the significance value (sig<0.05) and T-values, it was concluded that pavement condition and geometric characteristics have a significant impact on traffic performance. However, in the specific cases of Coca-Cola to Mesalemia and Tikelhaimanot-Mexico Square, there is a difference in walkway width. In addition, to the weak correlation between speed and walkway, the p-value from the multiple regression model for walkway impact on travel speed is 0.444, which is greater than 0.05. This suggests that the walkway condition does not have a significant impact and therefore is not included in the regression model.
- ❖ Despite considering the acceptable differences in geometric characteristics and travel speeds in a survey taken during off-peak hours in clear weather conditions, there is a noticeable decline in average travel speeds in the distressed sections, primarily due to poor pavement conditions. Among the sections, Mesalemia to Medehanialem Square and Lafto Betach to St. Geberial stand out with the highest reduction in travel speed, recording a decrease of 0.6885, or 68.85%. This particular section has the most significant impact on

the overall decrease in travel speeds compared to the other sections, which also experience substantial reductions, ranging from 53.42% to 66.2%.

- The economic analysis shows that maintaining early a pavement surface expences is less than that of damaged road pavement

5.2 Recommendations

In the context of Addis Ababa city, high traffic congestion is a prevalent issue caused by various factors. This study specifically identifies pavement condition and geometric characteristics as one of the causes of the reduction in traffic performance in urban street facilities, particularly in the mid-block sections. But in the future, this study strongly recommends that

- The study focused on investigating the impacts of pavement condition and geometric characteristics on traffic performance in the mid-block sections of urban street facilities. However, it is important to note that the majority of distressed streets in Addis Ababa have already been maintained by the Addis Ababa Road Authorities. Consequently, the study primarily examined collector and sub-arterial streets that were available for analysis. Therefore, further investigation is necessary to explore the effects of pavement condition and geometric characteristics on traffic performance in other street functional categories.
- Further investigation is required for a segment that has different futures, such as horizontal and vertical curves, and geometric characteristics, such as lane width, lane number, and the presence of a median, while also considering the composition of traffic.
- For this study the cost impacts of pavement severity rating shows that when the severity increases the maintainace cost also increase for 3486.11m2 with the rate of kality project. But cost analysis on pavement severity rate needs further investigation for the future study

Based on the findings of this research, it is recommended that maintaining a distressed pavement surface and implementing reasonable road grades can effectively minimize traffic congestion in the mid-block sections of urban streets. By ensuring the quality of the pavement surface and road grades, travel speeds can be increased, leading to improved traffic flow and reduced congestion in urban areas.

6. References

A. Mohammed1, S. Y. (2015, jun). The Effect of Pavement Condition on Traffic Safety: A Case Study of Some Federal Roads in Bauchi State. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 12*, 139-146.

Adefemi, A. A. (2019, March). Testing for multicollinearity using microsoft Excell:using the variance inflation factor. pp. 1-24.

ALIZALTUOM, A. (2011, February 28). EVALUATION PAVEMENT DISTRESSES USING PAVEMENT CONDITION INDEX. p. 49.

Ary Setyawana, *. I. (2015). The effect of pavement condition on vehicle speeds and motor vehicles emissions. *The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)* (pp. 424-430). Elsevier Ltd.

B. Suresh, N. V. (2018, march). RESEARCH ON URBAN ROAD TRAFFICCONGESTION OF HYDERABAD A CASE STUDY. *International Journal of Civil Engineering and Technology (IJCIET), 9*(5), 694-699.

Changula, D. H. (2020). study on the effects of pavement condition on level of service of the road segment. *JournalOfBasicAndApplied*, 118-137.

Conshohocken, W. (2011). ASTM D6433-11, 2011: Standard Practice for Roads and Parking Lots, Pavement Condition Index Surveys, ASTM International.

Conshohocken, w. (2011). Standard Practice for Roads and Parking Lots ,Pavement Condition Index Surveys,ASTM International. *ASTM D6433-11*, 1-3.

Daniel, M. (2018, june). Assessment of the effects of Road Geometric Design Consistency On Traffic Safety. *Assessment of the effects of Road Geometric Design Consistency On Traffic Safety*, pp. 50-160.

Demisa, M. G. (2020, January). Speed hump effect on pavement condition. pp. 20-27.

Demisa, M. G. (2020, January). Speed hump effect on pavement condition. pp. 21-22.

Demisa, M. G. (2020, January). Speed hump effect on pavement condition for Addis Ababa City roads case study.

Deni1, S. a. (2020). Application of pavement condition index (PCI) on the assessment of the Kalumata highway sectionof the City of South Ternate. *IOP Conference Series: Earth and Environmental Science*, (pp. 1-5).

Donald L.Basham, J. W. (2004). *unified Facilities Criteria/Pavement Maintenance Management.* UFC. Retrieved from UCF 3-2700-08

Dr. Abdul-Razzak Tarish Ziboon1, D. Z. (2019). TRAFFIC PERFORMANCE EVALUATION AND ANALYSIS OF Al-FALLAH INTERSECTION IN BAGHDAD CITY UTILIZING SYNCHRO.10 SOFTWARE.

Duwa Hamisi Chengula .olume 39, N. 1.-5. (2018). Study on Performance of Road Signs and Markings along TANZAM Highway in Mbeya Region, Tanzania. *International Journal of Sciences: Basic and Applied Research (IJSBAR) (2018)*, *39*(1), 34-50.

E.Pagan-ortiz, J. (May 2014). *Distress identification manual for the Long-term pavement peformancee program.* FHWA-HRT-13-092.

Etika, J. O. (2012, August, 8). Traffic Congestion in Major Cities of Nigeria. *International Journal of Engineering and Technology Volume 2* , 1436.

Eyob, E. (2022, march). Identification of Problems on Road Maintenance and Assessment of the Effects of Poor Road Maintenance on Road Function (in the case of Federal Roads of Ethiopia). pp. 49-93.

Ford, K. A. (2012). Estimating life expectancies of highway assets.

Gehegn, M. E. (2019, june). Travel Time and Reliablity Modeling on Urban Road Segment .

Hazratullah Paktin1, A. M. (2021, february). CAUSES AND SOLUTIONS OF TRAFFIC CONGESTION OF KABUL CITY. 24.

Ibrahim H. Hashim 1, Rania M. Badawy 2,* and Usama Heneash 2. (2023). Impact of Pavement Defects on Traffic Operational Performance. *Sustainability*, 1-18.

Ibrahim H.Hashim a*,Mohamed A.Younes b,Saad A.EL-hamrawy c. (2018). Impactes of pavement condition on speed change for Different Vehicles classes. *American Scientific Rearch Journal for Engineering,Technology, and Sciences*, 1-20.

Materials, A. S. (2009). ASTM D6433-09.

Mekonen, F. (2015, August). Evalution of Traffic Congestion and Level of service at Major intersection in Adama city. pp. 1-60.

Melissa Humphrey1, S. D. (2017., June 28). A Comparison of Traffic Performance in Highly Congested Urban Areas.

Michael R.Morris, Neil J.pedersen and Robert E.Skinner,Jr. (2010). *Highway capacity manual.* Washington,DC.

Ostom, G. E. (2019). *Long-Term Pavement Performance Information Management system User Guide.*

P. T. Adeke1, *. A. (2019, January). SESSMENT OF PAVEMENT CONDITION INDEX: A CASE OF FLEXIBLEROAD PAVEMENTS ON THE UNIVERSITY OF AGRICULTURE. *Nigerian Journal of Technology (NIJOTECH), 38.*

Prof. Dr Fareed M.A. Karim, *. D. (2016, August 2). The Road Pavement Condition Index (PCI) Evaluation and Maintenance: A Case Study of Yemen. *8*, pp. 1446–1455.

Rahul Deshpande, N. H. (2010). Urban Street Performance Level of Service and Quality of Progression Analysis. *Transportation Research Record: Journal of the Transportation Research Board,*, 57-64.

Rijal Psalmen Hasibuan1*, a. M. (2019). Study of Pavement Condition Index (PCI) relationship with International Roughness Index (IRI) on Flexible Pavement. *MATEC Web of Conferences , 258*, pp. 1-6. kepton.

S. B. Raheem, W. A. (2015, septamber). The Cause, Effect and Possible Solution to Traffic Congestion onNigeria Road (A Case Study of Basorun-Akobo Road, Oyo State). *International Journal of Engineering Science Invention, 4*(9), 10-14.

Smith, D. (2002). Handbook of Simplified practice for traffic studies. In D. Smith, *Handbook of Simplified practice for traffic studies.* south loop.

Smith, D. (2002). *Handbook of Simplified Practice for.* lowa.

Stephen A. Arhin1, *. N. (2015). Predicting Pavement Condition Index Using International Roughness Index in a Dense Urban Area. *Journal of Civil Engineering Research, 5*(1), 10-17.

VENCATAYA Lomendra*, P. S. (2018, march 13). ASSESSING THE CAUSES & IMPACTS OF TRAFFIC CONGESTION ON THE SOCIETY, ECONOMY AND INDIVIDUAL: A CASE OF MAURITIUS AS AN EMERGING ECONOMY. pp. 236-237.

Wagari, L. (2016, November). Assessment of the impactes of Drainage Structures on Road Asset in Ethiopia. p. 35.

Wahyu Widodo, E. A. (2020). Street, An Analysis of the Performance of Unsignalized Intersection and the Impact of Vehicle Exhaust Emissions at Selokan Mataram. ATLATIS press.

7. Annexes

Annex-A: -Pavement condition index analysis

			Branch	Road						section	From Deberezeit road to gelan Condo:		
			Surveyed by:-							Date:-			sample area:-
Section no	Pothole		Rutting		corrocodile crack		corrugation	Transevers	failed	longtiudenal	Bleeding	Ravelling	
	No	deth(mm)	Area(m2)	depth(mm)	crack widt(mm)	Area(m2)	Area(m2)	Length(m)	Area(m2)	Length(m)	Area(m2)	Ravelling depth(mm)	Area(m2)
1	0.3*0.3	40										3	2.52
	0.99*0.99	45										3.5	1.14
2												4.2	15
												4	3
												3	7.5
3	2.8595	14	1*0.8	21									
	3	13											
4	6.4	14.5											
	8.84	12											
5	4.5	14.5			9	2.016					0.89		
	20.1	16											
	7.2	17.45											
6	10.64	40	3.6	25.5	20	3.08	2*1	7		1		0.8*0.9	
	5.004	30	32.5	26	19.5	3.5712	0.900*0.800	5.2		1.5	0.60*0.40	0.3*0.8	
7	1.5625	20	4.125*8.253	7	26	4.34636						13	1.331
	7.8725	30	.162*.200	13								20	
	0.09	14										39	

Table 7-1 For Deberezeit road to Glean condominium street for distress section

Asphalt road surface and parking lots									
Condition survey data sheet				Sketch					
For Sample unit									
Branch:- Gelan conduminum		**section :- 01**		**sample unit:-16**					
Surveyed by:Group		**date:-____________**		**sample area:-770m2**		100M			
1.Alligator cracking(m2)		6.Depression(m2)		11.paching/utility cut pacting(	16.Shoving(m2)	Survey Direction			
2.Bleeding(ml)		7.Edge cracking(ml)		12.polishing Agregate(m2)	17.Silppage cracking				
3.Block cracking(ml)		8.Reflection cracking		13.potholes(No)	18.Swell				
4.Bump or sag		9.Lane/shoulder drop off		14.Rail road crossing(mL)	19.Weathering and Raveling(m2)				
5.Corrugation(m2)		10.long or trans cracking(ml)		15.Rutting(m2)					

sample unit No.	Distress severety	Quantity							Total	Density	Deduct
20	13L	4							4	1.9	62.5
	19H	3	0.8272						3.83	1.8	35
	19M	0.36							0.36	0.2	0.9

m=1+(9/98)*(100-HDV)
m=1+(9/98)*(100-62.5)=4.44 4.443878
Use highest 4 deducts and 0.44 of five deduct
0.396

Iteration No	DV			q	TDV	CDV
1	62.5	35	0.396	3	98	62
2	62.5	35	0.396	2	98	70
3	62.5	2	0.396	1	65	76

24

Max CDV =76
PCI = 100- Max CDV =24
Rating =Serious

Table 7-2 Mesalemia -Medhanialem square and Lafto Betach to Gebrial Ch..

	Asphalt road surface and parking lots									
	Condition survey data sheet						Sketch			
	For Sample unit									
	Branch:- Mesalemyia - medhanialem square and Lafto betach to Gebrial ch.		**section :-**		**sample unit:-01**					
	Surveyed by:Group		**date:-_____________**		**sample area:-1050m2**			100M		
	1.Alligator cracking(m2)	6.Depression(m2)		11.paching/utility cut pacting(		16.Shoving(m2)		Survey Direction		
	2.Bleeding(ml)	7.Edge cracking(ml)		12.polishing Agregate(m2)		17.Silppage cracking				
	3.Block cracking(ml)	8.Reflection cracking		13.potholes(No)		18.Swell				
	4.Bump or sag	9.Lane/shoulder drop off		14.Rail road crossing(mL)		19.Weathering and Raveling(m2)				
	5.Corrugation(m2)	10.long or trans cracking(ml)		15.Rutting(m2)						

sample unit No.	Distress severety	Quantity							Total	Density	Deduct
34	13H	0.8978	0.1058						1	0.5	40
	13M	0.12005							0.12	0.1	6
	15H	1.35							1.35	0.6	23
	15M	0.33							0.33	0.2	9
	1L	0.0076	0.02695	0.1505					0.19	0.1	5
	5M	0.1925							0.19	0.1	7
	5H	0.595							0.6	0.3	21

m=1+(9/98)*(100-HDV)
m=1+(9/98)*(100-40)=6.51
Use highest 6 deducts and 0.51 of seven deduct
4.845

Iteration No	DV						q	TDV	CDV
1	40	23	21	9	7	4.845	6	105	54
2	40	23	21	9	7	2	5	102	52
3	40	23	21	9	2	2	4	97	56
4	40	23	21	2	2	2	3	90	59.8
5	40	23	2	2	2	2	2	71	50.0
6	40	2	2	2	2	2	1	50	54.0

Max CDV =58
PCI = 100- Max CDV =40.2
Rating =Poor

Table 7-3 Coca-Cola to Mesalemia and Tikelhaimanot to Mexico Square

	Asphalt road surface and parking lots									
	Condition survey data sheet						Sketch			
	For Sample unit									
	Branch:- Coca-cola to mesalemia and Tikelhayimanot to mixco square			**section :-**		**sample unit:-11**				
	Surveyed by:Group			**date:-____________**		**sample area:-1050m2**		100M		
	1.Alligator cracking(m2)		6.Depression(m2)		11.paching/utility cut pacting(		16.Shoving(m2)	Survey Direction		
	2.Bleeding(ml)		7.Edge cracking(ml)		12.polishing Agregate(m2)		17.Silppage cracking			
	3.Block cracking(ml)		8.Reflection cracking		13.potholes(m^2)		18.Swell			
	4.Bump or sag		9.Lane/shoulder drop off		14.Rail road crossing(mL)		19.Weathering and Raveling(m2)			
	5.Corrugation(m2)		10.long or trans cracking(ml)		15.Rutting(m2)					
sample unit No.	Distress severety	Quantity						Total	Density	Deduct
42	13H	2	2.25					4.25	2.0	68
	15M	1.25						1.25	0.6	16
	19H	9						9	4.3	28
	11L	0.9						0.9	0.4	0.2

m=1+(9/98)*(100-HDV)

m=1+(9/98)*(100-68)=3.94 — 3.938776

Use highest 3 deducts and 0.51 of Four deduct

0.102

Iteration No	DV						q	TDV	CDV	
1	68	28	16	0.102			3	112	71	21.2
2	68	38	2	0.102			2	108	78.8	
3	68	2	2	0.102			1	72	75	

Max CDV =78.8

PCI = 100- Max CDV =21.1

Rating =Serious

Table 7-4hana kelebet to Dama hotel

	Asphalt road surface and parking lots										
	Condition survey data sheet						Sketch				
	For Sample unit										
	Branch:- Hana kelebet to Dama			**section :-**		**sample unit:-**					
	Surveyed by:Group			**date:-____________**		**sample area:-1050m2**			100M		
	1.Alligator cracking(ml)		6.Depression(m2)		11.paching/utility cut pacting(		16.Shoving(m2)		Survey Direction		
	2.Bleeding(ml)		7.Edge cracking(ml)		12.polishing Agregate(m2)		17.Silppage cracking				
	3.Block cracking(ml)		8.Reflection cracking		13.potholes(No)		18.Swell				
	4.Bump or sag		9.Lane/shoulder drop off		14.Rail road crossing(mL)		19.Weathering and Raveling(m2)				
	5.Corrugation(m2)		10.long or trans cracking(ml)		15.Rutting(m2)						
sample unit No.	Distress severety	Quantity							Total	Density	Deduct
2	11L	6							6	2.9	18.7
	6M	2.7							2.7	1.3	21.6
	19H	15	7.5						22.5	10.7	43

m=1+(9/98)*(100-HDV)
m=1+(9/98)*(100-43)=6.24
Use highest 6 deducts and 0.24 of six deduct
0.24*17.7=4.25

Iteration No	DV			q	TDV	CDV
1	43	21.6	4.25	3	68.85	47
2	43	21.6	2	2	66.6	48
3	43	2	2	1	47	52

Max CDV =52
PCI = 100- Max CDV =48
Rating = Poor

Annex-B: -Road Gradient data

Table 7-5 survey data for coca cola to Mesalemia

1	470316.156	996469.435	2368.761	EX. CL
2	470316.133	996470.374	2368.737	EX. CL
24	470298.668	996470.098	2367.364	EX. CL
25	470298.735	996469.096	2367.31	EX. CL
44	470280.66	996468.677	2365.887	EX. CL
45	470280.667	996469.827	2365.849	EX. CL
85	470268.098	996468.765	2364.964	EX. CL
86	470268.282	996469.997	2364.994	EX. CL
87	470260.447	996471.512	2364.402	EX. CL
88	470259.898	996468.643	2364.383	EX. CL
89	470256.193	996472.91	2364.119	EX. CL
90	470255.016	996468.506	2364.044	EX. CL
95	470251.654	996468.484	2363.854	EX. CL
96	470250.467	996468.698	2363.789	EX. CL
97	470253.797	996473.928	2363.98	EX. CL
98	470250.609	996469.612	2363.787	EX. CL
99	470252.353	996474.383	2363.877	EX. CL
168	470194.846	996431.114	2361.289	EX. CL
168	470194.846	996431.114	2361.289	EX. CL
169	470213.788	996459.887	2362.562	EX. CL
170	470212.986	996459.837	2362.531	EX. CL
171	470213.91	996459.139	2362.532	EX. CL
188	470201.692	996443.802	2361.812	EX. CL
189	470202.468	996443.184	2361.794	EX. CL
230	470197.952	996496.887	2362.726	EX. CL
231	470198.279	996497.247	2362.73	EX. CL
235	470204.227	996492.372	2363.14	EX. CL
236	470204.52	996492.967	2363.139	EX. CL
237	470206.25	996490.918	2363.271	EX. CL
238	470206.875	996491.663	2363.256	EX. CL
239	470207.069	996490.388	2363.278	EX. CL

Table 7-6 Coca-Cola to Mesalemia right side

3	470315.858	996459.508	2368.51	RHS
4	470315.268	996480.246	2368.386	RHS
26	470297.449	996459.211	2367.06	RHS
39	470282.267	996458.995	2365.807	RHS
57	470298.506	996480.342	2366.897	RHS
58	470292.487	996481.921	2366.334	RHS
59	470289.171	996483.519	2366.092	RHS
60	470260.392	996498.714	2364.908	RHS
61	470253.094	996490.979	2364.348	RHS
62	470286.319	996486.116	2365.877	RHS
63	470284.316	996488.722	2365.771	RHS
64	470282.266	996492.313	2365.568	RHS
65	470251.316	996488.452	2364.225	RHS
66	470280.484	996495.703	2365.497	RHS
67	470279.162	996500.861	2365.532	RHS
68	470251.472	996487.602	2364.194	RHS
73	470256.282	996484.157	2364.13	RHS
74	470278.914	996509.725	2365.969	RHS
75	470278.694	996503.619	2365.639	RHS
109	470261.387	996458.379	2364.307	RHS
110	470252.432	996458.436	2363.778	RHS
119	470244.826	996458.294	2363.418	RHS
120	470240.304	996457.753	2363.281	RHS
127	470235.753	996455.961	2363.025	RHS
127	470235.753	996455.961	2363.025	RHS
131	470229.123	996454.685	2362.806	RHS
131	470229.123	996454.685	2362.806	RHS
144	470224.554	996453.688	2362.631	RHS
145	470221.464	996451.75	2362.466	RHS
146	470219.012	996449.077	2362.261	RHS
156	470217.48	996447.273	2362.134	RHS
159	470208.024	996433.332	2361.336	RHS
167	470203.177	996425.704	2360.983	RHS
242	470209.814	996500.972	2363.256	RHS
243	470203.89	996504.611	2362.83	RHS
245	470206.873	996502.684	2363	RHS
252	470218	996500.49	2363.748	RHS
257	470223.314	996502.042	2363.976	RHS
265	470235.968	996504.504	2364.338	RHS
266	470239.397	996507.188	2364.42	RHS
267	470227.301	996502.702	2364.101	RHS
279	470249.107	996517.144	2365.043	RHS
289	470261.302	996528.936	2366.046	RHS
307	470285.868	996522.567	2366.874	RHS
309	470282.944	996519.203	2366.586	RHS
314	470281.063	996515.762	2366.33	RHS

Table 7-7 Deberezit road to Glean condominium

1	982121.369	472652.451	2084.45	GPS10A
2	982166.588	472663.176	2085.062	CL
3	982156.232	472669.933	2084.93	SH
4	982144.465	472676.812	2084.683	SH
5	982176.317	472658.135	2085.469	SH
6	982184.465	472655.082	2085.665	SH
7	982137.098	472681.36	2084.424	SH
8	982189.018	472649.27	2085.577	SH
9	982163.846	472663.046	2084.879	EP
10	982168.98	472680.675	2087.289	CL
11	982159.821	472686.567	2087.035	SH
12	982148.816	472692.391	2087.236	SH
13	982195.514	472666.818	2087.796	SH
14	982180.501	472674.552	2087.393	SH
15	982142.498	472696.844	2087.14	SH
16	982205.405	472661.48	2088.208	SH
17	982171.15	472681.406	2087.527	Asphalt
18	982156.599	472689.461	2087.292	Asphalt
19	982143.626	472697.174	2087.074	Asphalt
20	982198.427	472667.368	2088.074	Asphalt
21	982207.397	472663.068	2088.294	Asphalt
22	982143.731	472697.144	2087.058	Asphalt
23	982171.971	472693.327	2086.906	Asphalt
24	982158.196	472700.944	2086.646	Asphalt
25	982146.698	472707.962	2086.608	Asphalt
26	982191.525	472682.925	2087.331	Asphalt
27	982205.164	472676.174	2087.586	Asphalt
28	982138.916	472712.861	2086.478	Asphalt
29	982163.948	472710.306	2088.218	SH
30	982171.186	472712.411	2088.485	BM1.1
31	982161.601	472630.373	2085.539	SH
32	982172.998	472692.917	2087.05	walkway
33	982156.379	472702.43	2086.81	walkway
34	982174.779	472695.863	2087.129	walkway
35	982187.723	472685.04	2087.322	walkway
36	982158.022	472705.191	2086.895	walkway
37	982188.828	472688.172	2087.411	walkway
38	982180.211	472689.012	2087.201	walkway
39	982199.442	472679.086	2087.612	walkway
40	982181.072	472692.181	2087.251	walkway
41	982155.831	472703.73	2086.795	EP
42	982147.474	472711.496	2086.681	walkway
43	982144.975	472709.172	2086.489	walkway
44	982173.528	472696.702	2087.213	EP
45	982184.452	472693.246	2086.533	H
46	982193.019	472689.295	2088.383	H

Annex-C: -Traffic volume data

Table 7-8 Traffic volume for hana kelebet to dama hotel

Disstressed section													
	Roads and highways Department				Traffic count sheet					Sheet 04			
Name of Roads Hana Kelebet to Dama Hotel					Road NumberS :- Section					date 16/04/2015			
	Enumerator :-hiwet				supervisor yematawork								
sample unit 04	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajiaj	moter cycle	bicycle	Gari	
	8:30-8:45		1	7	2	5	2	10	5		1		
	8:45-9:00	*1*	*5*		*4*	*3*	*1*	*6*	*7*	*1*		*1*	
	9:00-9:15	4	2		6	4	5	7	9		1		
	9:15-9:30			4		3	4	4	8	1			
	PCU multiple	5	8	11	12	15	12	27	29	2	2	1	
	Total	10	16	22	24	30	12	27	12	1	0	1	154

Hana Kelebe to Dama hotel													
Disstressed section													
	Roads and highways Department				Traffic count sheet					Sheet 05			
Name of Roads Hana Kelebet to Dama Hotel					Road NumberS :- Section 06					date 16/04/2015			
	Enumerator :-gashew				supervisor yematawork								
sample unit 05	hour count	heavy truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajiaj	moter cycle	bicycle	Gari	
	11:00-11:15	1	1		2	5	14	11	13				
	11:15-11:30	*2*	*3*	*9*	*4*	*12*	*13*	*22*	*21*	*1*		*1*	
	11:30-11:45		2			4	9	12	19		3		
	11:45-12:00	2		4		3	17	14	18	2			
	PCU multiple	5	6	13	6	72	53	59	71	3	3	1	
	Total	10	12	26	12	144	53	59	28	1	1	1	743

Table 7-9 Traffic volume for Coca-Cola to Mesalemia street

From Deberezeit road to gelan Condominium													
Distressed section													
	Roads and highways Department				Traffic count sheet					Sheet 01			
Name of Roads	From Deberezeit road to gelan Condominium				Road NumberS :- Section 01					date 11/07/2015			
	Enumerator :-Hiwan				supervisor yematawork								
					sumple 01	Sunday	megabit						
sample unit 01	hour count	heavey truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajiaj	moter cycle	bicycle	Gari	
	8:30-8:45	2			4	12	6	20	1	1			
	8:45-9:00		*4*	*3*	*1*	*9*	*4*	*13*	*3*				
	9:00-9:15	3		1	4	4	5	10	1		1		
	9:15-9:30	3	1	4	3	7	11	9	5	1			
	PCU multiple	8	5	8	12	32	26	52	10	2	1	0	
	Total	16	10	16	24	64	26	52	4	1	0	0	213
	Roads and highways Department				Traffic count sheet					Sheet 02			
Name of Roads	From Deberezeit road to gelan Condominium				Road NumberS :- Section 01					date 11/07/2015			
	Enumerator :-sosi				supervisor yematawork								
sample unit 02	hour count	heavey truck	medium truck	small truck	Large bus	minibus	4WD	Car and taxi	Bajiaj	moter cycle	bicycle	Gari	
	8:30-8:45	2			4	12	5	19	1	1		1	
	8:45-9:00			*3*	*1*	*9*	*8*	*14*	*3*				
	9:00-9:15	3	4	1	4	4	5	9	1			1	
	9:15-9:30	3	1	4	3	7	11	6	5	1			
	PCU multiple	8	5	8	12	32	29	48	10	2	0	2	
	Total	16	10	16	24	64	29	48	4	1	0	1	213

Annex-D: - travel Speed data

Table 7-10 Average travel speed analysis

Date: DD/MM/YY								Start Time:
Name: ___________	section. 01		sample unit:-01					End Time:
Location:lafto to st .Geberial								Down Time: N.A.
Speed Limit: 30 mph								Weather: Clear
		Passengar Vehicls		Bus		Trucks		
Seecond	KPH for 100m	Record	frequency	Record	frequency	Record		Total frequency
4	27.0		2					2
3	36.0		3					3
4.3	25.1		1		2			3
5.1	21.2		6		1			7
6	18.0		4		2			6
9.2	11.7			3	1			4
6.5	16.6		6		2			8
7	15.4		4		1			5
6.3	17.1				3			3
8	13.5		3					3
5.2	20.8			2	1			3
7.3	14.8		7	3	2			12
4.5	24.0		3	1				4
6.4	16.9		4	1				5
8.3	13.0		7		2			9
9	12.0		8	1				9
7.5	14.4		4	2				6
9.6	11.3		8					8
	328.8							100

Table 7-11travel speed colleting sheet


Gel ane To KT project

Date:-	Start time:- 7:30
Name:-	End time:-
Location:-	Down time
Speed Limi	Weather :-
Second	mph

passenger vehicles			Buses			Trucks			Total
Record	Frequency	speed(Kph)	Record	frequency	Speed(kmp	record	frequency	peed(kmph)	

5-5

6-6

7-7

Table 7-12 Speed calculation

												1feet/sec	=	0.681818	mph			
Date: DD/MM/YY								Start Time:				1m/s	=	2.236936	mph	100		
Name: ________________	section. 01		sample unit:-01					End Time:				5		11				
Location: crossing gelan conduminum to selam tower								Down Time:				3.75		8				
Speed Limit: 30 mph								Weather: Clear				2.727273		6				
		Passengar Vehicls		Bus		Trucks						3		7				
												3.333333		7				
Seecond	KPH for 30m	Record	frequency	Record	frequency	Record		Total frequency								speed	frequancy	comulative frequancy
6	18.0		1		1	1		3	6.8	15	15	15.0%				18	3	3
8	13.5				3			3	7.7	10	25	25.0%				14	3	6
11	9.8		1		1			2	7.7	1	26	26.0%				10	2	8
10	10.8		5			2		7	8.3	15	41	41.0%				11	7	15
9	12.0		4		2			6	8.7	2	43	43.0%				12	6	21
8.6	12.6		1			1		2	9.0	1	44	44.0%				13	2	23
7.5	14.4				2			2	9.8	2	46	46.0%				14	2	25
5.8	18.6		2			1		3	10.8	2	48	48.0%		50th		19	3	28
14	7.7				1			1	10.8	7	55	55.0%				8	1	29
13	8.3		11			4		15	12.0	6	61	61.0%				8	15	44
10	10.8				2			2	12.6	2	63	63.0%				11	2	202
7	15.4		8			1		9	13.5	3	66	66.0%				15		
16	6.8		12		2	1		15	14.4	2	68	68.0%				7		
6.6	16.4		6			3		9	15.4	9.0	77	77.0%		85th		16		
12	9.0				1			1	16.4	9	86	86.0%				9		
12.4	8.7				1	1		2	18.6	3	89	89.0%				9		
3	36.0		6		2			8	18.0	3	92	92.0%				36		
14	7.7		7			3		10	36.0	8	100	100.0%				8		
	236.5							100				0.0%				236		
												0.0%			Average travel speed			50th
								0.0	236.5	100	100	100.0%					0.888889	17.38289297
																	0.9	
																	19.6	

Annex-E: -Geometric characteristic measurement

From Deberezeit road to glean Condominium

Distressed section

sample unit	Length (M)	No of lane(no)	Width of Lane(m)	median	walkway width(m)
1	100	2	7	No	0
2	100	2	7	No	0
3	100	2	7	No	0
4	100	2	7	No	0
5	100	2	7	No	0
6	100	2	7	No	0
7	100	2	7	No	0
Non-distressed section					
sample unit	Length (M)	No of lane(no)	Width of Lane(m)	median	walkway width(m)
8	100	2	7	No	0
9	100	2	7	No	0
10	100	2	7	No	0
11	100	2	7	No	0
12	100	2	7	No	0
13	100	2	7	No	0
14	100	2	7	No	0

Mesalemia-Medehanialem and Lafto - St. Gebrial Ch.					
sample unit	Length (M)	No of lane(no)	Width of Lane(m)	Presence of median	walkway width(m)
1	100	1	7	No	0
2	100	1	7	No	0
3	100	1	7	No	0
4	100	1	7	No	0
5	100	1	7	No	0
6	100	1	7	No	0
7	100	1	7	No	0
8	100	1	7	No	0
9	100	1	7	No	0
10	100	1	7	No	0
11	100	1	7	No	0
12	100	1	7	No	0
13	100	1	7	No	0
14	100	1	7	No	0
15	100	1	7	No	0
16	100	1	7	No	0
17	*100*	*1*	7	No	0
18	100	1	7	No	0
19	100	1	7	No	0
20	100	1	7	No	0
21	100	1	7	No	0

Annex-F AACRA maintenance data

Addis Ababa City Roads Authority (AACRA)

Own Force Road Maintenance

Project: LOT 11 Region:- (South)

Pavement Maintenance Work Monthly report of Tahisase, 2015

No.	Location	Unit	Work Activity	
			Asphalt Base Patching	Asphalt Overlay
1	Gofa Gebriel RA	ml	-	-
2	Cadisco Intersection to Haile Germen RA	ml	686.57	-
3	hana mareyam over pass saris dama hotel	ml	-	274.29
4	haile garment to jamo michael	ml	180.00	-
5	lebu varnero RA	ml	-	-
6	saris 58 to hana maryam over pass	ml	-	217.14
7	lebu varner to lebu musica sefer	ml	200.71	-
8	adey abeba intersection area	ml	-	-

Addis Ababa City Roads Authority (AACRA)

Own Force Road Maintenance

Project: LOT 1 Region:- (West)

Pavement Maintenance Work Monthly report of yekatit 2015

No.	Location	Work Activity	
		Asphalt Base Patching	Asphalt Surface Overlay
1	Stadium - Ambasader	13.71	-
2	Kesanchis - Yordanos Hotel	9.14	-
3	Churchil - Beherawi	30.00	-
4	Kesanchis - Beherawi	65.57	-
5	Mesalemia - Cocacola	25.00	-
6	UAE Embassy - Total	141.71	162.86
9	Torhayiloch -Total	6.00	-
11	Zenebewark - Total	72.14	-
12	Sefara Selam -Medanialem	31.57	18.86
13	Kesanchis -Hilton Hotel	11.14	-

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	Upper Bound	Collinearity Statistics Tolerance	VIF
1	(Constant)	50.627	2.157		23.471	.000	45.880	55.375		
	GRAD	1.035	.579	.425	1.787	.101	-.240	2.310	.975	1.026
	traffic flow	-.008	.004	-.534	-2.248	.046	-.016	.000	.975	1.026

a. Dependent Variable: SPEED

Correlations

		SPEED	GRAD	traffic flow
Pearson Correlation	SPEED	1.000	.340	-.467
	GRAD	.340	1.000	.158
	traffic flow	-.467	.158	1.000
Sig. (1-tailed)	SPEED	.	.117	.046
	GRAD	.117	.	.295
	traffic flow	.046	.295	.
N	SPEED	14	14	14
	GRAD	14	14	14
	traffic flow	14	14	14

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	120.557	2	60.279	3.578	.064[b]
	Residual	185.334	11	16.849		
	Total	305.891	13			

a. Dependent Variable: SPEED

b. Predictors: (Constant), traffic flow, GRAD

From debrizet road to Glean condominium Gradient (%)

Sample unit	Average travel speed	Outlier
1	10	FALSE
2	12	FALSE
3	20	FALSE
4	21	FALSE
5	23	FALSE
6	28	FALSE
7	29	FALSE
8	30	FALSE
9	31	FALSE
10	34	FALSE
11	34	FALSE
12	36	FALSE
13	38	FALSE
14	41	FALSE

QTL1	21.50
QTL3	34.00
IQRS	12.50
Lower Limit	2.75
Upper Limit	52.75

Coca-Cola to mesalaemia

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial
1	(Constant)	9.449	1.481		6.381	.000	6.360	12.537		
	PCI	.411	.020	.676	21.000	.000	.370	.451	.903	.978
	Traffic flow	.012	.001	.500	14.367	.000	.010	.013	.804	.955
	Road grade	-81.520	10.309	-.229	-7.908	.000	-103.025	-60.016	.096	-.870
	walkway width(m)	.156	.351	.013	.444	.662	-.577	.889	-.306	.099

a. Dependent Variable: ATS(Kph)

Model Summary[b]

Model	R	R Square			Change Statistics

			Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.993[a]	.986	.983	.71073	.986	355.305	4	20	.000

a. Predictors: (Constant), walkway width(m), PCI , Road grade, Traffic flow

b. Dependent Variable: ATS(Kph)

EMPLOYER			CONSULTANT								
Addis Ababa City Roads Authority			Engineer Zewdie Eskinder & Co.Plc								
BILL-2 and Bill -3	Description		Rate	Serious		failed		very poor		poor	
			ETB	quantity	Amount ETB	quantity	Amount ETB	Quantity	Amount ETB	Quantity	Amount ETB
2	Bill No. II										
	Earthworks										
205 P5	Capping Layer under the subbase layer with maximum compacted layer thickness 300mm,and as specified on the agreement and irrespective of the hauling distance	m3	245.10	2,091.67	512,667.34	2,091.67	512,667.34	1,201.53	294,495.00	8.1	1,985.31
Total BILL-2 Carried Forward to Summary											
3	Bill No. III Pavements										
	a. Carriageway										
301 P3.4 (ii)	30cm thick Gravel Subbase Compaction to 96% of AACRA Test S-11 Test S-11 Density (Compacted layer thickness of maximum 150mm)	m3	476.38	1,045.83	498,213.92	1,045.83	498,213.92	865.80	412,451.23	87.018	41453.63484
302 P1.2 (i)	25cm thick Crushed Stone Base Compaction to 98% of AACRA Test S-11 density (miximum compacted layer thickness 150mm)	m3	515.93	871.53	449,647.18	871.53	449,647.18	636.66	328,473.28	871.5275	449647.1831
401 P1.1	Supply and spray MC- 30 Cut Back Asphalt Prime Coat application at a Rate of 1lit/m^2 between aspalt concrete and Base Course.	Lit	31.81	3,486.11	110,893.16	3,486.11	110,893.16	3,486.11	110,893.16	3486.11	110893.1591
403 P1	Supply and apply RC-70 Tack Coat application at a Rate of 0.3 lit/m^2 on every layer of Asphalt Concrete.	Lit	37.18	3,486.11	129,613.57	3,486.11	129,613.57	3,486.11	129,613.57	3486.11	129613.5698
403 P4	Dense Graded Ashpaltic Concrete (AC) Wearing Course Compacted thickness of 70mm	m2	427.56	3,486.11	##########	3,486.11	1,490,521.19	3,486.11	1,490,521.19	3486.11	1490521.192
403 P3 (b)	Dense Graded Ashpaltic Concrete (AC) in intremediate Courses for bottom layer Compacted thickness of 80mm	m2	472.88	3,486.11	##########	3,486.11	1,648,511.70	3,486.11	1,648,511.70	3486.11	1648511.697