ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

INVESTIGATING EFFECTS OF ROAD GEOMETRY ON ACCIDENT BLACKSPOT OF ADDIS ABABA TO GOHATSION TRUNK ROAD

A thesis submitted to School of Graduate Studies of

Addis Ababa University

In Partial Fulfillment of the Requirements for the Degree of

Masters of Science in Civil Engineering

(Road and Transportation Engineering)

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We the under signed members of board of examiners of final M.Sc. Open Defense, verify that we have read and evaluated the thesis prepared by **Berhanu Seyoum**, entitled: Investigating **Effects of Road Geometry on Accident Blackspot of Addis Ababa to Gohatsion Trunk Road** and recommended for the acceptance as fulfillment of the requirements for the **<u>Degree of Masters of Science in Civil Engineering (Road and Transportation Engineering)</u>**

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Declaration

I certify that the research work titled, "***Investigating Effects of Road Geometry on Accident Blackspots Along Addis Ababa to Gohatsion*** Trunk Road" is my own work. The work has not been submitted for any academic achievement in other academic institutions. All sources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

Ethiopia is experiencing high number of traffic accident record contrary to the low road network density and least number of vehicle fleet when compared to the world. The increase in occurrence of traffic accident is due to increase in motorization without regulation and rapid population growth and increase in road network density with poor attitude and safety consideration while designing and constructing the roads. Along with expansion of the road network mandatory road safety policy was not developed, clear and updated legislations were not formed and capable institutional organization for implementation were not established to take safety into consideration at early stage of the design of the road. The purpose of this study is to identify the black spots along the road under the study and to investigate the relationship of the geometric design parameters of the road at blackspot locations with road traffic accident when compared to the recommended standard set by ERA. Three years' traffic crash data were collected from six woredas (Wacaalee, Debrelibanos, Giraar Jaarsoo, Dagam, Kuyyuu and Warra Jaarsoo) and three town administrations (Fitche, Chancho and Sululta) along Addis Ababa to Gohatsion trunk road and as built data were collected from Ethiopian Roads Administration (Road Asset Management Directorate). Supporting these secondary data with primary data, thirty-seven blackspot locations were identified using Rate Quality Control (Accident Rate, Accident Frequency and Severity Index) method and Accident density method and these 37 blackspot locations are mapped using GIS Software. The geometric design parameters of the road at these black spot locations are further analyzed using SPSS software. Multiple linear regressions were fitted to explain the number of accident based on lane width, shoulder width, supper elevation, vertical curve, gradient, 85th percentile speed and minimum clear zone. Among the explanatory variables supper elevation significantly affects number of traffic accident, whereas others moderately.

Keywords: Geometric Parameters, Traffic Accident, Blackspot, Multiple Regressions

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ABBREVATIONS AND ACRONYMS

AADT – Annual Average Daily Traffic

ADT – Average Daily Traffic

ANOVA – Analysis of Variance

APPP – Active Public Participation Program

ASI – Average Severity Index

BE- Broken edge

Bs – Below Standard

BS – Blackspot

CSA – Central Statistical Agency

Cum – Cumulative

df – Degree of freedom

e – Supper elevation

ERA – Ethiopian Roads Authority/Administration

Fig. – Figure

G – Gradient

GDP – Growth Domestic Product

GIS – Geographic Information System

GNP – Growth National Product

H.Rad. – Horizontal Radius

HCM – Highway Capacity Manual

KM – Kilometer

LW – Lane Width

Max. – Maximum

MCZ – Minimum Clear Zone

Min – Minimum

NA – Not Applicable/Available

NCHRP – National Cooperative Highway Research Program

NGO- Non Governmental Organization

NPL – No Parking Lane

NPS – No Proper Shoulder

NWW – No Walk Way

OSZSF – Oromia Special Zone Surrounding Finfinnee

PD – Desired Percentile

PDO – Property Damage Only

Pmax – Cumulative Maximum Percentile

Pmin – Minimum Cumulative Percentile

PS – Percentile Speed

SD – Desired Speed

Sh.W – Shoulder Width

Sig. – Significance

Smax – Maximum Speed

Smin – Minimum Speed

SPSS – Statistical Package for Social Science

Std. – Standard

TVET – Technical Vocational Education and Training

VC – Vertical Curve

VIF – Variable Inflation Factor

VIP – Vertical Point of Intersection

VPC – Vertical Point of Curvature

VPT – Vertical Point of Tangency

Vs – Versus

WHO – World Health Organization

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CHAPTER ONE

1. Introduction

1.1 Background of the study

People travel from one place to another either to work or to do business or to study or to enjoy and, goods are also transported across different places using various transport options. Vehicle is one of the most widely used transport alternative and the major source of road traffic accidents in the world. Due to road traffic accidents, the majority of road users could not return to home: farewell this world for once and all, spent long days, weeks, months, and even years in health centers and/or hospitals, and never be able to work or play as they used to do before. Particularly, nowadays, road traffic accident has been both public health and development issue and attracted the attention of governments, civil society organizations, and business and community leaders throughout the world (Kussia, 2017).

According to the study from World Health Organization (WHO), deaths from road traffic crashes have increased to 1.35 million a year. That’s nearly 3,700 people dying on the world’s roads every day (WHO, 2018). Between 20 and 50 million more people suffer non-fatal injuries with many incurring a disability as a result of their injury. Road traffic injuries cause considerable economic losses to individuals, their families and to nations as whole. These losses arise from cost of treatment as well as lost productivity due to those killed or disabled by their injuries and due to family members who need to take time off work or school to care for the injured (WHO, 2017).

Currently, developing countries contribute to over 90% of the world’s road traffic fatalities. In Africa over 80% of commodities and people are transported by roads while in Ethiopia road transport accounts for over 90% of all the interurban freight and passenger movements in the nation (Kussia, 2017). So there is a great chance of road traffic accident occurrence due to the poor quality of the infrastructure and other factors. According to the data gained from Ethiopian Federal Transport Authority, in Ethiopia about 5,118 people died of road traffic accident during Ethiopian fiscal year 2017/2018 only. The authority also indicated that Ethiopia's rate of traffic incidents during the just concluded fiscal year has registered a 6-percent increase as compared with the previous year (2016/2017). Though Ethiopia has one of the lowest per capita car ownerships in the world, deadly traffic accidents are fairly common with bad roads, flawed driving license issuance system and lax enforcement of road safety blamed.

Out of this, majority of the accident occur in Oromia regional state due its location at the center of the country, is a center for trade and mass number of population in the region. The study area under research (Addis Ababa to Gohatsion Trunk Road) is the accident prone track as mass composition of vehicles travel on this road connecting Northern part of the country to the center.

1.2 Statement of the problem

The reason why this research aims to investigating the effect of road geometric parameters on accident black spot is due to the rapid traffic accident growth and little attention given to the effect of road specially the road geometric design elements on safety impact. Geometric design standards specify appropriate minimum, maximum and desirable values of the road elements. These values are usually separately specified, although usually many are interrelated. Sometimes there may exist substantial difference between the standards specified and the constructed road. Even if it is difficult to quantify the safety implications of departures from the standard, since these standards are mainly based on logically derived relationships rather than on safety studies there is a relationship between design parameters and safety.

Little attention is given to the effect of road geometry in causing traffic accident. Many of the researchers in highway safety have focused on different factors which affect the road way safety. These factors are categorized as traffic characteristics, road way surface conditions, weather and human factors. There are also the influences of various geometric design variables on the occurrence of accidents and not all variables have the same level of influence in all places. So, the major influential variable should be identified from the identified black spot locations for the sake of relevant application of countermeasure.

The departure from the standard may exist due to trouble terrain and other factors throughout the country (Ethiopia). The selected study area is the accident prone corridor which is the trunk road from Addis Ababa to Gohatsion (Qarreegohaa) due the reason that this road incorporates different trouble terrain including Abay gorge and many other places which seek attention of the designers and builders to look in detail to geometric design parameters to assure the safety of the road primarily.

1.3 Research Questions

At the completion of this thesis the following questions will be answered.

1. Where are the black spots along the Addis Ababa to Gohatsion trunk road located?
2. Does the road geometry of black spot sections along Addis Ababa to Gohatsion trunk road really cause traffic accident? If the answer is yes, which geometric design parameter's defect, more affects which section of the black spot locations?

1.4 Objective of the research

1.4.1 General Objective

The aim of this thesis is identifying the black spot locations along the indicated road and investigating the effect of road geometry regarding to causing the road traffic accident at the identified black spot locations.

1.4.2 Specific Objectives

- To identify the black spots on the road section under the study, ranking of the black spot and analyzing the top ranked black spots and giving suggestion of possible improvements
- To identify the main road geometry defects that lead to cause more traffic accident and giving appropriate solutions.
- To analyze the effect of the road geometry on the identified accident black spot in causing accident and finally recommending the possible solutions to fill observed gaps and problems investigated during the research.

1.5 Significance of the study

The study mainly concerned with the traffic safety in Oromia regional state North Shoa zone (Salaale). Emphasis is given to studying and investigating the effect of the geometry of the road on accident black spot locations of the road along Addis Ababa to Gohatsion. Black spot locations of the road are first identified and then defects of geometry of the road at those black spot locations is investigated one by one compared to standard set by Ethiopian Roads Authority (ERA). Therefore, the significance of the study will be stated as follows.

- Even if the study is conducted for academic purpose and limited to single route it will be helpful to have detail knowledge about the complicated problem of rural and urban road transport in general and accidents in particular.
- The findings obtained from the study would be helpful to gain information and knowledge about the geometric defects of the road at black spot locations in rural and the town, which in turn could help to develop countermeasures that could reduce the number and severity of accidents and insure the safety of the road.
- It is important for the traffic police, for enforcing the traffic rule and distribution of man power for surveillance.
- It is important to the government, Ethiopian Ministry of Transport and Ethiopian Roads Authority to determine the need for road safety improvements and to initiate programs for campaign and teaching the people for awareness creation purposes.
- It also helps as a source of information for the institutions concerned with road safety management and helps to improve the quality of decision-making in rural and urban road transport safety planning.

- Finally, it helps to carry out further research to refine the conceptual and methodology of this study to come up with the best solution research in its kind.

1.6 Scope of the research

The scope of the research was limited to the trunk road from Addis Ababa to Gohatsion (Qarree Gohaa) capital town of Warra Jaarsoo woreda which borders the Amhara regional state. Even if the project is named Addis Ababa Gohatsion, the data used extends up to Abay River Bridge which is the border of the two regional states Oromia and Amhara (197.237 KM). In addition, the study focuses on effects of geometry of the road only on accident black spot locations in general and how to identify black spot location in particular. All necessary scientific countermeasures which are supposed to fill the gaps are proposed finally.

1.7 Limitation of the Research

Even if it is planned to conduct the thesis in detail on the tittle "*Investigating the effect of road geometry on accident black spot on Addis Abeba to Gohatsion trunk road* "so many factors limit not to undertake the study as wanted. The content of the road accident reporting, as it exists now, misses relevant details of an accident report required for road safety improvement works. The reporting form, in the daily report book, is not designed to include details of each vehicle and road user involved in an accident. The report, further, does not contain details of the road section and precise location of an accident. The location of an accident is reported broadly by district, *Kebele and Wereda* or the name of the surroundings. Besides, because a plain paper is used on the spot, the investigating policeman is unlikely to remember the required accident details and as a result the form available at the local traffic police office is never fully recorded. The information recorded could generally be adequate for the police work (crime investigation), but it is of limited use to other bodies requiring information for identifying the causes and appropriate remedial measures. It is primarily inadequate in determining the exact location of accidents and the factors involved. Moreover, accident reporting lacks a significant level of consistency. There also exists a significant variation in accident reporting from woreda to woreda. In addition to the indicated limitations of accident reporting, there is no established system of computerized accident data recording to store detailed information of each road traffic accidents occurring in the country. All these drawbacks contribute to inefficient traffic accident data management and its reporting system.

1.8 Organization of the research

The research comprised of 5 chapters, namely: Introduction, Literature review, Research Methodology, Results and discussion, and Conclusion and Recommendation.

In introduction part background of the study, statement of the problem, objective of the study, significance of study scope of the research and limitations of the study are discussed. In the second chapter the literatures written by different scholars are reviewed and highlighted to have a good insight about the title of the research.

Chapter three deals with methodologies how data is collected, types of data and the methods how to analyze these collected data. In chapter four depending on the traffic data that are collected from police stations, black spots are identified and the results are discussed in detail. Furthermore, the geometry of the black spot sections of the road are discussed in general and their correlation with the accident is seen particularly. Finally, the conclusions are drawn from the result of the research and appropriate recommendations are suggested to solve the problems identified during the research.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction to road Safety

Road traffic safety nowadays has the top priority and topic within sustainable transport system. The top challenges of the road traffic are loss of human live and loss of economy. Every person regardless of color, race, religion, gender, and etc. has the right to live on this world except when committed crime that is punishable by death. On contrary to this road traffic accident is picking the lives of many productive forces. Many young went out for work and don't return to their home, farewell this world for once and forever due to road traffic accident. Another challenge is loss of economy. On one hand, property is lost due to road traffic crash, and the productive forces are died and injured (become disabled) and cost is expended to recover from injuries on the other hand. Road traffic safety Engineering has to find answers to serious challenges of today's road traffic safety problem.

Studies have attempted to relate geometric elements and accident rate; but only a limited amount of reliable information is available and quantifying the safety impact of marginal changes in the values of geometric parameters is difficult. Geometric design standards or guide lines specify appropriate minimum, maximum and desirable values of the visible road elements and these values are specified separately although many are interrelated (O'Cinneide, 1995). Since these standards are mainly based on logically derived relationships rather than on safety studies, it is difficult to quantify the safety implications of departures from standards due to environmental or terrain restrictions. This paper draws general conclusions on the available international knowledge on the relationships between design parameters and safety.

In the future road transport will introduce solar panel roads and cars where solar sell replaces asphalt and concrete. Solar road ways generate energy and electronic vehicles are charged with the energy from the solar road and can be driven using remote that results in avoiding emission and reducing road accident.

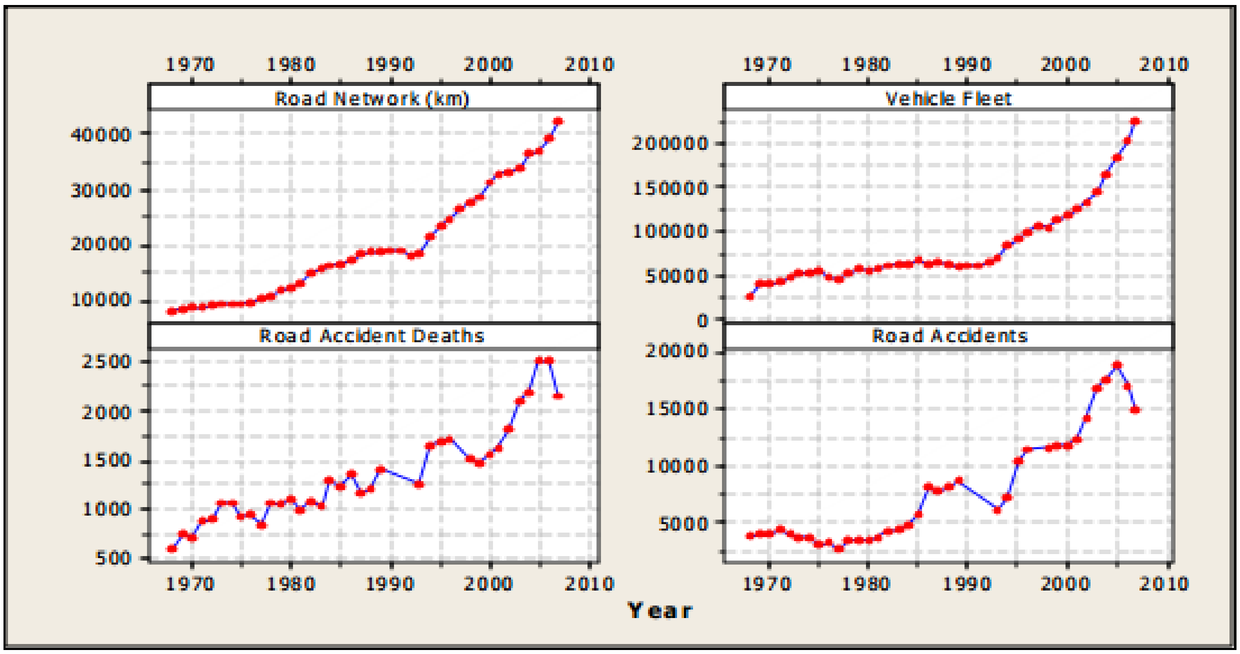
2.2 Global Road Traffic Safety

Road traffic injury is the 8th leading cause of death for all age groups, up from 9th leading cause of death. It is also now the leading cause of death for children and young adults aged 5-29 years, signaling a need for a shift in the current child health agenda, which has largely neglected the road safety (WHO, 2018). Road traffic injuries are among the three leading causes of death for people between 5 and 44 years of age. Unless immediate and effective action is taken, road traffic injuries are predicted to become the fifth leading cause of death in the world, resulting in an estimated 2.4 million deaths each year. This is, in part, a result of rapid increases in motorization without sufficient improvement in road safety strategies and land use planning. The economic consequences of motor vehicle crashes have been estimated between 1% and 3% of the respective GNP of the world countries, reaching a total over $500 billion.

Reducing road casualties and fatalities will reduce suffering; unlock growth and free resources for more productive use. Activities taken as part of a Decade of Action for Road Safety will also have an impact on steps taken towards improving systems of sustainable development (WHO, 2021).

2.3 Ethiopian Road Traffic Safety

Ethiopia promotes road safety as a national issue with a road safety lead agency accountable to the Ministry of Transport. However, there is no self-standing road safety policy. Legal instruments to enhance road safety have been revised and some are yet to be updated. There is a road safety national strategic plan in which the country targets to reduce fatalities by 50% in the Decade. However, the plan is not translated into achievable targets for each stakeholder with sufficient resource allocations required for the implementation to attain the national target (Berhanu, 2013).



Data Source: United Nations Economic Commission for Africa Report

Fig.2. 1Trends of road crash, Vehicle fleet, and road network expansion

Laws on seatbelt and helmet are enacted, but the enforcement is not strict. Drink driving and child restraint legislations are not enacted. Speed limits are regulated at national and local levels, but enforcement is not strict. Road safety education is provided for school children, but trained teachers and training materials are significantly lacking.

Public campaigns are regularly made but do not target specific road users' group or road safety issues based on relevant information from the road crash data.

Safety consideration in the road infrastructure is very limited (Berhanu, 2013). Road agencies lack capacity. There are no road safety audit and inspection manuals. Works to improve accident black spot are not practiced. Standards for vehicle import, manufacture and use are available, but need revision to cope with the current requirements. The enforcement of the standards is not strict.

Mandatory vehicle inspection and insurance are enacted and strictly enforced. Rescue and emergency system for road crash victims is nonexistent. The Road Fund has a provision to finance road safety from its collections. The available fund is not utilized effectively due to lack of capacity. The road crash cost in Ethiopia was estimated to about US$104 million or 0.5% of its GDP in 2009/10 (Berhanu, 2013).

2.3.1 Road accident deaths in Ethiopia

Ethiopia stands as one of the worst countries with respect to road accident deaths as the country contributed to a high proportion (23%) of road accident related deaths to the African continent (K. Guerts, and G. Wets, 2003). According to WHO data published in 2017, road traffic accident deaths in Ethiopia reached 27,140 or 4.27% of total deaths. The age adjusted death rate is 36.36 per 100,000 population ranks Ethiopia number 22 in the world (EVERA, 2019). In addition, the road accident deaths reached above 3,874.3 deaths per 100,000 vehicles and 80% of these deaths are attributed to driver's faults and the remaining due to road construction maintenance and technical problems of the vehicles including other leading causes of drinking and driving, noncompliance with traffic rules and speeding (Mathios, 2017).

Table 2. 1 Magnitude of Road Accident in Ethiopia

Types of accident	Year of traffic accident Recording				
	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Light injury	6,016	6,316	5,888	6,508	7,071
Heavy injury	4,979	5,042	6,039	5,918	6,886
Death	3,132	3,362	3,331	3,847	4,352
Percentage share of death	22.17%	22.83%	21.83%	23.64%	23.76%

Source; Federal police commission central Information and crime Intelligence Directorate, May 2017

Table: 1 above shows traffic accident rate in Ethiopia is growing. In 2011/2012 the number of registered traffic accident death was 3,132, but this reached 4,352 in year 2015/2016. The situation is likely to be even more severe than shown in the statistics due to the possible significant under-reporting.

2.3.2 Legislations Related to Road Safety in Ethiopia

Ethiopia has no defined transport policy. However, the Government of Ethiopia has defined a long term strategy and developed huge investment programs for the road network expansion and rehabilitation. Accordingly, it has been taking actions since 1997 to establish the foundations of a competitive road transport market. However, despite road traffic accident being a very critical problem to the road transport, the country has no road safety policy, strategy or program to tackle this problem. TRL in association with Ross Silcock11 underlined the absence of government policy regarding road safety which resulted in giving too low priority by road safety government agencies. The report indicated the greater attention started to be given to road safety, but pointed that the input is insufficient by any standard compared to the scale of the problem. Some of the reasons why the country has no road safety policy are: ·

- The presences of other pressing economic and social issues of priority for the government

- The economic effect is not fully appreciated by decision makers because much of it is indirect government expenditure, and more cost is borne by the society in general; ·
- Lack of awareness, knowledge, and experience on how road safety can be improved; and
- Constraints of funding.

Transport legislations and regulations used in Ethiopia are generally old for the current situations.

A study on road transport regulations identified problems related to the Road Transport Legislations among which (i) misinterpretation and misunderstandings of definitions of powers and duties of federal and regional transport organs; and (ii) amendments, deletions and replacements of old legislations and regulations without systematic compilation are the most important ones to road traffic safety. Legislations used in road transport activities in Ethiopia can be categorized in to the following groups:

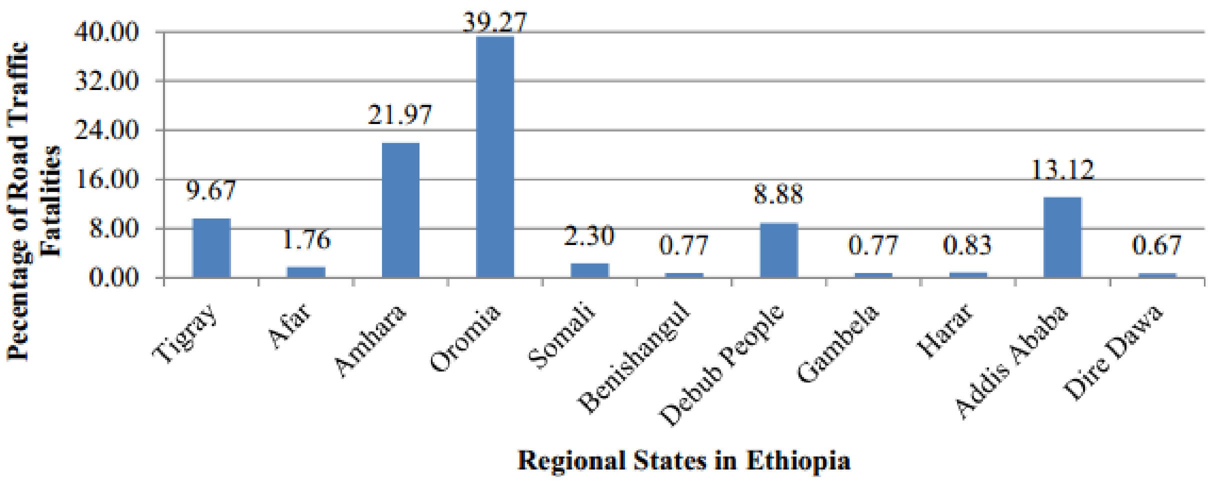
- Legislations on identification, registration, and inspection of motor vehicles
- Legislations on motor vehicle operator's (driving) license
- Legislations on traffic control (Road Code)
- Legislations on vehicle sizes and weights and
- Legislation on vehicle insurance against third party risks (Road safety in Ethiopia. Addis Ababa, 2009).

2.4 Oromia Regional State Road traffic and safety

Oromia is one of the nine ethnically based regional states of Ethiopia , covering 286,612 square kilometers. It is bordered by the Somali region to the east, the Amhara region, the Afar region and the Benishangul-Gumuz region to the north; South sudan, Gambela region, and Southern Nation Nationalities and Peoples region to the west; and Kenya to the south. The 2011 census reported Oromia Region population is 35,000,000; making it the largest state in population (Oromia Wekipidia, 2019).

Oromia region is found at the center of the country that covers 34.3% of the country's wide and big roads that take from Finfinnee to regional cities passing through it. Because of this reason the region hosts many traffic movements in its kind and number in the country and this causes the traffic accident to be occurred (Oromia Police Commission, 2019).

Accordingly, road traffic injury crashes in Ethiopia are clustered in the central parts of Ethiopia. Oromia regional state and Addis Ababa city account more than fifty percent (50%) of the total road traffic injury crashes in the country.



Sources: Federal Police Commission of Ethiopia, 2013

Fig.2. 2 Percentage of Road Traffic Fatalities Distribution by Regional States of Ethiopia in 2012/13

Oromia police commission and Oromia travel Agency are working together in order to minimize traffic accident that is becoming threat. The 143/2004 proclamation of Oromia region travel agency is implemented in order to give verdict again. Beside this, modern equipment like radar is being used and now alcohol tester is ready to be used. Because of the fact that it is not impossible to avoid traffic accident by only controlling criminals, the awareness on traffic accident is being given for road users of wide community so that they have to be careful of traffic accident. The traffic safety Education is being given once in two weeks for drivers and pedestrians on road and it is encouraging. Minimizing the traffic accident is being under taken by identifying the place where traffic accident occurs frequently. Due to this awareness creation, pedestrians are accustomed to using of left side while walking. In this case we can take many Oromia region's Zones as example. Even though, Oromia police commission and Oromia travel agency are trying to minimize the traffic accident in Oromia, still now the traffic accidents occur is becoming a threat and it should be given high emphasis.

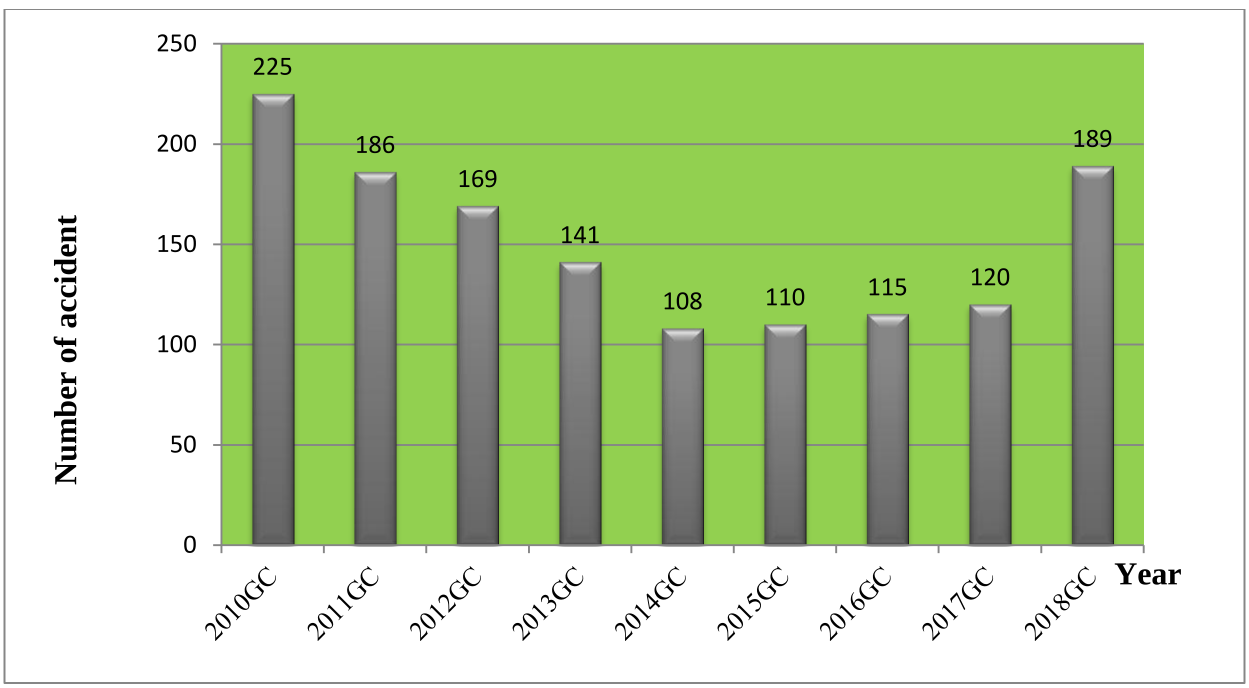
Because of this infliction high damage on human life and property is faced. Depending on this it is not difficult to guess the damage brought to economy and community by traffic accident. This traffic accident can be obstacle to our developmental activity in the future even if it is a threat for inflictions it brings on live and property. So, minimizing traffic accident in order to ensure the traveling safety shouldn't be left for one body. Therefore, every citizen of the country should participate in minimizing this traffic accident that may knock each of our houses (Oromia Police Commission, 2019).

2.5 Salaalee zone Road Traffic Safety

Salaale /North Shewa /is one of the Zones of the Ethiopian Region of Oromia. North Shewa takes its name from the kingdom or former province of Shewa.

North Shewa is bordered on the south by Oromia Special Zone Surrounding Finfinnee, on the southwest by West Shewa, on the north by the Amhara Region, and on the southeast by East Shewa. Towns and cities in North Shewa include Muka Xurrii, Debresige(Shararoo), Debre Libanos, Fiche and Garba Guracha Tulluu Milkii and Gohatsion(Qarreegohaa).

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this Zone has a total population of 1,431,305, of whom 717,552 are men and 713,753 women; with an area of 10,322.48 square kilometers, North Shewa has a population density of 138.66. While 146,758 or 10.25% are urban inhabitants, a further 9 individuals are pastoralists. A total of 314,089 households were counted in this Zone, which results in an average of 4.56 persons to a household, and 303,609 housing units. Since more towns and cities in this zone are found along the road from Addis Ababa to Gohatsion, many people use this road every day especially on market day. This corridor is accident prone corridor as there is a lot of composition of vehicles using this road and also due to unsuitable terrain along the road. Zonal traffic accident report in 2019 indicates significant decrease from year 2010 to 2014 and suddenly returns to become increasing from 2014 to 2018. The traffic accident data from year 2010 to 2018 is shown the graph below.



Data source: North Shoa transport bureau

Fig.2. 3Traffic accident data of North shoa zone from year 2010 to 2018 G.C.

2.6 Effect of Road Geometry on Road Traffic Accident

Geometric design elements play an important role in defining the traffic operational efficiency of any roadway. Key geometric design elements that influence traffic operations include the width and number of lanes, the presence and widths of shoulders and highway medians, and the horizontal and vertical alignment of the highway. The current philosophy of design is based on the implicit assumption that any design developed in accordance with established geometric design policies is safe and that any design that does not meet key aspects of established policies is unsafe (Douglas, W., Joseoh, E., and Kelth, K., 2000).

Most of the studies have shown the influence of various geometric design variables on the occurrence of accidents and have concluded that not all variables have the same level of influence in all places. From the relation of factor mentioned above, different researchers have developed the relationship of roadway safety in terms of crash frequency and crash rates, fatality and injury rates and the road elements, traffic characteristics, and pavement conditions. Many of these previous studies investigated the relationship of crash rates or frequency in terms number of lanes, lane width, presence of median, median width, type of median, shoulder width, access density, speed limit, vertical grade, horizontal curvature, weather condition. The relationship between safety on the highway and factors mentioned above is the primary focus in crash reduction and predictions (Deo, 2004).

2.7 Effects of Characteristics of Road Geometrical Design Elements on Traffic Accidents

Some of the primary geometric design elements that can affect the highway safety are carriageway, grade, horizontal curvature, shoulder, median, vertical curve. The relationship between some characteristics of these elements and traffic accidents, including studies made in different countries are classified into groups: *Cross-section effects and Alignment effects*. (A.F. Lyinam, S. Lyinam, and M.Ergun, 2004).

2.7.1 Cross-Section Effects

The widths of the various cross section elements affect the capability of driver to perform evasive maneuvers and determine the lateral clearances both between vehicles and between vehicles and other road users (O'Cinneide, 1995). Different scholars generalized the following about the effect of cross section on safety of the road.

a) **Lane width –** Traditionally wider lanes are associated with higher operating speeds and increased safety. The Highway Capacity Manual (HCM) documents states that wider lane for multilane highways result in higher free-flow speeds (Noland, R.B., and Oh.L., 2004). On the other hand, very little has been found on the safety implications of wider lanes. It is reasonable to assume that wider lanes may provide additional space to the driver to correct potential mistakes and thus avoid crashes.

However, a driver could be expected to adapt to the available space, and the positive safety effects from the wider lanes may be opposed by the higher operating speeds (Noland, R.B., and Oh.L., 2004). Generally, most studies agree that lower accident rates are associated to wider lanes. But it seems that there is an optimal lane width around 3.5m to 3.6m. Studies have also noted that approaches should base on more parameters of the cross section, at least also on traffic volume. According to (Md Hasibul Islam, Law Teik Hua, H.Hamid and Arash Azarkerdar, 2019) lane width, road width, median (overtaking restrictions), emergency (hardened shoulder) and number of lanes are very essential indicators of cross section accident factors. On the other hand, (Hearne, 1976) results suggested that there was a marginal increase in accident occurrence with an increase in carriageway width. (Hedman, 1990) noted that some results indicated a rather steep decrease in accidents with increased width of 4m to 7m, but that little additional benefit is gained by widening the carriageway beyond 7m. (Zegeer, Deen, and Mayes, 1981), (Zegeer, and Council, 1993), and (Mclean, 1985) have shown that width of 3.4 - 3.7m show the lowest accident rates. This idea is supported by (Transportation Research Board, 1978) conclusion that says there is little difference between the accident rate for 3.35m and a 3.65m lane width. However, studies on low volume rural roads indicate that accidents continue to reduce for widths greater than 3.65m, although at a lower rate (O'Cinneide, 1995). Transportation Research Board (Transportation Research Board, 1987) found that lanes wider than 3.70m do not contribute to a higher safety because they may result in unsafe maneuvers such as over taking despite of oncoming traffic. Another reason is the higher speed on wider lanes which leads to more accidents. (Yager, M., and Van Aerde, R., 1983) pointed out the passage of a vehicle requires a minimum lane width and that any additional width beyond this minimum allows one to drive faster and /or with a greater measure and perception of safety. For lane widths from 3.3m to 3.8m, they reported that the operating speed is decreased by approximately 5.7 km/hr for each 1m reduction in width of the road (O'Cinneide, 1995). (Lamm, R., Psarianos, B., and Mailaender, T., 1999) found a significant decline of accident rate up to 7.5m cross sections. In USA data of four states are analyzed to develop a prediction model for non-intersection and non-intersection related accidents (Council, F., and Steward, J.R., 2000). The results were statistically for two states only and indicate great differences regarding the benefits of widening cross sections. In North Carolina widening the surface by 1m reduces accidents by 14% and by 34% in California. (Elvik, R. and Vaa,T., 2004) also figured out a decline of accident cost rates if the cross section is widened by maximum 3m. Wider cross sections are not attributed by positive influence on road safety. All mentioned works have pointed out a decline of accident risk for wider cross sections. This positive trend is proved up to a certain lane width; wider cross sections are characterized by a lower safety benefit or even by increasing accident risk.

b) **Number of Lanes-**The number of lanes is another variable which has been discussed in detail by various researchers.

Almost all studies conclude that the higher the number of lanes, the higher the crash rate (Deo, 2004). (Noland, R.B., and Oh.L., 2004) found that increasing the number of lanes was associated with increasing traffic crashes in their research. In another study, (Abdel-Aty, M.A., and Radwan, A.E., 2000) found that more lanes in urban roadway sections are associated with higher crash rates. (Garber,N.J. and Hotel, L.A., 2002), considered flow per lane and found that there was an increase in the crash rate as the flow per lane increased. Evidence of the effect of the number of lanes can be seen when a study is done on the conversion of a two-way roadway to four or six lanes. With such studies, most have shown an increase in the crash rate.

c) **Shoulder Width and Type-** Shoulders are provided adjacent to the travel lane for several functions. These include: accommodating stopped vehicles so that they do not encroach on the travel lane, to make maintenance work, to facilitate access by emergency vehicles, using as recovery area for driver error and to protect the structural integrity of the pavement (Deo, 2004). About the impact of shoulder width or shoulder in general there are various opinions in the literature; several positive as well as negative aspects are discussed. As an obstacle free zone the shoulder gives drivers the possibility to regain control after losing control over the vehicle (G.Gatti, C.Polidori (poliba), and et.al, 2007). There is also evidence that wider shoulders may encourage higher operating speeds because they may communicate to the driver the presence of wider space for correcting errors. Finally, the number of lanes, lane width, and shoulder width are interrelated, and the choice of geometric value for each of these elements typically affects the other elements (Jerry, Pigman, John, S., Wendel, R., and Dominique, L., 2009). The effect of shoulder width and type has been pointed out by different studies as an important aspect in crash frequency. The effect of shoulder width and shoulder paving material goes hand-in hand with lane width, and road side events (Deo, 2004). The study of (Zegeer, Deen, and Mayes, 1981) has shown that increasing the shoulder width is associated with a decline of accidents. 21% reduction of total accidents was determined on road with shoulders of 0.9m-2.7m compared to road without shoulders. They suggested that for roads without shoulders the optimum shoulder width is about 1.5m. An investigation by (Turner, D.S., Fambro, D.B., and Rogness, R.O., 1981) has shown that addition of full-width paved shoulder to a two lane road way was effective in reducing the total number of accidents that occurred. Similar results were worked out by (Hedman, 1990) who found an accident reduction when shoulder increases up to 2m, above 2m the benefit became less. For 2-lane roads a reduction of accidents by 1% -3% and of injuries of 2% – 4% when the shoulder is widened by one foot (G.Gatti, C.Polidori (poliba), and et.al, 2007). (Miaou, 1996) indicates a reduction of signal-vehicle accidents by 8.8% related to one-foot widening. In general, the design of shoulders regarding the pavement and width has positive influence on road safety.

These effects were shown in numerous research works over the last years. A like the road width the positive effect becomes smaller up to a certain shoulder width.

Wider shoulders have no positive impact. Paved shoulders also influence safety positively; especially on narrow roads (G.Gatti, C.Polidori (poliba), and et.al, 2007).

d) **Median Width and Type-**The most important objective for the presence of medians is traffic separation. Additional benefits from medians include the provision of recovery areas for errant maneuvers, accommodation of left-turn movements, and the provision for emergency stopping. Median design issues typically address the presence of median, along with its type and width (Jerry, Pigman, John, S., Wendel, R., and Dominique, L., 2009). One study which evaluated median types found that flush unpaved, raised curb, crossover resistance and stripped medians are associated with the decline of road safety (Hadi, M.A., Aruldhas, J., Chow, L.F., and Wattleworth, J.A., 1995). Wider medians also seem superior to narrow medians plus a physical barrier, since these can only be effective if vehicles actually collide with them. Another study (Sawalha, Z., and Sayed, T., 2001) found that type of median and nature of land use affect crash rate significantly. (Srinivasan, 1982) found that on high-speed roads with two or more lanes in each direction, medians improve safety in a number of ways, for example by reducing the number of head-on collisions. The Danish design standards (The Roads Directorate, 1981) which was showed the relationship between the median width, the accident frequency of through section and a severity index for medians with and without a crash barrier, medians, particularly with barriers, reduce the severity of accidents, but medians wider than 3m show little additional benefit. In contrast, United States studies show continuing reductions in the number of injury crashes for widths up to 12m and over (Hughes, 1995).

e) **Access Density-**Access density refers mainly to the number of driveways within a roadway segment. Access density is one of the factors which have been pointed out as the determinant of accident rates on the highways. One study done in New Jersey (Mouskos, K.C., Sun, W., and Qu.T., 1999) on the impact of access driveways on accident rates for multilane highways found that approximately 30% of the reported crashes were in mid-block sections and were caused by the presence of access points. Another finding in this study was that approximately 25% of the entering/exiting vehicles to/ from access points have impact on mainline traffic. (Karlarftis, M.G., and Golias, 2000) found that for rural multilane roads, median with and access control were the most important factors followed by the influence of pavement conditions in the crash. Some empirical evidence suggests that the accident rate increases linearly with access density, but some find that the increase is more than linear. The model developed by (Gluck, J., Levinson H.S.,and Stover, V.G., 1999) suggests that an increase from 10 access points to 20 access points per mile would increase crash rates by roughly 30%. (Papayannoulis, Gluck, Jerome.S., Kathleen Feeney., 1995) related traffic safety to access spacing, and presented results from eight states.

They found that most literatures show an increase in accidents as a result of the increase in number of driveways. The study suggested that a road with 60 access points per mile would have triple the accident rate compared to 10 access point per mile.

f) **Median Barrier -**The literature review has identified conflicting results for the presence of median barriers. Some have noted that the effectiveness of the presence of medians on safety cannot be conclusively identified but noted that there is potential for the median to impact safety (Martha Leni Siregar, 2015). Other has shown that median barriers have a positive effect, i.e. reduce crashes (Council, F., and Steward, J.R., 2000), and others have indicated that there is a relationship between median barriers presence and left shoulder width (Fitzpatrick, K., Lord, D., and Park, B., 2008). Another trend that was noted in the literature is the overall increase of crashes with median presence but a reduction of the level of severity for these crashes (Elvik, 1995). In general, the fact that an obstacle is placed within the roadway environment that provides a target for collisions can lead to an increased number of crashes (Nikiforos S., Dominique L., Jerry P., John S., and Wendel R., 2010). The type of the median barrier is also an important aspect, since studies have shown that different types (especially concrete) have the potential to increase crashes (Elvik, R. and Vaa,T., 2004). The presence of a barrier will result in a reduction of cross-median type crashes but it also has the potential to increase median-related crashes, since its absence could allow drivers opportunities to stop their vehicles in the median (Nikiforos S., Dominique L., Jerry P., John S., and Wendel R., 2010). Finally, the severity and type of the crash with and without the median barrier should be considered. Median barriers have the potential to reduce crossover crashes, which often result in serious injuries. Therefore, the presence of the barrier has the potential to impact severity levels (Nikiforos S., Dominique L., Jerry P., John S., and Wendel R., 2010). In case of this research since the road under investigation is two way two lane rural roads without median, the median barrier is not that much the issue to be discussed on.

2.7.2 Alignment effect

A) Horizontal Alignment

The horizontal alignment consists of the serious of straight sections (tangents), circular curves, transition curves and super elevations.

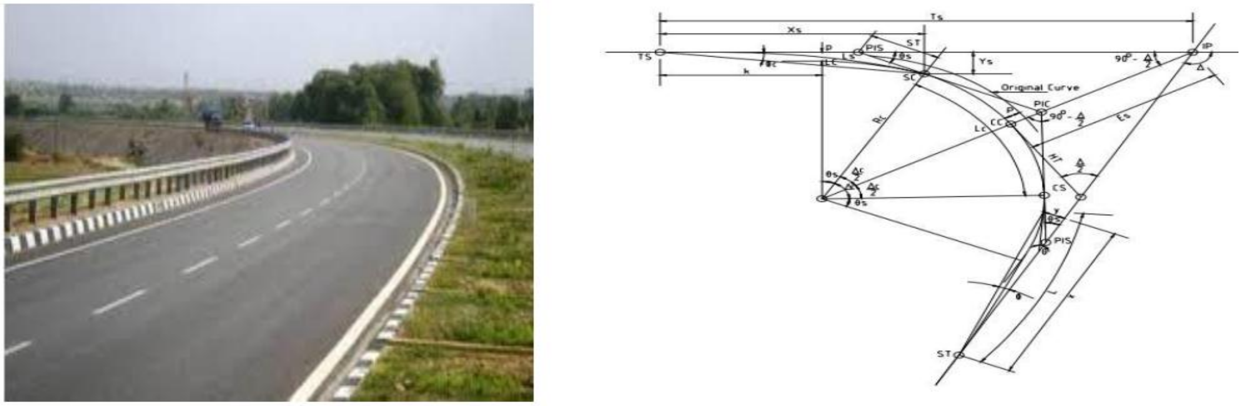


Fig.2. 4Typical horizontal curves

i) Horizontal curves – Horizontal curves are designed to ensure that vehicles can negotiate them safely. The alignment design should be aimed at avoiding sharp changes in curvature, there by achieving a safe uniform deriving speed. Transition curves between straight sections of road and circular curves whose radius changes continuously from infinity (tangent) to the radius circular curve (R) are used to reduce the abrupt introduction of centripetal acceleration that occurs on entering the circular curve. They are required for higher class road where radius of circular curve is small and are confined to road with design speed of 80 km/hr and above. According to (Md Hasibul Islam, Law Teik Hua, H.Hamid and Arash Azarkerdar, 2019) radius of circular curve is a primary element of roads geometric design that is associated with horizontal curve design and it is related to traffic accidents as the smaller the curve radius, the higher the possibility of accidents to occur on roads. In similar way the UK Department of Transportation (Department of Transportation, 1984) study result showed a significant increase in accident rates when the curve radius reduces. (Zhang Yingxue, 2009) also computed the radius mean and curvature degree for all categories used in his research and then he regressed them against the mean of accident rates in every category, his findings supported some previous studies which found and stated that the curve sharpness has a significant impact on the accident rates. (Zegeer, Deen, and Mayes, 1981) on his study showed that sharper curves are associated with higher accident rates compared to milder curves which are associated with lower accident rates. Generally, most studies show that sharper horizontal curves are associated with road traffic accident occurrence.

ii) Super elevation and Cross fall – In order for a vehicle to move in circular path, an inward radial force is required to provide the necessary centripetal acceleration or, in other words, to counteract the centrifugal force. This radial force is provided by the sideways friction between the tires and the road surface assisted by the cross fall or super elevation. We can define super elevation as the traverse slope which is designed as higher elevation on outer side and as lower elevation in inner side in order for acting against a centrifugal force that influences the vehicle's running on curves.

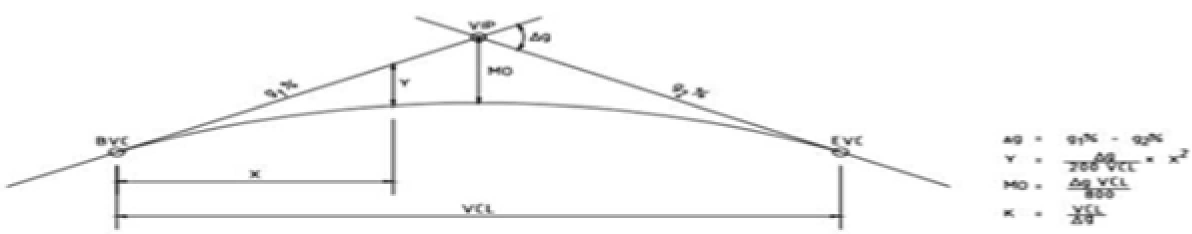
(Zhang Yingxue, 2009) mentioned that the use of proper super elevation value can mitigate incidents which could contribute to accident severity. He suggested that super elevation traverse slope should be between 2.0 % to 3.0 %.

B) Vertical Alignment

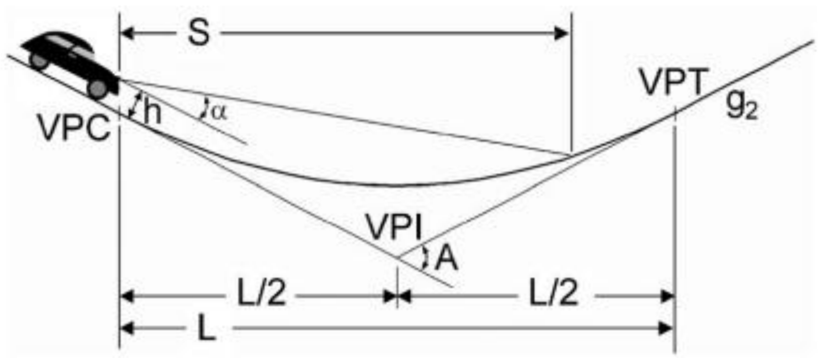
Vertical alignment is the combination of parabolic vertical curves and tangent sections of a particular slope. It should be designed to be aesthetically pleasing.

i) Vertical curves – Vertical curves are required to provide smooth transitions between consecutive gradients. Vertical curve that coincides with horizontal curve should, if possible, be contained within the horizontal curve, and should ideally have approximately the same length. Vertical curves are of two types. These are crest vertical curve and sag vertical curve. Safety problems which are associated with vertical curves are categorized in two types; sight distance problem and distortion of horizontal curves. (G.Gatti, C.Polidori (poliba), and et.al, 2007) in their study concluded that radius of crest mainly influences the sight distance. Therefore, minimum for crest radius is usually limited to guarantee a required stopping sight distance. In addition, they pointed out that sag vertical curve is not affected by sight distance problem during day, but at night the sight is restricted by light beam of the vehicle. According to their study more important is the effect of distortion that is associated with sag vertical curve. In contrast to crest vertical curve sags cause an optical enhancement of horizontal curves, so that the curve may appear larger than they are. This may result in inappropriate speed and finally come up with accident.

(Transportation Research Board, 1987) in their report No. SR 214 concluded that the geometrical design of vertical crest has not been proven to significantly affect the frequency and severity on roadways. On the other hand, a research conducted by (Srinivasan, 1982) showed that changes in vertical alignment can cause sight distances reduction at the vertical crest curves which is observed to influence the accidents occurrence frequency.



a) crest vertical curve



b) sag vertical curve

Fig.2. 5 Typical Vertical Curves

Where L= AS^2/ [200(h+Stanα)] for S<L

L=2S-[200(h+Stanα)]/A for S>L

L=Length of sag vertical curve (measured horizontally)

S= Light beam distance (equal with stopping sight distance)

A= Algebraic difference in grades %

α=Upward angle of head lump beam

h= Head lump height

VPI=Vertical point of intersection

VPC= Vertical point of curvature

VPT= Vertical point of tangency

ii) Gradients – Vehicle operations on gradients are complex and depend on a number of factors: severity and length of gradients, volume and composition of traffic; and the number of overtaking opportunities on the gradient and in its vicinity. Small commercial vehicles can usually negotiate an 18 % gradient, whilst two-wheel drive trucks can successfully manage gradients of 15-16 % except when heavily laden (Ethiopian Roads Authority, 2013). Many researchers have done their research work on the influence of gradient on the road safety and came up with almost the same conclusion that the higher the gradient the higher the accident rate. (Hedman, 1990) found that grades of 2.5% and 4% increase crashes by 10% and 20%, respectively, compared with near-horizontal roads.

iii) Climbing Lanes -A climbing lane is an extra lane in the upgrade direction for use by heavy vehicles whose speeds are significantly reduced by the grade. The increasing rate of crashes directly associated with the reduction in speed of heavy vehicles on steep sections of two-lane highway (Garber,N.J. and Hotel, L.A., 2002). (Hedman, 1990) quotes a Swedish study which concluded that climbing lanes on rural two-lane roads reduced the total accident rate by an average of 25%, 10% to 20% on moderate up gradients (3% to 4%) and 20% to 40% on steeper gradients. It was also observed that additional accident reduction can be obtained within a distance of about 1km beyond the climbing lane (O'Cinneide, 1995).

In earlier studies, (Jorgensen, 1996) found no change in accident experience in the United States due to provision of climbing lanes while Martin and Voorhees found a 13% reduction in accidents in the UK (Martin and Voorthees Associates, 1978).

iv) Vertical clearances – Bridges over water shall normally have a minimum clearance height according to ERA Bridge design manual, unless a refined hydraulic analysis has been made. The standard minimum head room or clearance under bridges or tunnels shall be 5.1m for all classes of roads. This clearance should be maintained over the roadways and shoulders. Where future maintenance of the road way is likely to lead to rising of the road level, then an additional clearance of up to 0.1m may be provided (Ethiopian Roads Authority, 2013).

2.8 Black spot identification

There are four basic approaches to reduce road traffic accidents by applying engineering treatments or countermeasures (K. Guerts, and G. Wets, 2003).

- Single sites or black spots-treating specific sites or short sections of road;
- Route action-applying known remedies on a route with an abnormally high crash rate;
- Area-wide action-applying several treatments over a wide area; and
- Mass action-applying a known remedy to locations with common crash problems or causal factors.

It is needed to focus on the first approach, since the investigation is about the effect of road geometry on accident black spot locations along Addis Ababa to Gohatsion trunk road. In this approach it is important to identify the section of the road which falls under black spot category. However, jurisdictions do not rely solely on crash history to identify black spots and prioritize them for treatment. Local knowledge and judgment are used as well as statistical information.

There are several ideas on the definition of black spot by different researchers. Locations are in general classified as black spots after an assessment of the level of risk and the likelihood of a crash occurring at each location. At certain sites, the level of risk will be higher than the general level of risk in surrounding areas. Crashes will tend to be concentrated at these relatively high-risk locations. Locations that have an abnormally high number of crashes are described as crash concentrated, high hazard, hazardous, hot spot or black spot sites. Sites with potentially hazardous features are sometimes described as grey spots (K. Guerts, and G. Wets, 2003).

Some studies reveal that; black spot was originally defined as “a road location of limited area with a high concentration of accidents”. The term “Black spots” is said to derive from the method that was originally used to identify hazardous sites. Accidents were pinpointed on a map, using colored pins to represent the trauma severity of each of these events. Black was reserved for accidents having caused property damage only and the significant proportion of these accidents created black dots at concentration points. There is no universally accepted definition of a black spot to the best knowledge of the author.

The terms "hazardous location" and "high accident locations" often used as synonym. This definition has progressively evolved as several researchers now recommend including the concept of "Potential for Improvement (PI)" (I. Hafeez & M. A. Kamal, 2016).

2.8.1 Black spot identification methods

To have safer roads, it is important to identify the right section for safety improvement; if not, resources can be wasted on places that are incorrectly identified as potentially unsafe but places that are truly unsafe will left untreated and remain unsafe. Therefore, black spot identification is an essential step for black spot improvement program. The technique to determine a black spot location varies from place to place.

Methodologies vary from the simple flag sites that have high-accident records to the more complicated ones of which the expected number of accidents is estimated and potential for safety improvements is determined. The following sub sections discuss the methods to identify black spot.

2.8.1.1 Rate Quality Control Method

The Rate Quality Control Method consists of calculating three different parameters for each road section. A road section is defined as one kilometer of road. The three parameters are:

- Accident rate,
- Accident frequency,
- Severity index.

Each of these values is compared with a critical value. Thus the accident rate is compared with one critical value, the accident frequency with another critical value and the severity value with a third critical value. If a certain road section shows higher values than the critical ones for all these three parameters, the section is considered to be a black spot (General Directorate of Highways, 2001).

i) Accident rate method

This method uses accident numbers divided by vehicle exposure to provide rates such as accidents per million entering vehicles per spot location and accidents per million vehicle-miles for sections of highways.

From the accident rate point of view Section *j* is considered to be a black spot, if:

$$R_j > R_c \quad \text{where } R_c = \hat{\lambda} + k_\alpha \sqrt{\hat{\lambda}/m_j} - 0.5/m_j$$

$\hat{\lambda} = \dfrac{\sum_{i=1}^{n} A_i}{\sum_{i=1}^{n} m_i} = \dfrac{1}{n}\sum_{i=1}^{n} \dfrac{m_i}{m} R_i$ -is the estimated average accident rate for sections belonging to the same population. It is assumed that there is 'n' such sections.

Where:

- A_j is number of accidents on section j during a certain time period.
- m_j is number of vehicle kilometers in millions on section j during the same time period.
- $R_j = A_j/m_j$ is the accident rate on section j during that time period.
- Rc is the critical value for accident rate.
- -0.5 /mj is a correction for continuity when approximating with the normal distribution.
- k_α is a constant that is chosen for the significance test. It is determined from a normal distribution and selected to give a certain significance level α:

  α = 0,1% gives k_α=2.576

  α = 5% gives k_α=1.645

  α = 10% gives $k\alpha$=1.282

k_α=1.282 is recommended so that it is better to include more false black spots and thereby get more real black spots.

ii) Accident frequency method

This method uses the number of accidents at a location to identify its safety performance. Locations with more than a predetermined number of accidents are classified as high-accident locations. A road section is considered to be a black spot, from the accident frequency point of view, if:

$Aj > Ac$, where $A_c = F_{ave} + k\sqrt{Fave/Lj} - 0.5/L_j$

- Ac is the critical value for accident frequency (= number of accidents).
- L_j is the length of the road section. Here, Lj is assumed to be 1 km.
- F_{ave} is the average accident frequency for all road sections.

iii) Accident Severity index method

The concept of this method is that the number of fatal and/or injury accidents at a location or section of highway are given a greater weight than property damage-only accidents. Cautions should be exercised to select the proper weights when using this method.

The weights should ideally be based on socio-economic values. Accident Severity Index (ASI) is a dimensionless value indicating the hazardous of a location. The following equation has been used:

$ASI = N_f W_f + NsWs + NmWm$

Where,

- N_f =No. of fatal accidents at the spot in the last 3 years

- W_f=Weight assigned to fatal accident=9
- Ns=No. of serious accidents (injured persons) at the spot in the last 3 years
- Ws=Weight assigned to serious accident=3
- Nm=No. of minor accidents (damaged vehicles) at the spot in the last 3 years
- Wm=Weight assigned to minor accident=1

This value (ASI) can be divided by a suitable value. One such value could be the number of accidents. The relative severity value is then $Q_j=S_j/A_j$ which means severity per accident. Here the assumption of Poisson-distribution cannot be used. The average value is estimated with:

$Q_{av}=\frac{\sum_{j=1}^{j} Sj}{\sum_{j=1}^{j} Aj}$ and the variance σ^2 is estimated with:

$$\sigma^2 = \frac{1}{n-1}\sum_{j=1}^{n}(Qj - Qav)2$$

The road section is considered to be black spot from severity point of view, if $Q_j > Q_c$. Where critical severity value $Q_c=Q_{av}+k_\alpha\sqrt{\sigma^2}_{-0.5}$

2.8.1.2 Accident density method

The accident density is calculated from the number of accidents per unit length for a section of highway. Sections with more than a predetermined number of accidents are classified as high accident locations (R.R.Sorate, R.P.Kulkarni, S.U.Bobade, M.S.Patil, A.M.Talathi, I.Y. Sayyad, S.V.Apte, 2015).

Step 1. Unit length of road is to be selected and accidental data is formed in tabulated form. The total number of accidents that has occurred in selected stretch of road is calculated.

Step 2. The accident density at particular chainage is calculated by calculating numbers of accidents at that chainage per unit length of road.

Step 3. Accidental density benchmark

The accidental density value which is above this value is considered as the accidental black spot. Accidental density benchmark can be calculated by dividing total number of accidents on selected stretch of road to number of unit length of selected stretch of road.

2.8.1.3 Public Participation Approach

Determining whether a site has a safety problem is frequently based on the accident history for the road as mentioned in the previous section. However, implementation of such program requires relevant accident data, which are normally unavailable or limited in developing countries like Ethiopia. Nevertheless, there are other inputs such as public input that proved to be useful in the identification processes.

(Kowtanapanich, 2011) proposes the framework of an Accident Public Participation Program (APPP) to assist the road user to report/inform the site with poor safety performance. The real world applications of such a program are presented through a selected case study in Khon Kaen City (Kowtanapanich, 2011). The findings indicate statistically significant agreements between the two datasets-the user inform locations and the black spot location identified by using historical accident data. This implies that residence can identify locations where accidents occurrences are unusually high and their input is potentially useful for the identification process. In addition to the indirect benefits in creating public awareness, the proposed methodology is potentially useful as a means for both speeding up and economizing the black spot locations identification process.

(T. Fukuda, C. Tangpaisalkit, T. Ishizaka, T. Sinlapabutra and A. Fukuda, 2005) introduce HiyariHatto method to identify and collect data on existing and potential black spot locations. The Hiyari-Hatto (Near-Miss), initiated in Japan, is a traffic psychological method to encourage road users to participate/involve in the traffic safety program in order to elicit information through their expression of potential accident experiences that almost occurred/caused them dead or injured (T. Fukuda, C. Tangpaisalkit, T. Ishizaka, T. Sinlapabutra and A. Fukuda, 2005). According to Fukuda et al., Hiyari-Hatto method is a significant alternative method for public participatory enhancement to develop black spot database nationwide. This method includes one way of primary data collection (interview) which is discussed earlier in Primary data collection and also discussion with the surrounding population.

2.8.1.4 Geographic Information System (GIS) applications

In different countries many highway agencies are using Geographic Information System (GIS) for analyzing accident data. Identification of problematic locations is one of the most important aspects in accident studies. The GIS based application combines the data collection capability, analysis and visualization. Since accident is spatially distributed in nature, use of Geographic Information System (GIS) and database software will provide the capability to store data, update data, retrieve data, compare data and spatially display the data (Kowtanapanich, 2011). These modern computer technologies allow black spot map to be electronically generated from a well-designed accident database. Computer record systems can also produce rankings of high-accident locations based on either total accident occurring or accident rates. Mapping of accident location on the given road enables one to simply identify where the accidents occurred more and can also justify that the black spots are located there.

2.8.2 Statistical Considerations

2.8.2.1 Random variation

Accidents normally occur at random. Since it is a random outcome, the actual number of accidents for a road section cannot be trusted to be the true value. The number of accidents differs from one year to another even if nothing has been changed.

One spot can have more accidents than another spot during a certain year. But this does not necessarily mean that the first spot is more unsafe than the second one. To handle this randomness, statistical methods can be used. Accidents are normally considered to follow a Poisson-distribution. This means, the number of accidents during a year is an outcome of the statistical process and can be assessed with statistical theory. One very convenient feature with the Poisson-distribution is that the mean value and the variance are the same. Thus only one parameter has to be estimated (Hedman, 2001).

2.8.2.2 Choice of confidence level

The purpose of discussing confidence levels especially in Rate Quality Control Method of analysis is to decide the risk of making wrong decisions. Normally, a confidence level of 95 % is used. This means that there is a 5 % risk that a road section is considered a black spot when in fact it is not. Or said in a more understandable way, 5 out of 100 identified black spots are not really black spots. This is called type 1 error in statistical literature. These are spots where the random variations have been unfavorable during the actual period. But why do we accept to have 5 % risk? Why do we include false black spots at all and why we do not at least take a much smaller risk. 1 % or 0.1 % would be better than 5 %. The reason is that there is another type of error that can be made. Random variations can also be favorable for some spots. A spot can be a black spot, but due to favorable accident outcome during one year, the site is not identified as a black spot. This is a type 2 error in statistical literature. The errors are related in such a way that fewer type 1 errors give more type 2 errors.

If one really wants to be absolutely sure that almost no false black spots are included (by selecting a very low type 1 error) many real black spots will be missed. The level chosen must strike a balance between these two types of errors.

The choice of 95 % by KGM can be questioned and there are arguments for another confidence level, for example, 90 %. The reason is mainly that it is better to risk to include more false black spots and thereby get more real black spots.

The first step of the black spot analysis is the identification of the spots. This is a selection procedure that is employed by following certain steps to analyze the identified spots. Then it will be shown if the spots have potential for improvement or not.

So the error made with a higher confidence level is that some “unnecessary” work has to be carried out for some spots. By selecting 90 % instead of 95 %, however, no serious errors are made. The only drawback is that the list to work with is extended. But also with a longer list, the work starts from the top. So having a longer list does not necessarily create more work. But, on the other hand, if a real black spot is missed, then a more serious error has been made, which cannot be corrected until new accident data is available for the next period. That is why it is better to have a 90 % confidence level than a 95 % level. Even 80 % is a level that could be considered (Hedman, 2001).

2.9 Summary of Literature and gaps in research/Knowledge

Geometric design variables have several traffic safety impacts if not safety is properly considered during the early design stage of the road. This reveals that there is a relationship between geometric design variables and road safety which is described in terms of traffic accident. The effects of road geometric design elements are categorized into two groups.i.e. Cross sectional effects and alignment effects. Lane width, number of lanes, shoulder width and type, median width and type, access density and median barrier are among the cross sectional effects category; while alignment effects comprise effects of horizontal alignment like horizontal curve, super elevation, and cross fall and vertical alignment like vertical curve, gradient, climbing lane and vertical clearance.

Different researchers have developed the relationship of roadway safety in terms of crash frequency and crash rates, fatality and injury rates and the road elements, traffic characteristics, and pavement conditions. Many of these previous studies investigated the relationship of crash rates or frequency in terms of number of lanes, lane width, presence of median, median width, type of median, shoulder width, access density, speed limit, vertical grade, horizontal curvature, weather condition and etc. with the primary focus in crash reduction and predictions. Depending on the developed relationship it is possible to predict and reduce the crash which will be happened by taking necessary measurements. However, these geometric design elements have no the same level of impacts at all places, since the terrain type and environmental condition have their own role in crash occurrence. So, it is necessary to differentiate the riskiest variables to apply the counter measures according to the increasing nature of their causing effect. It is also better to identify the black spots first before setting the counter measures against the riskiest variable. Blackspots are a road location of limited area with high concentration of accidents. GIS and SPSS software are used to locate the blackspot on the selected route and develop the relationship of geometric design variables and traffic accident respectively.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Introduction

In the research methodology the study area at which the research is conducted is described first. For the research to be conducted, collecting necessary data of the study area is very useful. So, data collection of both primary and secondary are discussed here. The collected data has to be analyzed, discussed on and finally conclusion has to be derived. Here in the research methodology method of data analyses and statistical considerations are highlighted and others are to be discussed in the next chapters.

3.2 Study Area

The selected study area Addis Ababa to Gohatsion road is located in the Northern part of Oromia Regional State (Salaalee) in Northern Ethiopia. The entire distance of the road is 197 km. The terrain types of the area are flat, rolling and escarpment. The road section under the study crosses Oromia special zone surrounding Finfinnee and Woredas of North Shoa zone like Wacaalee, Debrelibanos, Giraar Jaarsoo, Dagam, Kuyyuu and Warra Jaarsoo. Even if the road is named Addis Ababa to Gohatsion, the study area covers the whole length of the road section which is found under Oromia regional state administration.

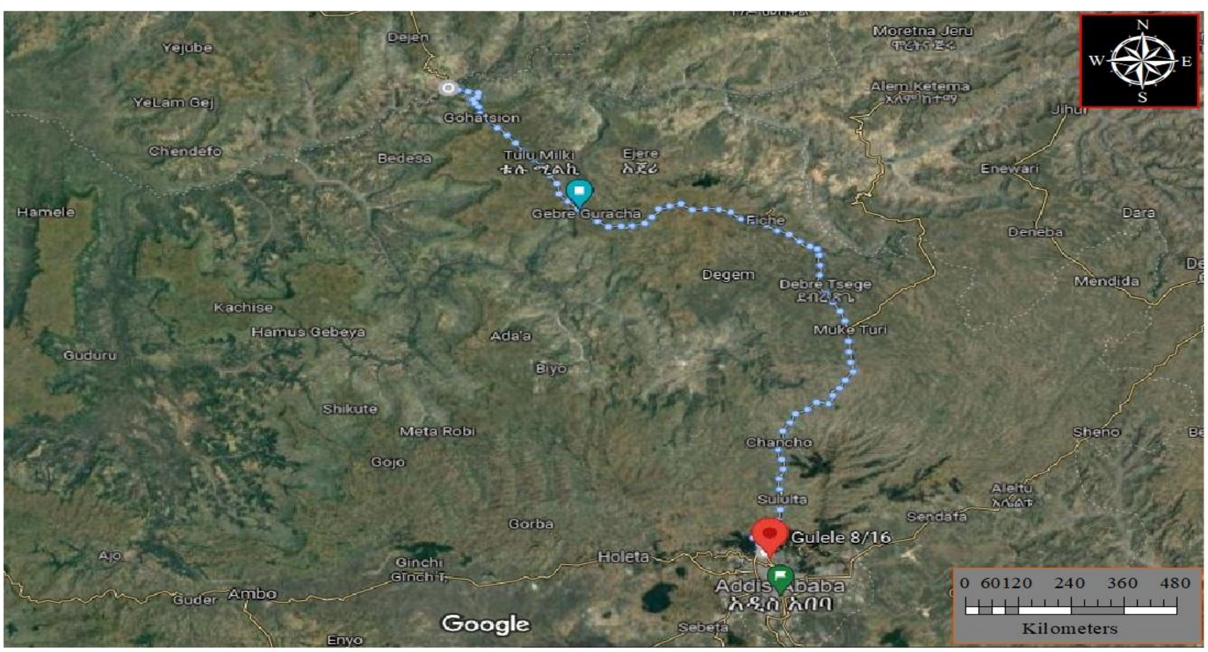


Fig.3. 1 Addis Ababa to Gohatsion part of A3 road connecting northern part of the country to the center (Addis-Ababa)

3.3 Data Collection

In conducting one research data collection is the main and decisive task to start. Without having data no research can be thought to be started. In this research it was must to have both primary and secondary data.

3.3.1 Primary data collection

It is the first hand information (data) that was gathered in real time and very involving way. It was very expensive and time consuming. Primary data was collected in form of observation, survey, questionnaire (drivers, passengers, and officials (traffic policemen and authorities)).

3.3.1.1 Measurements of road cross sectional parameters

Cross sectional parameters are one of the primary data which is collected during this research. The road cross section elements are measured for the sake of knowing whether the parameters are in accordance with the standard which is set on Ethiopian Roads Authority or not. As the title of the research indicates, it is about investigating the effect of road geometry on accident black spot areas. Hence, the cross sectional data collection regards only the black spot areas; it does not cover the whole length of the route and is collected using the below format.

Table 3. 1 Format of recording cross sectional parameters in table form.

N.S	Terrain type	Roadway element	ERA Standard value	Observed value
1		Design speed		
2		Lane width		
3		Number of lanes		
4		Shoulder width		
5		Horizontal radius		
6		Super elevation		
7		Vertical curve		
8		Gradient		
9		Bridge width		
10		Clear zone		

3.3.1.2 Traffic Volume Count (AADT)

AADT was required for conducting traffic safety analysis of the road under study. Primarily it is required in identifying the black spot locations. In ‘Rate Quality Control Method’ of identifying black spot locations, when calculating three different parameters i.e. accident rate, accident frequency and severity index, vehicle exposure needed to provide rates such as accidents per million entering vehicles per spot location and accidents per million vehicle-miles for sections of highways. For these reason, traffic data was important and hence collected during field work.

Traffic counts were conducted on two locations along the road. The first location was taken at 10 kilo (sululta) 10 kilometers from Addis Ababa near to sululta town. The other one is taken at “Laga qallaa” about 150 km from Addis Ababa near Garba Guracha town. These locations were selected based on the traffic sites of the Ethiopian Roads Authority. The traffic count period was for seven days from 6:00 to 18:00 hour local time that included a 24-hour count on one normal day and on one market day (Saturday). Counts were carried out on two directions at each location. According to the Ethiopian Roads Authority, vehicles are classified in to 13 classes. The ERA vehicle types composed: Car (automobile), pick-up/4-wheel drive, small bus, bus/coach, small truck, medium truck, large 2-axled truck, 3-axled truck, 4-axled truck, 5-axled truck, 6-axled truck, 7-axled truck, 8-axled truck, 9-axled truck, 10-axled truck, 11-axled truck, 2-axled trailer and 3-axled trailer (Ethiopian Roads Authority, 2013). The same classifications of vehicles were used in this research. Based on the traffic count, ADT was calculated for each road segments. The factor that was applied for conversion to ADT is given below.

Estimate on ADT can be done as follows:

$ADT = V_i \times f$

Where, V_i = Average daily traffic of vehicle i of two directions of the week is divided by seven.

f = two days 24-hour traffic count data was summed up and divided by two to get average traffic for full day (24 hr). The average 24-hour traffic data will be divided by the sum of two-day time (6 a.m. - 6 p.m.) traffic.

3.3.1.3 Questionnaire

Spot interviews using semi- structured questionnaires were conducted with drivers who drive across Addis Ababa to Gohatsion. It is obvious that crash data which is recorded by Traffic police has many drawbacks starting from unreadability to underreporting. Since the recorded crash data alone couldn’t enable us to identify the black spot locations, the traffic police man, concerned authorities and the surrounding residents are included as respondents. As public participation approach of black spot identification method it is believed that resident can identify locations where accidents occurrences are unusually high and their input is potentially useful for the identification process. In addition, it gains great benefit in creating public awareness about road traffic safety. For all the respondents the same questionnaires were prepared and asked at the same time and also separately both on the field and in the office. The respondents are questioned almost three main questions. These are:

a) Where do the traffic accidents often occur around their surrounding (in case of residents and pedestrians) and along the road for drivers and passengers.

b) Because of what reason do they think it occurs around the area they have mentioned on question type indicated on (a).

c) What measurements do they think it is appropriate to take for the future and what measurements the drivers are taking to reduce crash at the points they have mentioned on question (a). Most of the responses from the respondents are nearly similar with what gained from crash record of traffic police. Since some of the traffic police men have worked almost in every woredas of the study area (North shoa zone and Oromia special zone surrounding Finfinnee), they know one by one where crashes are occurred most often. The questionnaire format used is attached on appendix (APPENDIX A1).

3.3.2 Secondary data collection

Mainly two types of secondary data are collected i.e. crash records from police station of 6 woredas and 3 town administrations and as built drawing data from Ethiopian Roads Authority (ERA).

3.3.2.1 Crash Records

Traffic crash records of study period 2014 to 2018 were collected from police stations across the extension of the road route from Addis Ababa to Gohatsion. Crash records are found inform of archive that is compiled by traffic police officers for several years on one book by designing road traffic accident form in order to put reliable and useful data for the purpose needed; may be court, research or any other. The designed form on which the traffic accident information is registered includes:

- Number, date and time of accident
- Full name, age and sex of defendant(driver)
- Number, sex and educational level of defendant(driver)
- Relationship of vehicle and driver
- Experience of the driver
- Vehicle type, vehicle ownership, vehicle service year, vehicle technical deficiency
- Road type, road location, road geometry, road condition, types of road pavement,
- Additional description of crash location, land use
- Intersection type, availability of median types
- Weather condition
- Defendant’s vehicle maneuvering condition
- Crash types, severity type
- Estimated cost of crash,
- Number of persons damaged, number of vehicles damaged
- Plaintiff details i.e. age, sex, maneuvering condition, category in accident

The designed form doesn’t comply with international standard. There is a lot of information to include in the form to use as a data for research. What surprising here is not standardizing the form, but missing of information when filling in to the form which is already wrongly designed.

In addition, the form is not consistent throughout every police station where the traffic accident data is recorded.

3.3.2.2 As built drawing

As built drawing is revised set of drawing submitted by contractor up on completion of a project. They reflect all changes made in the specification and working drawing during the construction process and show the exact dimensions, geometry, and location of all elements of the work completed under the contract. The drawing mainly consists of five sections.

i) General- includes drawing index and location map.
ii) Road- Under this section drawings of horizontal alignment, plan and profile, typical cross section, traffic safety structure, countermeasure for box culver soil, ancillary work structure, retaining work structure, drainage structure and pipe culvert structures are put.
iii) Bridge and culvert structures
iv) Cross sections
v) Cross culvert sections- pipe and box culvert drawings
vi) Additional drawings- includes plan of access road entrances, additional ditch works, location of culverts replacement, and etc.

All these data are collected from Ethiopian Roads Authority (ERA) after tiresome search from old files. In ERA data of roads were not being put in chronological order to get the file we want very easily.

CHAPTER-IV

4. RESULTS AND DISCUSSIONS

4.1 Road Traffic Crash Record

Road traffic crash record is the main resource to proceed in to the detail analysis and discussion about the results. It is an accident data base which is established by compiling together the crash records that are collected from woredas and town administrations police station. Primarily the crash records were found only in hard copy at all police stations. The photograph of crash record's archive is captured page by page and finally changed into soft copy using Microsoft excel. The established accident data base covers 197.237 km long road from Addis Ababa to Gohatsion (Qarree Gohaa) with four study period 2014 to 2018. The summary of the traffic crash record is given here below in tabular form.

Table 4. 1 Summary of traffic crash record

Descriptive variables			Description (Quantitatively in number or qualitatively in words)
Driver	Age	<18	2
		[18-25)	173
		[25-35)	687
		[35-45)	238
		≥45	135
	Gender	Male	1253
		Female	3
	Educational level	Illiterate	0
		Primary school(1-8)	320
		Secondary school(9-12)	772
		Diploma	22
		TVET	77
		Degree and above	46
		Unknown	81
	Relation with vehicle	Employee	1166
		Owner	128
		Rental	5
		Family	3
		Borrowed	4
		Trainer	1
		Other	15
	Experience	(0-2]	307

		(2-5]	421
		(5-10]	362
		>10	230
	Maneuvering condition	Not clearly indicated	
Vehicle	Ownership	Company	63
		Government	52
		NGO	1
		Private	1163
		Rental	1
	Service year	Not clearly indicated	
	Technical deficiency	Good	1256
		Bad	0
		Unknown	2
Environment	Land use	Church area	4
		Commercial area	213
		Industrial area	40
		Office	3
		Rural village	799
		School	11
		Residential (urban)	146
		Recreational	40
		Hospital	0
		Unknown	8
	Road condition	Dry	712
		Wet	448
		Unknown	103
	Lighting condition	Day light	1044
		Night light	220
	Weather condition	Good	696
		Cold	94
		Rainy	78
		Unknown	402
Road	Type	Rural two way two lane	
	Availability of median	No median	
	Geometry	Bridge	1
		Curve	226
		Gradient on tangent	65

		Gradient on curve	957
		Intersection	1
		Mountain	2
		Sharp curve	1
		Roundabout	9
	Intersection type	No intersection	
	Type of pavement	Asphalt	All
		Cobblestone	0
		Concrete	0
		Unknown	0
Crash	Nature		
	Severity type	Fatal	245
		Severe injury	206
		Slight injury	88
		Property damage only	725
	Estimated cost	53,749,306	
	Number of persons damaged		
	Number of vehicles damaged	Not clearly indicated	
Plaintiff details	Sex	Male	Not clearly indicated
		Female	Not clearly indicated
		Unknown	Not clearly indicated
	Age	<18	Not clearly indicated
		18-24	Not clearly indicated
		25-34	Not clearly indicated
		35-44	Not clearly indicated
		>45	Not clearly indicated
	Category in accident	Driver	Not clearly indicated
		Passenger	Not clearly indicated
		Pedestrian	Not clearly indicated
		Unknown	Not clearly indicated
	Maneuvering condition	Straight	Not clearly indicated
		Unknown	Not clearly indicated

4.2 Introduction to Quantitative Crash Data Analysis

4.2.1 Traffic accident analysis based on time

A) Based on hour

Accidents occur at different time with different accident frequency depending on many factors.

Pedestrian activities like school, working hour, church and market are few among these factors. In addition to pedestrian activities driver's activities also matters. Drivers don't move at equal rate throughout the whole day. Depending on the variation of the movement of the drivers, accident frequency also varies likewise.

Table 4-2: below illustrates hourly variation of accident frequency. All the hours are put in local hour starting from 00:00 morning.

Table 4. 2 Hourly variation of accident frequency

Code	Time interval	Crash category				Total No of crashes
		Fatal	Severe injury	Slight injury	PDO	
1	24:00-1:00	10	3	1	28	42
2	1:00-2:00	16	12	3	42	73
3	2:00-3:00	21	16	9	65	111
4	3:00-4:00	18	19	3	58	98
5	4:00-5:00	14	10	2	42	68
6	5:00-6:00	11	15	6	42	74
7	6:00-7:00	17	19	7	35	78
8	7:00-8:00	15	9	7	45	76
9	8:00-9:00	7	16	4	35	62
10	9:00-10:00	10	12	5	35	62
11	10:00-11:00	24	16	9	66	115
12	11:00-12:00	19	20	9	81	129
13	12:00-13:00	13	11	9	41	74
14	13:00-14:00	11	9	2	14	36
15	14:00-15:00	8	4	0	27	39
16	15:00-16:00	12	3	3	15	33
17	16:00-17:00	7	1	1	12	21
18	17:00-18:00	1	2	1	17	21
19	18:00-19:00	4	1	0	18	23
20	19:00-20:00	0	1	0	13	14
21	20:00-21:00	2	2	2	8	14
22	21:00-22:00	3	1	0	9	13
23	22:00-23:00	2	1	2	10	15
24	23:00-24:00	0	2	2	7	11
Total						1302

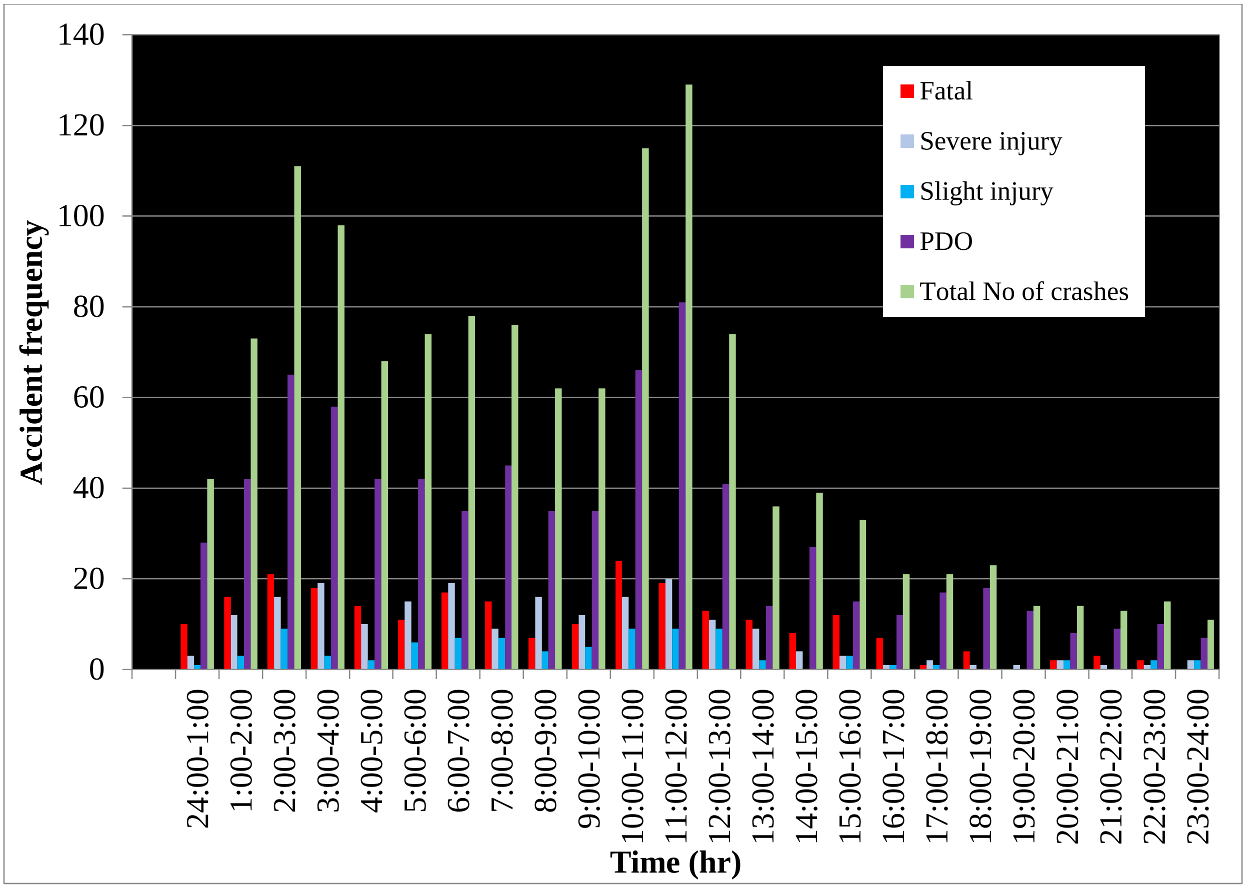


Fig.4. 1 Time in hour (hr) Vs Accident frequency

As it is observed from the above graph more accident frequency is recorded in the morning especially from 01:00 to 04:00 local time. Accident frequency which is recorded in the morning 01:00 to 04:00 local time, during the three consecutive study periods (2014 to 2018) is accounted for 21.34% which is almost around quarter of total number of accident. This is because there is quite number of activities like church, school, going to office/working place/, going to Addis Ababa for trade and many other activities in the morning. Another peak hour is from 10:00 to 13:00 local time. During this time interval there is almost highest number of accidents as the above graph indicates. 24.32% of accidents occur in this time interval. The reason why the frequency of accident became high during this time is that, workers go back to their home from offices and different working places, students also return to their home, many people go to the church for prayer (from 11:30 to 13:00), from around 12:00 to 13:00 many pedestrians are found on the street for refreshment after work and school. Merchants who go to Addis Ababa in the morning also return to their home during this time.

B) Based on day of the week

Like other variables traffic accident also varies depending on day of the week.

In day of the week there is market days, prayer days, working days, holidays, and etc. Depending on these factors, accident frequency differs throughout the week.

Table 4. 3 Comparison among number of crashes in seven days of the week

Code	Day of the Week	Fatal	Severe injury	Slight injury	PDO	Total No of crashes	Percent (%)
1	Sunday	31	28	13	99	171	13.60
2	Monday	38	21	11	108	178	14.16
3	Tuesday	36	20	13	104	173	13.76
4	Wednesday	39	33	15	107	194	15.43
5	Thursday	28	33	15	74	150	11.93
6	Friday	29	33	7	107	176	14.00
7	Saturday	44	36	14	121	215	17.10
Total		245	204	88	720	1257	100.00

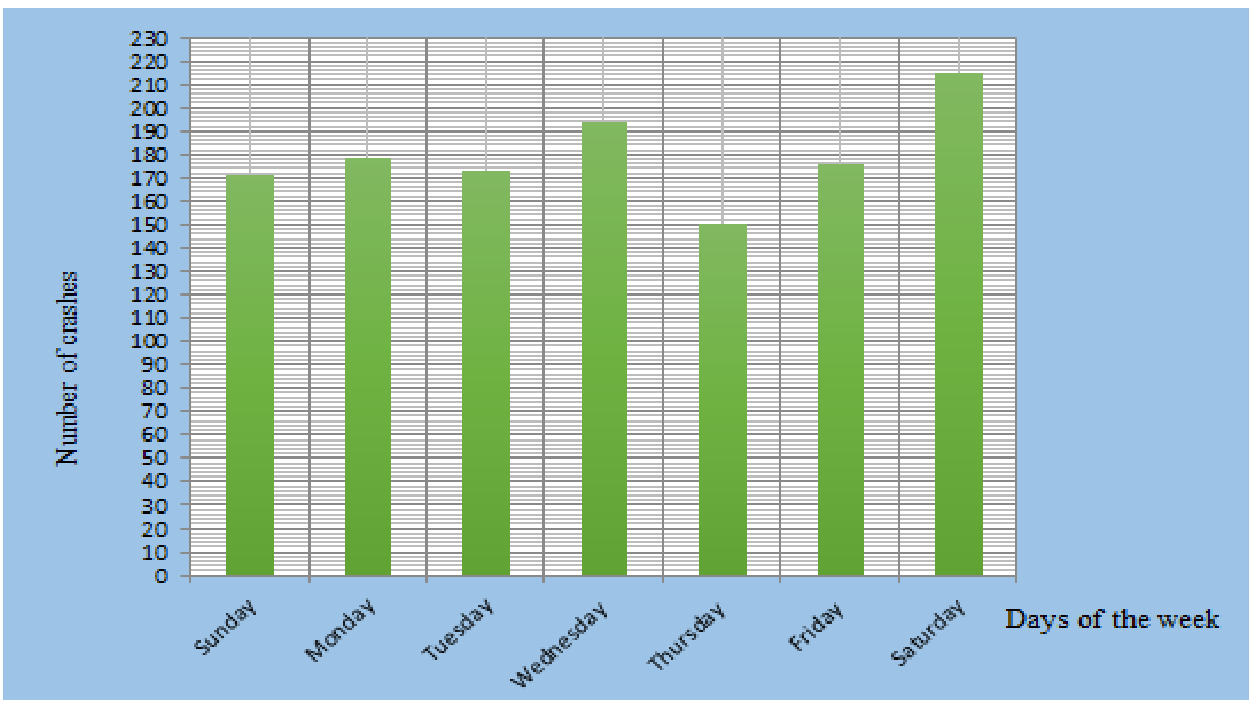


Fig.4. 2 Days of the week Vs Number of crashes

From the graph we can see that the number of crashes occur on each days of the week differ a little bit. However, on Wednesday (15.43%) and Saturday (17%) some increment from average share of each day (14.29%) is observed as these days are main market days in many towns along Addis Ababa to Gohatsion trunk road.

In addition, on Saturday there is too much church activities as most of the residents are Christians. Number of crashes on these two days is accounted to 32.54%, which is around one third of the total crashes throughout seven days of the week of the study period. On market days a number of populations go to the towns from rural areas and they prefer to go along the asphalt road. What worsen the situation on these market days is not only numbers of marketers, the behavior of the drivers also changes and most of the marketers are drunk returnee. The driver loads beyond load limit and drive beyond the speed limit in order to transport passengers faster from town to town to get a lot of many on these market days. What should be understood here is that, all other days' share of the total accident recorded cannot be ignored as they cover from 10% to 14% each.

4.2.2 Relationship of driver's situation and traffic accident

Most of the time the people understanding is that, accident is caused only due to some factors. However, occurrence of accident is related to many interrelated factors, which we cannot separate them from one another. Even, one factor can be seen from different perspective. For example, when we consider driver's situation as one factor causing traffic accident, we have to look at the driver's age, the driver's gender, the driver's educational back ground, the driver's relation with vehicle, the driver's experience and etc. Let us look one by one.

A) Distribution of traffic accident with age of the drivers

Age of the drivers' matters for traffic accident occurrence in many ways. As we know a person who is in different age group has different needs and acts differently. So, here we understand that drivers of different age group contribute differently in causing accident.

Table 4. 4 Distribution of traffic accidents with age of the drivers

Code	Driver Age category	Crash category				Total No of crashes	Percentage (%)
		Fatal	Severe injury	Slight injury	PDO		
1	Less than 18	1	0	1	0	2	0.16
2	[18-25)	33	29	11	100	173	14.01
3	[25-35)	139	112	51	385	687	55.63
4	[35-45)	41	41	17	139	238	19.27
5	$\geq$ 45	16	22	8	89	135	10.93
Total		230	204	88	713	1235	100.00

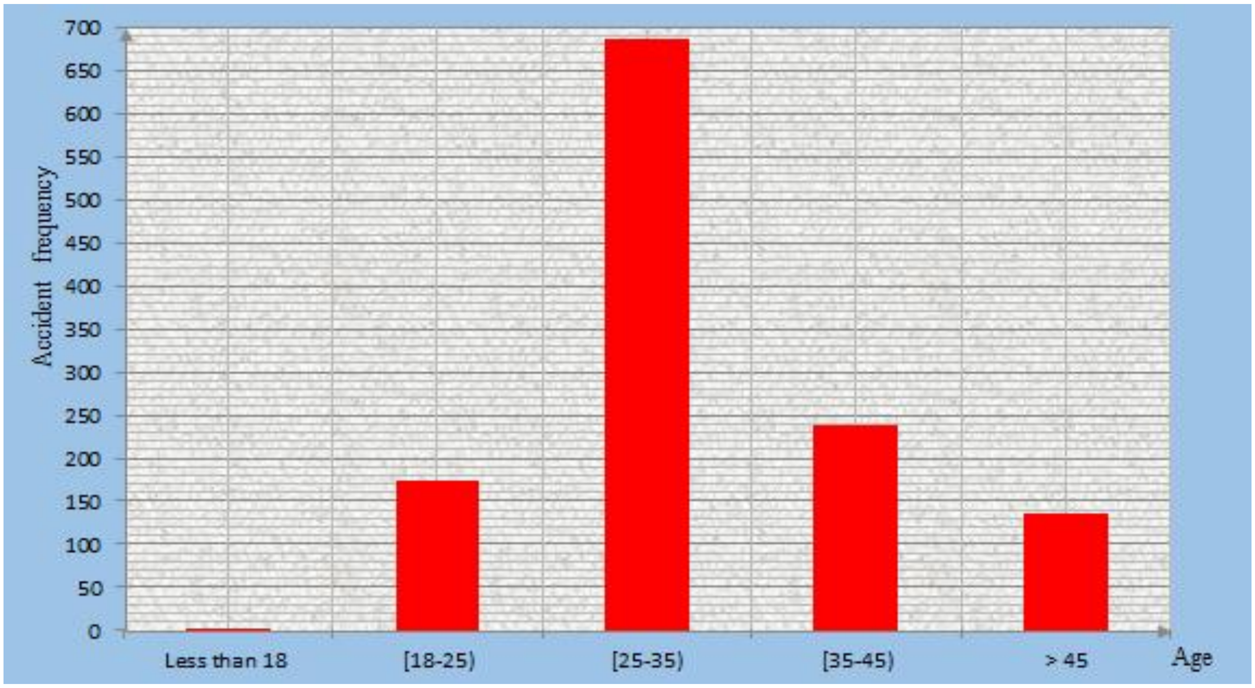


Fig.4. 3 Age Vs Accident frequency

The above graph depicts that about 55.63% of accident is caused by the drivers of age group 25 to 35. The drivers in [25,35) age group are very productive as their age forces them to collect resources for getting into marriage, helping their parents, putting base for the continuation of their tomorrow life and etc. For these and other reasons they work hard day and night without enough rest. Hence, there become fatigue; and if there is fatigue the driver becomes vulnerable for traffic accident. In addition, the drivers use stimulants like chat for driving fast without fatigue and for driving night and causes traffic accident as a result. It can be seen that the second leading drivers age group in causing traffic accident is [35, 45) by 19.27%. Even if it is the second leading it is much less than that of [25, 35) by around 188%. Drivers in [35, 45) age group are somewhat experienced, rethink everything of their activities and value their life. The age group on the third rank is from 18 to 25. In this age range most of the youth spend their time on education rather than work. So, share of committing traffic accident of this age group become less because of the small number of drivers engaged in driving and not because of the care they take. Next to [18, 25) age group drivers of greater than 45 years' age follows the trend by 10.93% and they take care for the vehicle and also value their life as experience and age teaches them more. By under age 18 the number of accident recorded are very small as the regulation restricts under 18 not to drive any kind of vehicles. According to proclamation No.1074/2018 of "Drivers Qualification License" which is printed on 14th February, 2018 on FEDERAL NEGARIT GAZETTE of the Federal Democratic Republic of Ethiopia, it says any person applying for driver's qualification certification license shall in case of motorcycle or automobile drivers' qualification certification license have at least attained the age of not less than 18 years.

B) Distribution of traffic accident depending on the gender of the driver's

As a matter of nature female behaves differently from male in different ways. Many scholars generalized that female drivers are very careful than male derivers because of many reasons.

Table 4. 5 Distribution of traffic accident depending on the gender of the drivers

Code	Gender	Crash Category				Total No of crashes	Percentage (%)
		Fatal	Severe injury	Slight injury	PDO		
1	Male	241	204	88	720	1253	99.130
2	Female	1	1	1	0	3	0.237
3	Unclassified	3	1	4	0	8	0.633
Total						1264	100.000

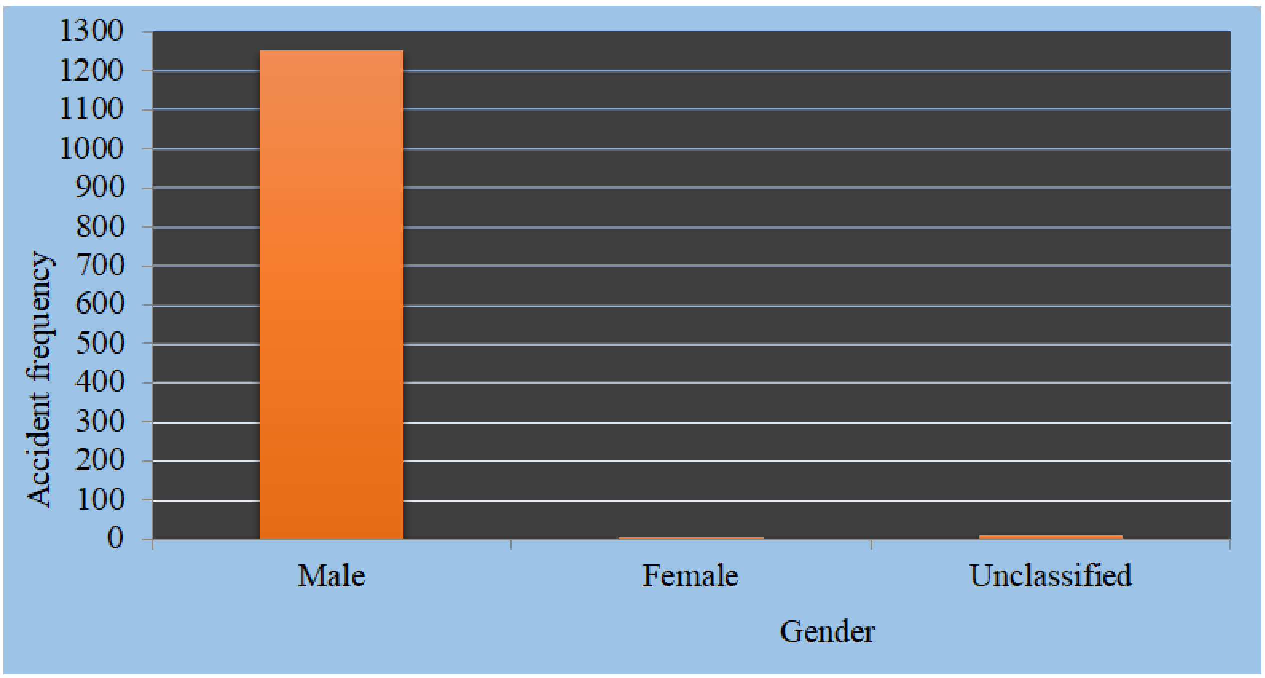


Fig.4. 4 Gender Vs Accident frequency

As we can see from the above figure majority of the drivers who are involved in traffic accident are the male groups. But, this is not enough evidence to generalize that male drivers cause more traffic accident than females since the participation of females is less in driving in Ethiopia.

C) Educational background of the driver's Vs traffic accident

According to a Proclamation No. 1074/2018 of the Federal Democratic Republic of Ethiopia which is released on the Federal Negarit Gazette on February 14, 2018, issuance of driver's-qualification license requires minimum standard set for educational background. A minimum of fourth grade education should be attained in the case of motorcycle or automobile (lowest level driving certification license) and minimum of tenth grade education should be completed for highest level driving qualification certificate license (for machinery operator). The educational background affects the cause of traffic accident due to various understanding of traffic accident and its consequence.

Table 4. 6 Educational background of the driver's Vs traffic accident

Code	Driver's Education Level	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Illiterate	0	0	0	0	0
2	Elementary School (1-8)	78	51	20	171	320
3	Secondary school (9-12)	134	120	60	458	772
4	Diploma	3	5	0	14	22
5	TVET	10	12	6	49	77
6	Degree and above	4	7	3	32	46
7	Unknown					81
Total						1318

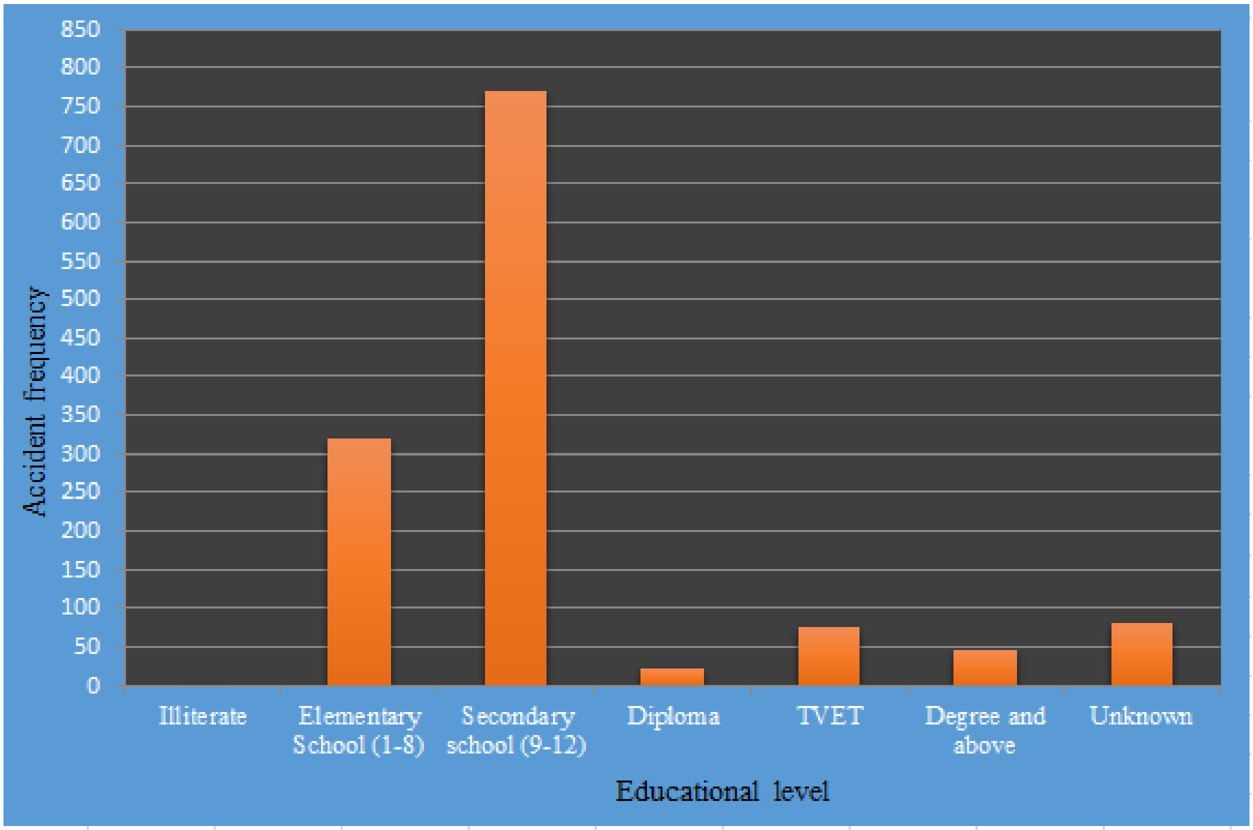


Fig.4. 5 Educational level Vs Accident frequency

From the above graph it is clear that accident frequency caused by drivers with educational background of secondary school is highest and those of elementary school follows. This indicates two things.

1. A mass number of both drivers with education level of elementary and secondary school are involved in driving than others. Specially, many young students drop their education and hold a driving license. In addition, students who failed to pass grade 10^{th} and 12^{th} national exam learn driving vehicle to get their driving qualification certificate license to manage their life being a driver or aide driver as one job opportunity.
2. Shortage of understanding about road safety due to lack of knowledge and weak psychology as they are not matured enough to take risk of handling human live.

D) Relation of the vehicle and the driver Vs traffic accident

Traffic accident has a relation with vehicle and driver relationship, as the care given for the vehicle depends on the possession of the vehicles. As the care given for vehicles increases during driving, the chance of occurrence of accident decreases. The table below depicts some information about the relationship between traffic accident and vehicle driver relationship.

Table 4. 7 Relation of the vehicle and the driver Vs traffic accident

Code	Driver vehicle Relation	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Employee	222	182	80	682	1166
2	Owner	27	22	10	69	128
3	Borrow	0	1	1	2	4
4	Rental	1	1	0	3	5
5	Family	1	2	0	0	3
6	Trainer	0	0	0	1	1
7	Uknown	3	2		10	15
Total						1322

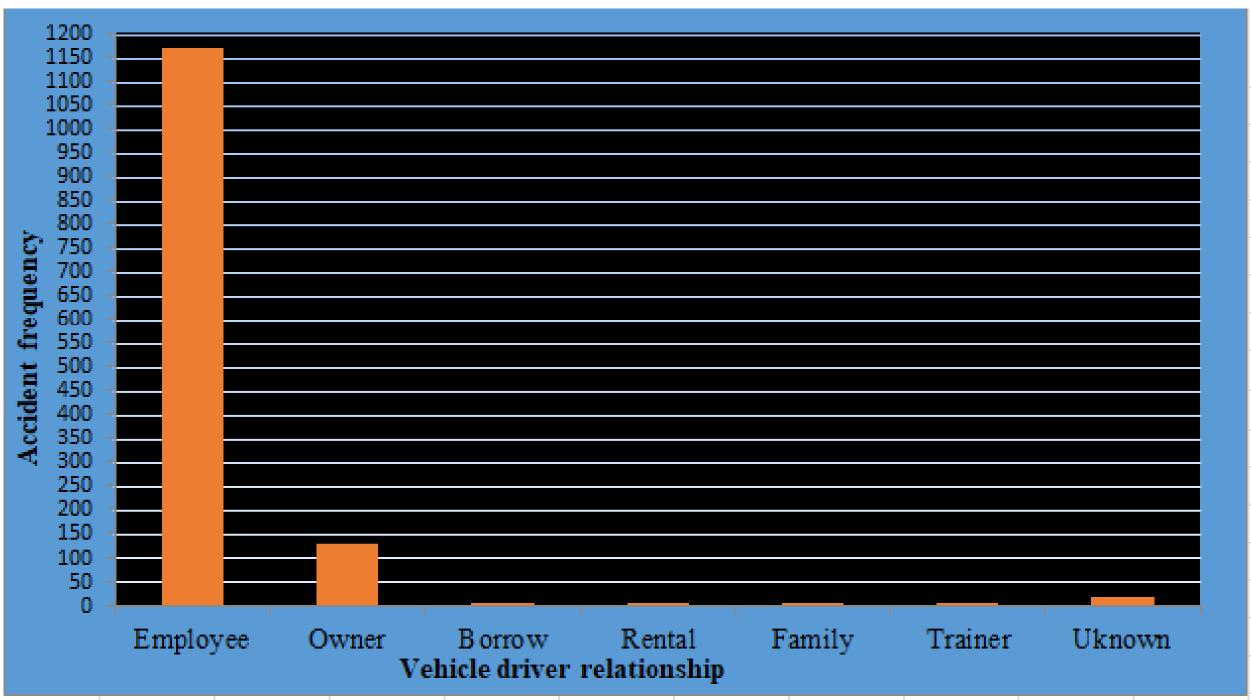


Fig.4. 6 Vehicle driver Vs Accident frequency

It is seen from the graph that the vehicle driver relationship is highly tightened with the accident frequency. Employee (vehicle driver relationship) contributes around 88.2% of accident frequency while owner contributes 9.68%. Other types of vehicle driver relationship totally share only 2.12% of the accident frequency recorded during this four study period of years. The reason why the employee shares majority percent (88.2%) of accident frequency is of two types.

i) Since the property (vehicle) doesn't belong to them they don't give care for vehicle. Majority of the employee drivers don't care whether the vehicle break, go to hell, or any other type of damage is happened to them. They want only earning their wage until they are alive.

ii) The employee drivers want to earn money more than they deserve by different mechanism. When the owner of the vehicle employ the driver, the employer and the driver make an agreement how the driver get his wage from the employer and also how the drivers give the daily income to the employer. Most of the time there is a fixed amount of income that has to be earned by the employer daily in agreement between driver and employer (vehicle owner). So, income that is beyond the agreement goes into the drivers' pocket and sometimes the driver's aide and the driver share it. Hence, most of the time the struggle of driver and his aide is getting money beyond the income agreed to be paid to the employer by any possible means. The familiar possible means are loading passenger beyond the capacity of the vehicle and speeding the vehicle beyond maximum speed limit. These kinds of act get the vehicle's safety under question and give the chance for the accident to be happened.

E) Experience of the driver Vs traffic accident

Every kind of job can be very easy as experience develops from time to time. It is not similar for experienced and inexperienced personnel to discharge their professional responsibility. Likewise, experienced drivers differ from the inexperienced one in controlling the accident and handling the vehicle in a good manner. The detail is given here in below table.

Table 4. 8 Experience of the drivers Vs number of crash

Code	Experiece of the driver	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	(0-2]	69	49	13	176	307
2	(2-5]	71	70	39	241	421
3	(5-10]	65	57	26	214	362
4	> 10	39	35	18	138	230
Total						1320

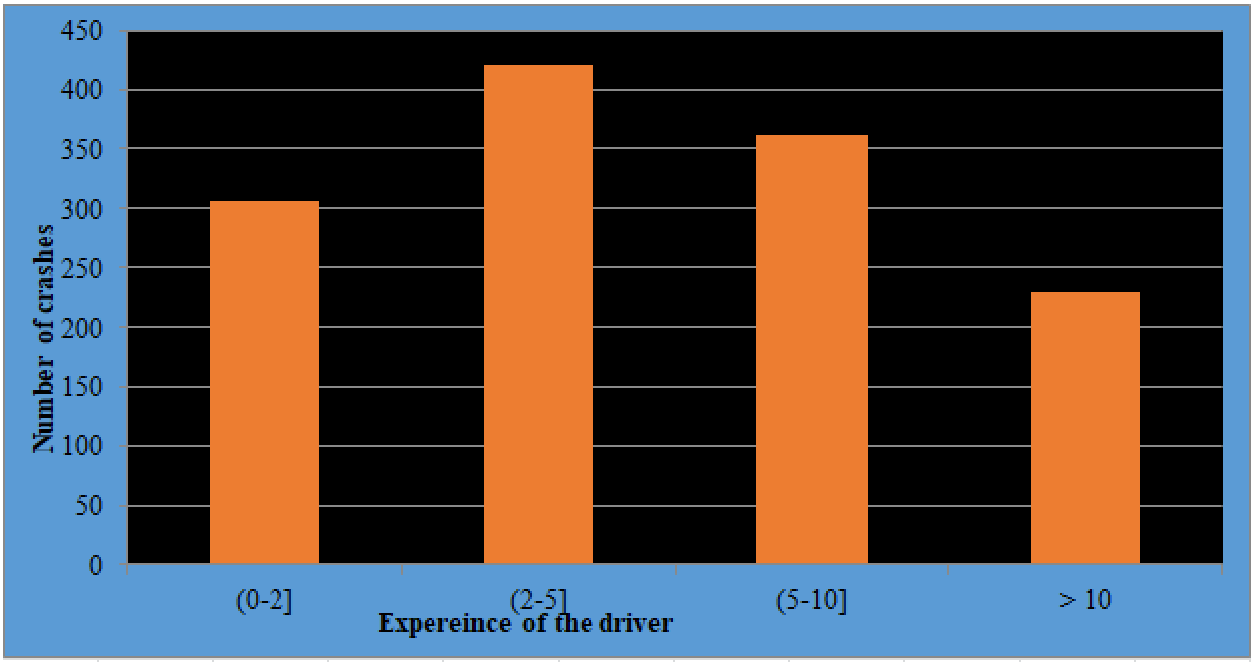


Fig.4. 7 Experience of the drivers Vs. Number of crashes

The above graph describes that 31.89% of total number of crash is happened by drivers with experience of 2-5 years. Drivers of experience with 5-10 years causes 27.42% of crashes, following crash happened by drivers with experience of 2-5 years. The question why the drivers with experience of 2-5 years cause many crashes than that of drivers with experience of 0-2 years may be raised. It should be understood that drivers of age 25-35 are 55.63% of total divers involved in crash causing. In another way majority of drives with age 25-35 (54.8% of total age drivers) fall under drivers with experience of 2-5 years.

4.2.3 Distribution of traffic accident depending on vehicles condition

Another factor which contributes in traffic accident is Vehicle condition. Vehicle condition includes vehicle type, vehicle ownership, vehicle technical deficiency and vehicle service year.

A) Vehicle type and traffic accident

Vehicle type means a kind of vehicle which is needed for particular service. Depending on the nature of the services one vehicle gives and on a design of that particular vehicle, the crash it brings will differ. There are many more type of vehicles causing different kind of accident at different places and time. According to Ethiopian Pavement Design Manual Volume I Flexible Pavements, there are 13 vehicle types/classes. The traffic accidents that are happened by these different types of vehicle throughout the study period is explained here below in tabular form and presented graphically.

Table 4. 9 Vehicle type and traffic accident

Code	Vehicle type	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Car	9	12	5	46	72
2	Pick-up/4-wheel drive	86	68	30	198	382
3	Small bus	7	6	2	13	28
4	Bus/Coach	15	9	5	30	59
5	Small truck	0	0	0	0	0
6	Medium truck	48	38	19	130	235
7	Large 2-axled truck	27	21	6	137	191
8	3- axled truck	24	25	4	98	151
9	4- axled truck	0	0	0	0	0
10	5- axled truck	0	0	0	0	0
11	6-axled truck	0	0	0	0	0
12	2- axled trailer	2	6	3	26	37
13	3- axled trailer	5	6	2	31	44
Total						1199

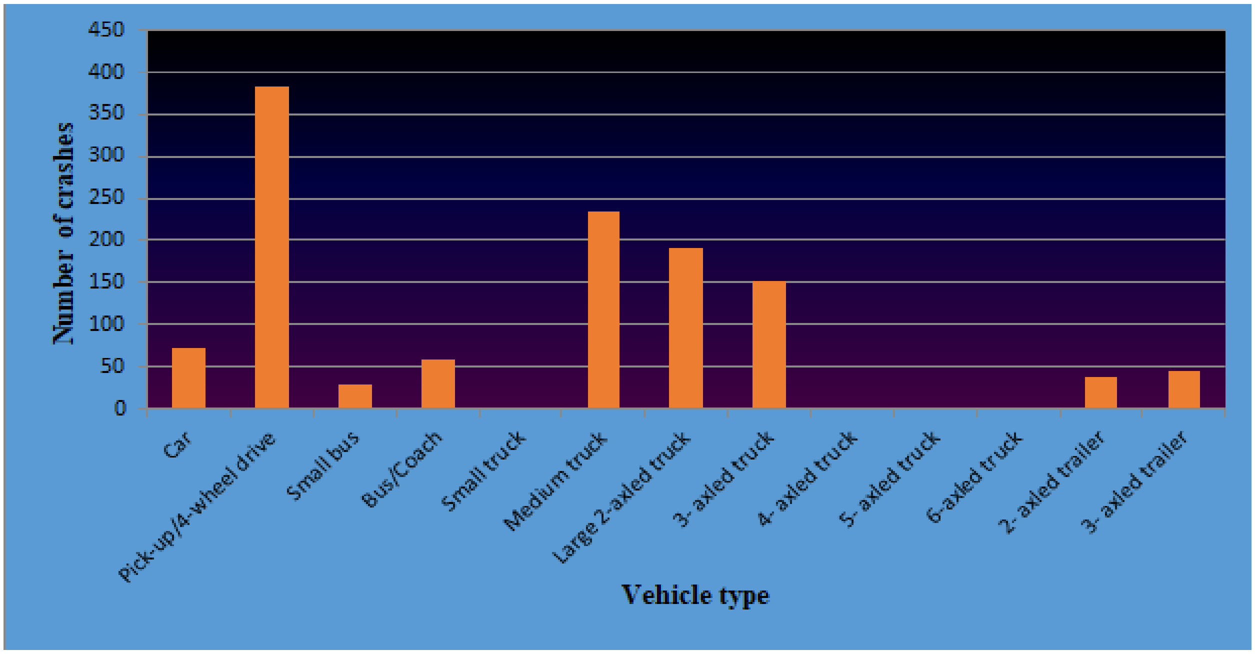


Fig.4. 8 Vehicle type Vs Number of crash

From the above graph it is observed that the traffic crash by small bus accounted for nearly one third of the total crash (31.86%). The reason that small bus holds majority percent of the traffic crash depends on the type of vehicle involved in the crash. Most of the time small bus specially "minibus" uses the road from Addis Ababa to Gohatsion (Qarree Gohaa) for transporting people from town to town. So, there is a probability of traffic crash caused by small bus to be high.

Following to the small bus it is Medium truck, large 2-axled truck and 3-axled truck that holds the significant next rank in causing the traffic crash along the selected study area. They account for about 19.6%, 15.93% and 12.59% respectively.

B) Vehicle ownership and traffic accident

Sometimes the ownership of the vehicle matters how often the crash occurred along some specified road. Vehicles can be owned in private, government, NGO, Company, rental and any other form. Depending on the ownership of vehicle, it is obvious that the care given to the vehicles and services given to the vehicles differ. In the same way, if the care given to the vehicles and services/maintenance/ for the vehicles differ, the crash that happened due to each type of vehicles ownership also differs.

Table 4. 10 Vehicle ownership and traffic accident

Code	Vehicle ownership	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Company	10	5	23	25	63
2	Private	216	191	86	670	1163
3	Government	12	9	1	30	52
4	NGO	0	0	1	0	1
5	Rental	1	0	0	0	1
Total						1280

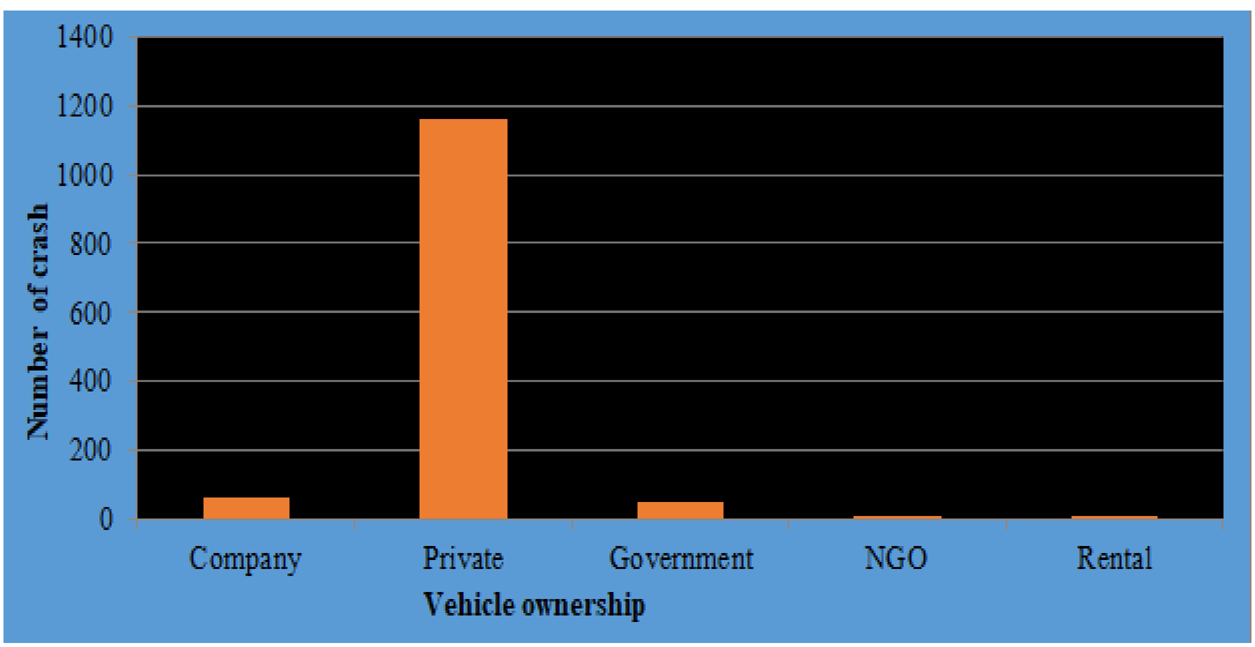


Fig.4. 9 Vehicle ownership Vs Number of crash

From the above graph it is observed that vehicle owned by the private (90.86%) is involved in causing traffic accident than other type of ownership. This implies that private vehicles dominate other types of vehicle in causing traffic crash, because of the fact that more of the road users' vehicles are that of privates. Other types of vehicle ownership account for only 9.24%.

C) Vehicle's service year and traffic accident

Vehicle service year is one the factor which affects occurrence of the traffic accident. In this paper there is no enough data to analyze which service year range can cause more traffic crash and which can cause least. However, there is no data, it is obvious that as service year of the vehicle become increase the probability of the vehicle to be involved in the crash become increase. This is because that as service year increases the spare parts of the vehicles becomes aging and finally damaged and cause crash.

D) Vehicle's technical deficiency and traffic accident

It is well known that vehicle technical deficiency affects the trend of traffic accident in one way or another. If one vehicle is technically good enough, it is assumed that the probability of causing traffic crash become less. But there are many other factors that lead one vehicle into crash causing.

Table 4. 11 Vehicle technical deficiency and traffic accident

Code	Vehicle technical deficiency	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Good	241	206	88	721	1256
2	Bad	0	0	0	0	0
3	Unknown	0	0	2	0	2
Total						1258

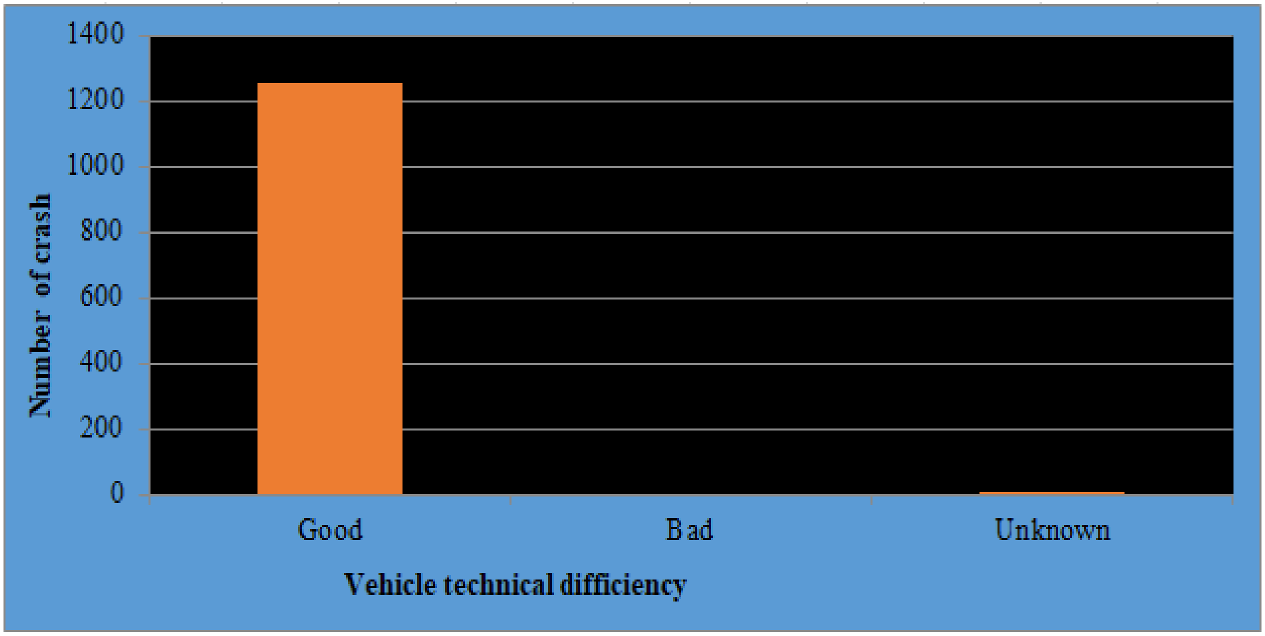


Fig.4. 10 Vehicle technical deficiency Vs Number of crash

From the above graph it is observed that most of the vehicles (99.84) are technically good. But, still they cause accident. This contradicts that the assumption “technically good enough vehicles causes less traffic accident”. The contradiction happens due to many other factors listed here below according to different sources.

- The technique investigation of vehicles is not that much persuasive to accept the result that vehicles are technically good enough.
- There may be dominance of other factors obscuring effect of vehicle’s technical deficiency as a cause of traffic crash.

4.2.4 Analysis of traffic accident distribution based on environmental condition

While much emphasis has been placed on the influence of human factors, vehicle characteristics, roadway characteristics and other variables such as time (based on hour and day of the week), there have been few studies examining the relationship between environmental condition and traffic crashes. There are some environmental conditions like land use, road conditions, lighting conditions and weather conditions which can be directly or indirectly related to traffic crash.

A) Land use Vs traffic accident

First of all, the relationship between land use and traffic accidents seems obvious, even though indirectly related. There are certain uses of land that tend to generate activities that help produce or attract travelers. It is known that trips originating from or are attracted to a particular land use influence the volume of traffic attracted to it, which is also believed to be associated with the occurrence of road traffic accidents.

However, it must be noted that people, more specifically those driving and travelling automobiles, are the ones involved in motor vehicle collisions. Hence it is not surprising to find that human factors typically dominate in terms of theories of accident causation.

Table 4. 12 Land use type and traffic accident

Code	Land use	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	School area	3	2	0	6	11
2	Industrial	8	6	6	20	40
3	Church area	0	0	2	2	4
4	Commercial area	58	41	19	95	213
5	Residential area	20	16	4	106	146
6	Recreational area	6	2	2	30	40
7	Office	0	0	0	3	3
8	Hospital	0	0	0	0	0
9	Rural village areas	150	137	57	455	799
10	Other	0	0	0	8	8
Total						1264

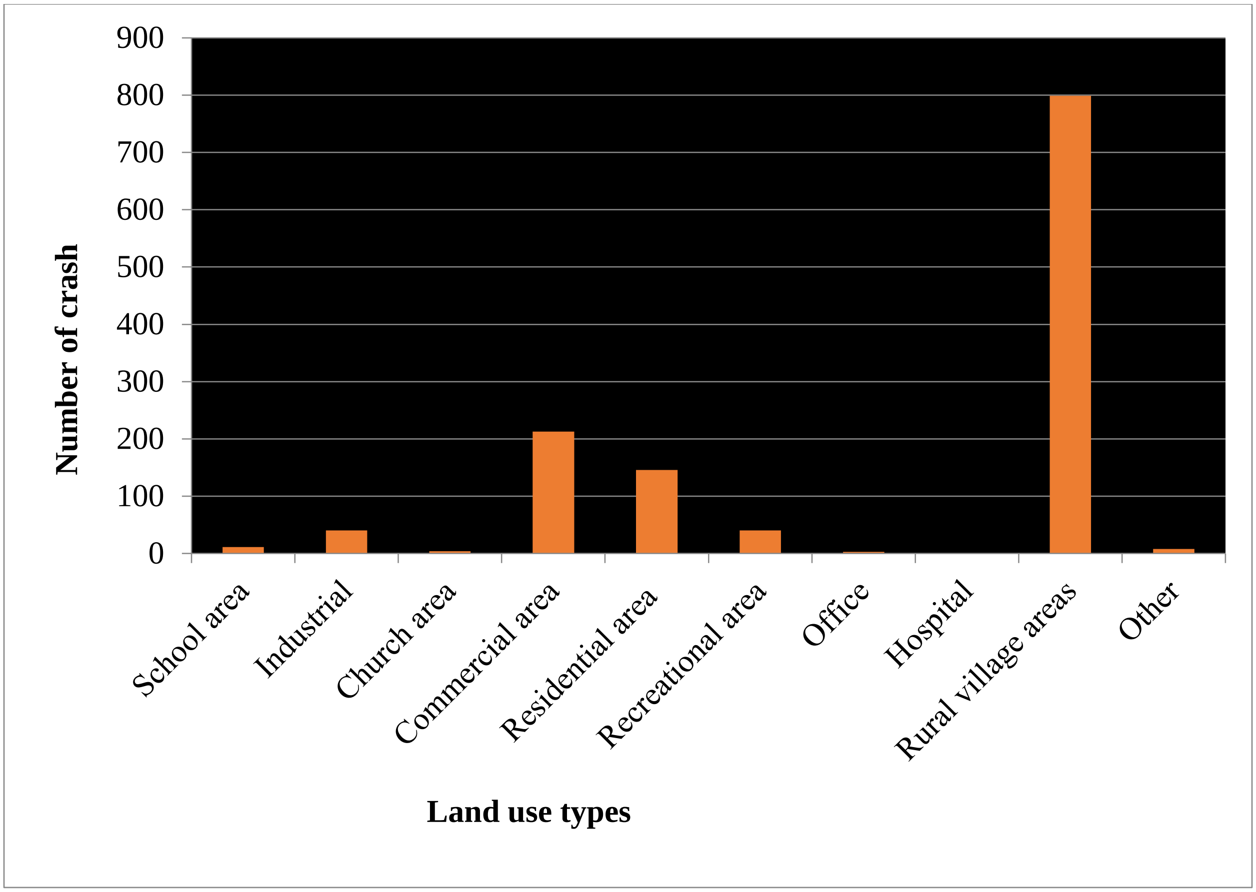


Fig.4. 11 Land use types Vs Number of crash

Fig 4.11 above shows the frequency of crashes produced by different land uses for the entire segment of the Addis Ababa-Gohatsion(Qarree Gohaa) road. It shows the number of crashes produced in 3-year period of time by each land use categories. It reveals very clearly that the largest proportion of crashes, about 63.21% occur in rural village area lands. This category of land use covers almost about 79.7% of all land uses along the study area with difficult terrain type which results with inconvenient road geometry to ride on. The largest area coverage of rural village area land leads to the large number of crash due to the reasons mentioned earlier (road geometry) and probability of crash to be happened. The next land use category amounting to almost 16.85% of all crashes includes commercial land. Other significant categories include residential land, recreational and Industrial land. It is agreed that trips originating from or are attracted to a particular land use influence the volume of traffic attracted to it, which is also believed to be associated with the occurrence of road traffic accidents. Commercial areas and other significant areas like residential area, recreational area and Industrial area are also one of the areas to which volume of traffic is attracted to and originated from which results with significant amount of crashes.

B) Road condition Vs traffic accident

Road condition in this case is the condition of the surface of the road whether it is dry, wet or other type. The road condition influences the crashes happening on the road in different ways. Many literatures demonstrated that the probability of accident occurrence can be increased as the humidity level and rainfall increased; which means when the surface of the road is wet. Wet road condition challenges the behavior of the diver in many ways. For example, on wet road the driver has to adapt longer headways, slower speed and avoidance of overtaking on two lane roads. Therefore, it would appear that the accident risk in wet conditions is higher than that in dry conditions.

Table 4. 13 Road Condition and traffic accident

Code	Road condition	Fatal	Severe injury	Slight Injury	PDO	Total No of crashes
1	Dry	147	117	52	396	712
2	Wet	78	73	26	271	448
3	Other	20	15	10	58	103
Total						1263

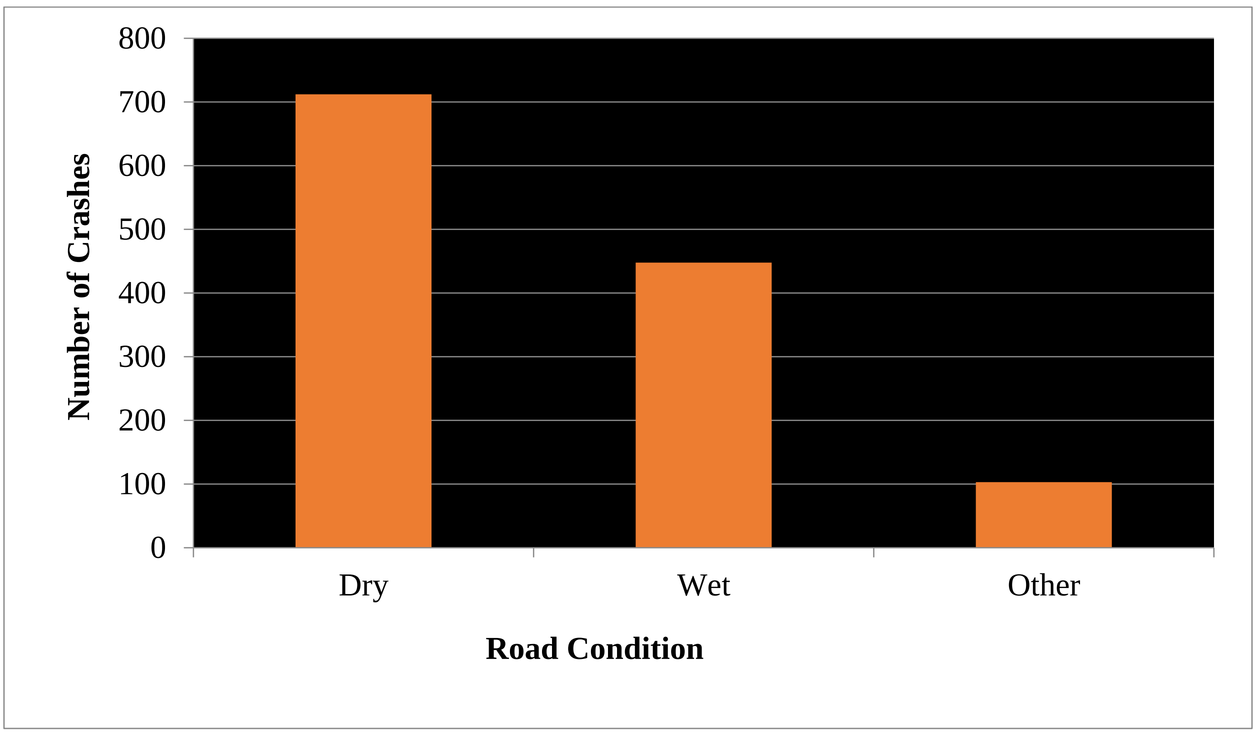


Fig.4. 12 Road condition Vs Number of crash

The above figure (fig.4.12) reveals that more crashes are happened on dry road. The crash occurred on dry road in percentage is amounted to about 56.37%. Accident occurred on wet road follows by 35.47%. Contrary to many literatures conclusion it is found here that traffic crash on dry road surface is higher than that of on wet road surface. This don't give full information to generalize the effect of road surface condition as wet road condition is less causes traffic accident than dry road. What to be known here is that in Ethiopia most of the seasons the road surface is dry. About 70% and above the Ethiopian roads are dry throughout the year. So, the probability of occurrence of traffic crash on dry road is higher than that of wet road. Therefore, the duration of wet or dry road condition matters to generalize in which condition the traffic crash become high. If wet road condition lasts for at least half of a year, the traffic crash during this period could be increased by 17.74% and become 53.21% throughout the year. Similarly, if the period of dry road condition becomes equal with wet road condition the occurrence of accident due to dry road condition could be reduced by 14.09% and covers 42.28% of traffic crash throughout the year.

C) Lighting condition Vs traffic accident

It is well known that darkness (or the absence of lighting) results in a disproportionately large number (in relation to exposure) of crashes and fatalities, and in particular, those involving pedestrians. Pedestrians are the most vulnerable population on roads at night and in terms of crash reduction appear to benefit the most from street lighting.

It is assumed that the issues involving pedestrian crashes at nighttime are primarily associated with visibility; hence these are scenarios in which lighting might have the greatest effect in regards to the reduction of nighttime crashes.

Table 4. 14 Lighting Condition and traffic accident

Code	Lighting condition	Fatal	Severe injury	Slight Injury	PDO	Total No of crashes
1	Day light	197	179	77	591	1044
2	Night light	48	27	11	134	220
Total						1264

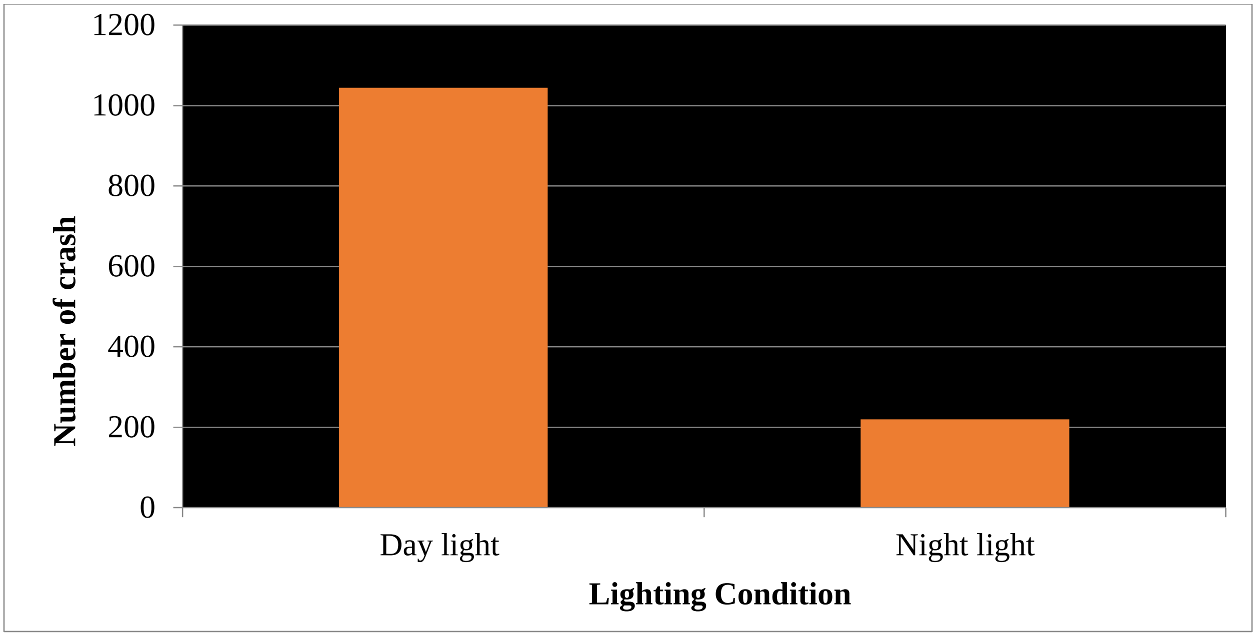


Fig.4. 13 Lighting condition Vs Number of crash

The above graph illustrates that number of crash on daytime is higher than at night time. Daylight crash accounted to about 82.59% of all crashes recorded throughout the study period. What to be considered here is that the number of crash observed during each type of light condition (day light and night light) is not in relation to exposure of the travelers during each light condition. In the study area it is forbidden to drive at night; especially for public transportation. Most of the time passengers travel from town to town between 6:00AM mornings to 6:00PM afternoon. It is forbidden to drive before 6:00AM in the morning for public vehicles. So, the exposure of travelers and drivers to crash at night time is much lower than at day light; and as a result the number of crash at night time become lower than at day light. If exposure for both of lighting condition becomes equal, the night time crash would be higher than daylight crash as a number of study reveals this kind of result.

D) Weather condition Vs traffic accident

Weather conditions, such as precipitation and air temperature are associated with considerable impacts on road safety, mainly their influence on both the exposure and the behavior of road users. The relationship between weather effects and the effects of other road safety factors, including roadway, driver, vehicle and intervention variables on road accident frequency is certainly a complex phenomenon that attracts increasing attention by researchers.

Most research indicates that increase in rainfall leads to increase in traffic accident. Some researchers come up with the result that suggests increases in rainfall reduce all types of incidents. This is attributed mainly with safety during driving in rain (less speeding) and characteristics of driver who are not accustomed to driving in wet/rainy weather condition.

Table 4. 15 Weather Condition and traffic accident

Code	Weather condition	Fatal	Severe injury	Slight Injury	PDO	Total No of crashes
1	Good	148	120	51	377	696
2	Cold	19	12	2	61	94
3	Rainy	18	12	3	45	78
4	Other	60	62	32	248	402
Total						1270

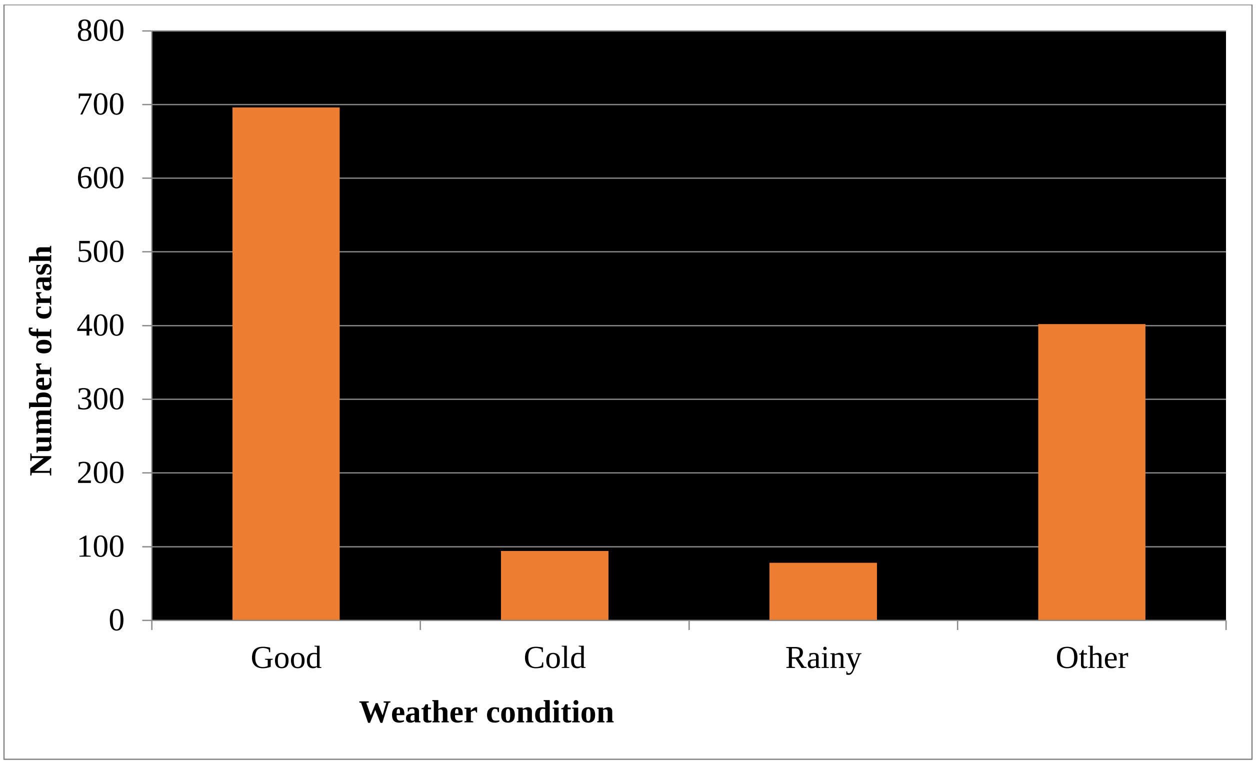


Fig.4. 14 Weather condition Vs Number of crash

Fig 4.14 above delineates that, number of traffic crash which is happened during good weather condition is accounted to about 54.80%. In unknown weather condition number of crash occurred is estimated to 31.65% of total crash. In rainy and cold weather condition the number of crash occurred is accounted to 6.14% and 7.4% respectively. Contrary to the conclusion of most researchers, it is found here that the highest number of crash is recorded during good weather condition. This may be associated with less speeding of the drivers during rainy season as some researchers concluded. But the main reason that can decrease the number of crash during cold and rainy season and increase during good weather condition in Ethiopia is that the length of cold and/rainy season is shorter than other seasons.

So, the probability of occurrence of crash in almost 66.67% of the whole year is higher than that happened in 33.33% of season of the year.

4.2.5 Distribution of traffic accident based on road characteristics

According to the crash data gained from traffic police stations the road from Addis Ababa to Gohatsion is characterized by its type, the geometry of the given road, its intersection type and type of the pavement. The road under the study traverses along flat, rolling and mountainous terrain. It’s known that type of the road from Addis Ababa to Gohatsion is rural two ways two lane. Along this road there is no median at any point and the pavement type across the given road is asphalt. Even if there are different types of intersection along this road, no crash is occurred at the intersection.

A) Distribution of traffic accident based on road geometry

In chapter two (2) of this paper it is discussed that most of the studies have shown the influence of various geometric design variables on the occurrence of accidents and have concluded that not all variables have the same level of influence in all places. As the objective of this research is investigating the effect of road geometry with regard to causing the road traffic accident at the identified black spot locations, it is better helpful to analyze the road geometry with respect to number of crashes recorded at that particular geometry of the road to achieve the goal of the research.

Table 4. 16 Road geometry and traffic accident

Code	Road Geometry	Fatal	Severe injury	Slight Injury	PDO	Total No of crashes
1	Bridge	0	0	0	1	1
2	Curve	47	30	11	138	226
3	Grade on tangent	10	17	1	37	65
4	Intersection	0	0	0	1	1
5	Mountain	0	0	0	2	2
6	Roundabout	0	3	2	4	9
7	Sharp curve	0	0	0	1	1
8	Grade on curve	187	156	74	540	957
Total						1262

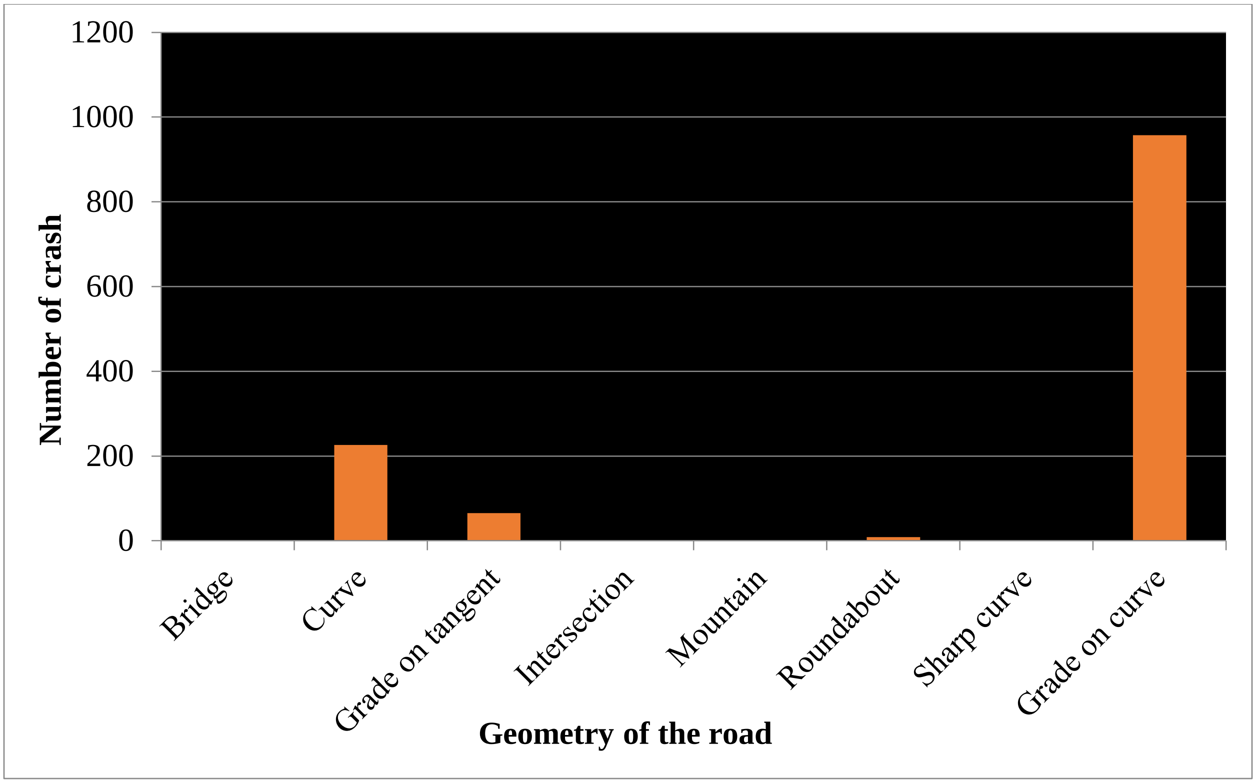


Fig.4. 15 Geometry Vs Number of crash

Fig 4.15 above reveals that 93.74% of the crashes happened is related with curved geometry of the road. Especially, at locations with grade on curve the traffic accident becomes very severe. Grade on curve is accounted to 77.25% of all recorded crash of the study period. This figure is very huge when compared to other geometric features of the road in causing the accident. Next to grade on curve is a curve with 17.9% contribution. As observed from the as built drawing of the road from Addis Ababa to Gohatsion (Qarreegohaa) the alignment of the road has many curves. Curve causes crash from different perspective; one from the defect of design and the other is defect of the construction of the curve itself (especially in provision of the super elevation) and the behavior of the drivers at the curve location.

B) Distribution of traffic accident based on Availability of median

It is known that the study (road from Addis Ababa to Gohatsion/Qarreegohaa) is two way two lane rural roads without median. Hence, the analysis of impact of availability of median on distribution of traffic accident is not significant. Different studies have identified conflicting results for the presence of median barriers. Some have indicated that the effectiveness of the presence of medians on safety cannot be conclusively identified but noted that there is potential for the median to impact safety. Other has shown that median barriers have a positive effect, i.e. reduce crashes, and others have indicated that increase of crashes with median presence but a reduction of the level of severity for these crashes.

C) Distribution of traffic accident based on Road type

Road type here indicates number of lane of the road with its direction as well. The type of road of the study area is completely fall under rural two lanes two-way road. So, the traffic accident occurred along the study area for the specified study period is distributed only through the two lane two-way road. Traffic crash that happened along the study area is 100% found in the specified type of road. This doesn’t mean two lanes two way roads is the worst type of road on which accident is frequently happened. It is the only option that is available for road users to use and as the result crash will occur and that is not due to the type of the road but may because of other factors which are discussed earlier in this chapter. Since there is no another type of road other than two lanes two way in this it’s insignificant to look at the distribution of traffic accident based on the road type.

D) Distribution of traffic accident based on Road pavement

The road under the study is a trunk road which connects Addis Ababa to the international boundary. The surfacing material of this road is asphalt; where all of the traffic crash occurred on this road fall under asphalt road pavement. The safety of the road in relation with the pavement type depends on the friction between the pavement and the tire. This on the other hand depends on the contact surface area between the tire and the pavement surface, which in turn depends on the several factors including pavement texture and tire rubber stiffness. Since the total recorded traffic crash is found on the same road pavement (asphalt), there shouldn’t be analyses of the distribution of the traffic accident based on the road pavement. Because it is known that there is no other pavement type along the study area other than asphalt to compare with, whether one type of pavement affects the distribution of the traffic accident than the other one.

4.2.6 Distribution of traffic accident based on crash condition

Crash condition here is defined to include the nature of the crash and the crash severity. Crash condition impacts the number of crash in one way or another. The crash conditions also influence each other by their correlation with crash number. For instance, nature of the crash (type of crash) has its own impact on severity of the crash.

A) Nature of the crash Vs traffic accident

Nature of crash or type of crash is the way the crash has happened or the way collision has happened to one vehicle or between two or more vehicles. The bodies involved in the crash are Bajaj, Car, Cart, Bicycle, Pedestrian, Motorcycle, Animal and Object. The way the crashes have happened is in the form of the collision of these involved parties, rollover and side swipe. The collisions are in the form of Bajaj-Car, Bajaj-Cart, Bajaj-Pedestrian, Bicycle-Pedestrian, Car-Animal, Car-Car, Car-Cart, Car-Motorcycle, Car-Object, Car-Pedestrian, Motorcycle-Pedestrian, and Motorcycle-Motorcycle.

Table 4. 17 Nature of crash and traffic accident

Code	Type of crash (Nature of accident)	Fatal	Severe injury	Slight injury	PDO	Total No of crashes
1	Bajaj-Car	0	3	0	2	5
2	Bajaj-Cart	0	0	0	1	1
3	Bajaj-Pedestrian	0	1	0	1	2
4	Bicycle-Pedestrian	1	0	0	0	1
5	Car-Animal	1	2	0	14	17
6	Car-Car	37	66	27	245	375
7	Car-Cart	0	0	0	4	4
8	Car-Motorcycle	1	2	1	0	4
9	Car-Object	3	5	1	41	50
10	Car-Pedestrian	132	46	21	5	204
11	Motorcycle-Ped	0	2	1	0	3
12	Motorcycle-Motorcycle	1	0	0	0	1
13	Rollover	57	67	24	239	387
14	Side swipe	11	12	11	73	107
Total						1161

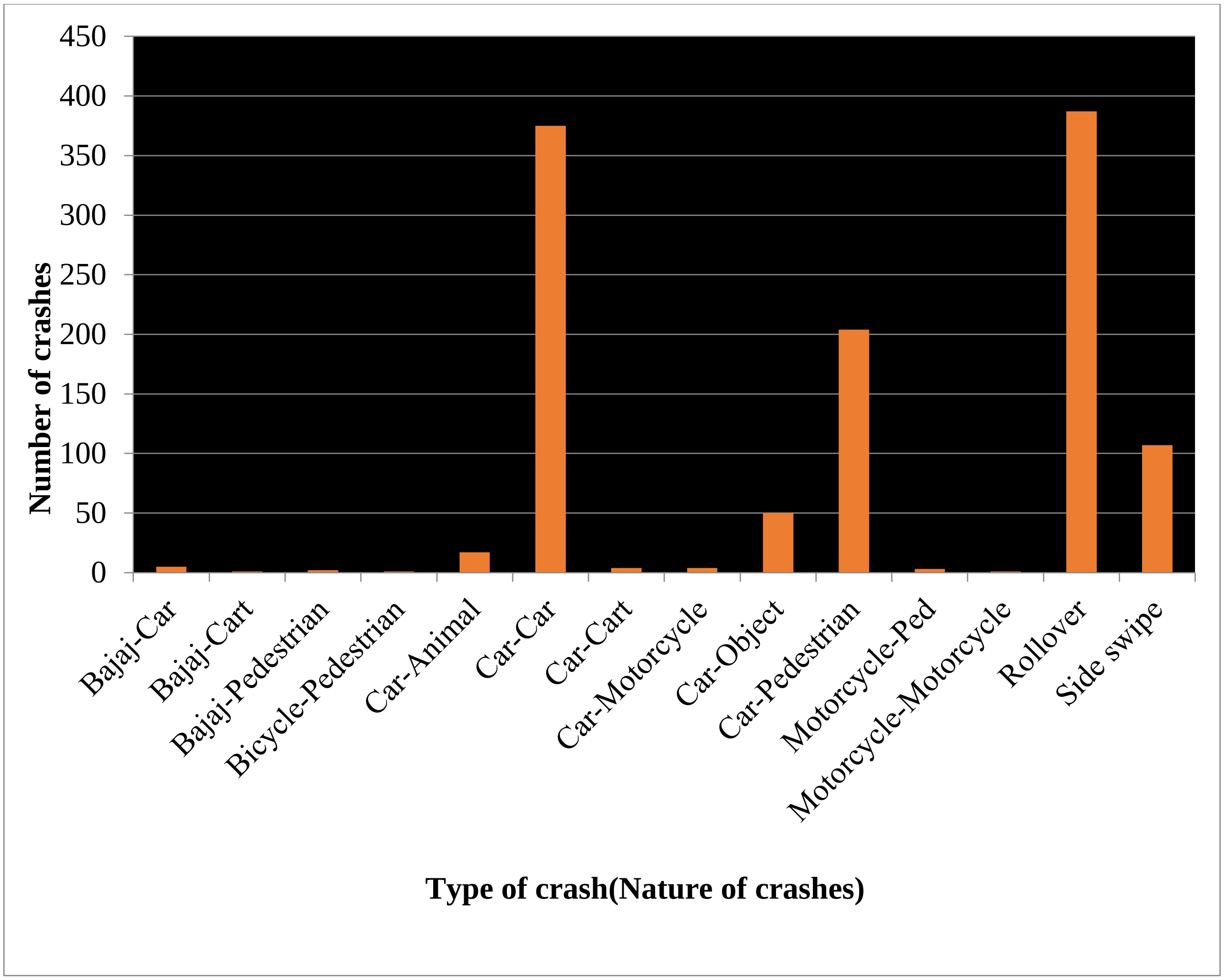


Fig.4. 16 Nature of crash Vs Number of crash

The above Fig 4.16 illustrates that rollover type of crash holds the highest number of crash among the above mentioned type of crash (nature of crash). It is accounted to about 33.33% of all the recorded number of crash throughout the study period. Next to Rollover type of crash it is Car-Car collision that shares 32.33% of all number of crashes. Car-Car collision is happened most of the time by two or more opposing vehicles. Such kind of collision happens several times at curvatures due lack of provision of enough sight distance and proper super elevation. Sometimes Car-Car nature of crash is happened on straight section of the road due to defect of drivers by losing attention because of anxiety and when searching for comfortable surface of the pavement at segments which are damaged.

B) Crash severity Vs traffic accident

Crash severity indicates the level of damage of the crash which is happened to either human (driver, passenger and pedestrian) or property. The crash severity begins with slight property damage and extends to fatal crash.

Table 4. 18 Type of severity and traffic accident

Code	Type of severity	Total No of crashes
1	Fatal	245
2	Severe injury	206
3	Slight injury	88
4	Slight property damage	725
Total		1264

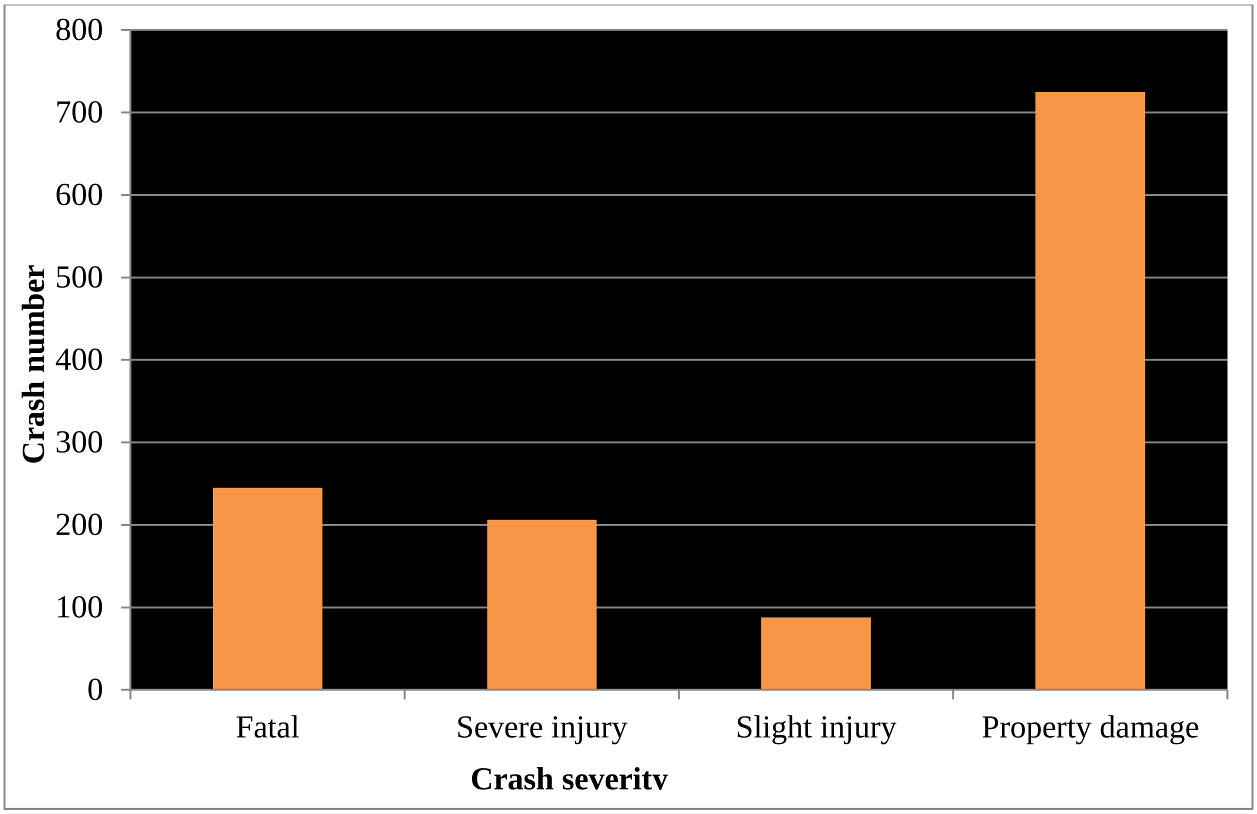


Fig.4. 17 Crash Severity Vs Number of crash

The figure elaborates that among the types of the crash severity discussed above slight property damage covers the highest percentage of all. About 57.34% of all crash is slight property damage which costs many million-birr loss when summed up. Next to slight property damage is fatal crash which cut short the life of many productive young. This type of crash is very dangerous as the victims farewell this world for once and the last.

4.3 Blackspots identification

Black spot identification is the first step in improving road safety at a black spot. Then it should be followed by diagnosis of the selected spots, finding countermeasures, estimating effects and costs, prioritizing, implementation and at the end follow-up and evaluation. There are different methods used to identify blackspot along specified road length. Among these methods Rate Quality Control Method and Accident Density Methods are used for this particular study.

4.3.1 Blackspots identification Using Rate Quality Control Method

In Rate Quality Control Method calculating three different parameters for each road section is necessary. The road section is defined here as one kilometer of road. The three parameters are:

- Accident rate,
- Accident frequency,
- Severity index.

Each of these values is compared with a critical value. Thus the accident rate is compared with one critical value, the accident frequency with another critical value and the severity value with a third critical value. If a certain road section shows higher values than the critical ones for all these three parameters, the section is considered to be a black spot.

Accident rate: To calculate accident rate (R_j), number of accidents on each section (A_j) and number of vehicles km in millions on each section ($m_{j)}$ is determined. If accident rate of each road section is greater than the critical accident rate (Rc), the section would be considered as blackspot. In this calculation it should be noted that the whole road length is divided in to two segments before dividing into sections of 1 km. Those two sections are section from Addis Ababa to Fitche and section from Fitche to Gohatsion (Qarree gohaa). This division is happened because of the variation of AADT of the two sections. AADT for Addis Ababa to Fitche is 2445, while AADT for Fitche to Gohatsion (Qarreegohaa) is 1583. Hence, number of vehicles km in millions for the sections differ. Accordingly, the result of the calculation for accident rate which is extracted from the table which is found on **(APPENDIX B1)** is given here below.

Table 4. 19 Accident rate for blackspot sections

S.N	Station/ Section(j) km	Number of accidents (Aj)	Number of Vehicle km (mj)	Accident rate on section j (Rj)	Critical value of accident rate (Rc)	Name of the places
1	4+000	14	2.68	5.224	5.055	*10 kilo
2	5+000	14	2.68	5.224	5.055	*Wasarbii
3	8+000	19	2.68	7.090	5.055	*Qimbirree
4	10+000	17	2.68	6.343	5.055	*Shuffunnee
5	11+000	16	2.68	5.970	5.055	*Doro irbata

6	13+000	15	2.68	5.597	5.055	*Ashewa
7	14+000	16	2.68	5.970	5.055	*Prime milk
8	15+000	14	2.68	5.224	5.055	*Kajima
9	19+000	16	2.68	5.970	5.055	*Leather factory
10	27+000	21	2.68	7.836	5.055	*Gajoo
11	29+000	31	2.68	11.567	5.055	*kosobar
12	31+000	23	2.68	8.582	5.055	*Derba mazoria
13	34+000	26	2.68	9.701	5.055	*Mesalemiya
14	35+000	29	2.68	10.821	5.055	*laga chancho
15	40+000	31	2.68	11.567	5.055	*laga leencaa
16	45+000	26	2.68	9.701	5.055	*Abbichuu
17	48+000	30	2.68	11.194	5.055	*Gorfoo
18	52+000	28	2.68	10.448	5.055	*Bacho
19	58+000	14	2.68	5.224	5.055	*Laga roobaa
20	60+000	14	2.68	5.224	5.055	*Dubar river
21	62+000	16	2.68	5.970	5.055	*Koran
22	65+000	15	2.68	5.597	5.055	*Wada
23	94+000	18	2.68	6.716	5.055	*Laga guurii
24	116+000	13	1.73	7.514	2.022	*Laga Silmii
25	128+000	17	1.73	9.827	2.022	*Eegduu
26	133+000	12	1.73	6.936	2.022	*Hambiso 01keb.
27	139+000	5	1.73	2.890	2.022	*Laga qallaa
28	149+000	5	1.73	2.890	2.022	*G/G River
29	151+000	4	1.73	2.312	2.022	*Misilii iraasuu
30	159+000	5	1.73	2.890	2.022	*Bitoo milkii
32	169+000	4	1.73	2.312	2.022	*Walee cilalloo
33	186+000	4	1.73	2.312	2.022	*Abay gorge

Source: Calculated

Accident frequency: Accident frequency is used to determine whether the accident frequency of each section of the road exceeds the critical accident frequency (Ac) or not. If accident frequency/number of accidents (Aj) of each section exceeds the critical accident frequency (Ac), the section shall be considered as blackspot. In order to determine the critical accident frequency, average accident frequency (Fav) should be determined. The table below illustrates more about accident frequency of the blackspot sections.

Table 4. 20 Accident frequency for blackspot sections

S.N	Station/ Section(j) km	Number accident frequency (Aj)	Number of Vehicle km (mj)	Average accident frequency (Fav)	Critical accident frequency (Ac)	Name of the places
1	2+000	10	2.68	6.430	10	
2	4+000	14	2.68	6.430	10	*10 kilo
3	5+000	14	2.68	6.430	10	*Wasarbii
5	8+000	19	2.68	6.430	10	*Qimbirree
6	10+000	17	2.68	6.430	10	*Shuffunnee
7	11+000	16	2.68	6.430	10	*Doro irbata
8	12+000	10	2.68	6.430	10	
9	13+000	15	2.68	6.430	10	*Ashewa
10	14+000	16	2.68	6.430	10	*Prime milk
11	15+000	14	2.68	6.430	10	*Kajima
14	18+000	10	2.68	6.430	10	
15	19+000	16	2.68	6.430	10	*Leather factory
16	23+000	13	2.68	6.430	10	
17	24+000	10	2.68	6.430	10	
19	26+000	11	2.68	6.430	10	Malima
20	27+000	21	2.68	6.430	10	*Gajoo
21	28+000	13	2.68	6.430	10	
22	29+000	31	2.68	6.430	10	*kosobar
23	30+000	12	2.68	6.430	10	
24	31+000	23	2.68	6.430	10	*Derba mazoria
26	33+000	10	2.68	6.430	10	Stadium
27	34+000	26	2.68	6.430	10	*Mesalemiya
28	35+000	29	2.68	6.430	10	*laga chancho
29	37+000	13	2.68	6.430	10	Guto
30	38+000	13	2.68	6.430	10	
32	40+000	31	2.68	6.430	10	*laga leencaa
33	41+000	10	2.68	6.430	10	Mooyyee gajoo
34	42+000	11	2.68	6.430	10	
35	44+000	13	2.68	6.430	10	
36	45+000	26	2.68	6.430	10	*Abbichuu
37	46+000	10	2.68	6.430	10	
38	47+000	11	2.68	6.430	10	
39	48+000	30	2.68	6.430	10	*Gorfoo

40	49+000	10	2.68	6.430	10	
42	51+000	12	2.68	6.430	10	
43	52+000	28	2.68	6.430	10	*Bacho
44	53+000	10	2.68	6.430	10	
46	56+000	12	2.68	6.430	10	
47	57+000	13	2.68	6.430	10	
48	58+000	14	2.68	6.430	10	*Laga roobaa
49	60+000	14	2.68	6.430	10	*Dubar river
50	62+000	16	2.68	6.430	10	*Koran
51	65+000	15	2.68	6.430	10	*Wada
52	94+000	18	2.68	6.430	10	*Laga guurii
53	106+000	10	2.68	6.430	10	*Torban Ashee
54	116+000	13	1.73	6.430	10	*Laga Silmii
55	128+000	17	1.73	6.430	10	*Eegduu
56	133+000	12	1.73	6.430	10	*Hambiso 01 keb.

Source: Calculated

From the above table it is noted that number of accident frequency is greater or equal with the number of critical accident frequency. Hence, these locations are considered as blackspot.

Severity index: This method depends on the value of severity of the sections of the road (Sj), relative severity (Qj) and critical severity of the accidents. The severity value for road section number *j* is $S_j = I_{f.j}*9+I_{b.j}*3+I_{d.j}*1$

Where I_f= Number of fatalities, I_b=Number of injuries and I_d= Number of property damages only accidents. The weighting factors in the calculations are assumed to be 9:3:1 for fatal accidents, injury accidents and damage only accidents. The sample of severity value of each section of the road under investigation is put in the table below where complete table attached on (**APPENDIX B2)**

Table 4. 21 Accident severity value

N.S	Station/ Section(j) km	Fatal	Injury	PDO	Total	Severity (Si)	Name of the places
1	0+000	0	0	0	0	0.00	
2	1+000	1	2	5	8	20.00	
3	2+000	2	2	6	10	30.16	
4	3+000	1	2	3	6	19.91	
5	4+000	3	3	8	14	42.22	*10 kilo

After determining the severity value for each sections it is so simple to calculate relative severity Q_j = Sj/Aj and critical severity (Qc).

Where, $Q_c = Q_{av} + k\alpha\sqrt{\delta 2} - 0.5$,

$Q_{av} = \frac{\sum_{i=1}^{n} Si}{\sum_{i=1}^{n} Ai}$, $\delta^2 = \frac{1}{n-1}\sum_{i=1}^{n}(Qi - Qav)2$

The road section is considered to be blackspot if Qj>Qc. Where, Qj-is relative severity at section j and Qc-is the critical severity of accident.

Table 4. 22 Severity value of blackspot sections

N.S	Station/ Section(j) km	Severity of road sections (Si)	Number of accidents (Aj)	Relative severity (Qj)	Qav	$(Qj-Qav)^2$	Ciritical severity (Qc)	Name of the places
100	99+000	11.54	2	5.77	3.02	7.570	4.02	
111	110+000	11.54	2	5.77	3.02	7.570	4.02	
116	115+000	11.54	2	5.77	3.02	7.570	4.02	
119	118+000	11.54	2	5.77	3.02	7.570	4.02	
125	124+000	11.54	2	5.77	3.02	7.570	4.02	
132	131+000	11.54	2	5.77	3.02	7.570	4.02	
142	141+000	9.49	2	4.74	3.02	2.973	4.02	Ula
154	153+000	11.54	2	5.77	3.02	7.570	4.02	Biriti junction
173	172+000	11.54	2	5.77	3.02	7.570	4.02	Laga hantuutaa
178	177+000	11.54	2	5.77	3.02	7.570	4.02	
193	192+000	11.54	2	5.77	3.02	7.570	4.02	

According to the above table the selected relative severity (Qj) is greater than the critical severity (Qc). Hence, these sections are said to be considered as blackspot.

4.3.2 Blackspots identification Using Accident Density Method

Since the AADT of the road along the study area is different for section of the road from Addis Ababa to Fitche and Fitche to Gohatsion (Qarreegohaa) we need to consider these sections differently one by one for identification of the blackspot. This is because of the fact that when calculating the "accidental density bench mark" the sections with low AADT will not be accommodated in the list of blackspot locations. In order to avoid such kind of discrimination against accommodation we need to look different things differently.

The section from 0+000 to 108+000 KM is named Addis Ababa to Fitche, whereas Fitche to Gohatsion (Qarreegohaa) is the section 108+000 to 197+237 KM. Accidental data is formed in tabulated form and is given in the appendix. **(APPENDIX B3)**

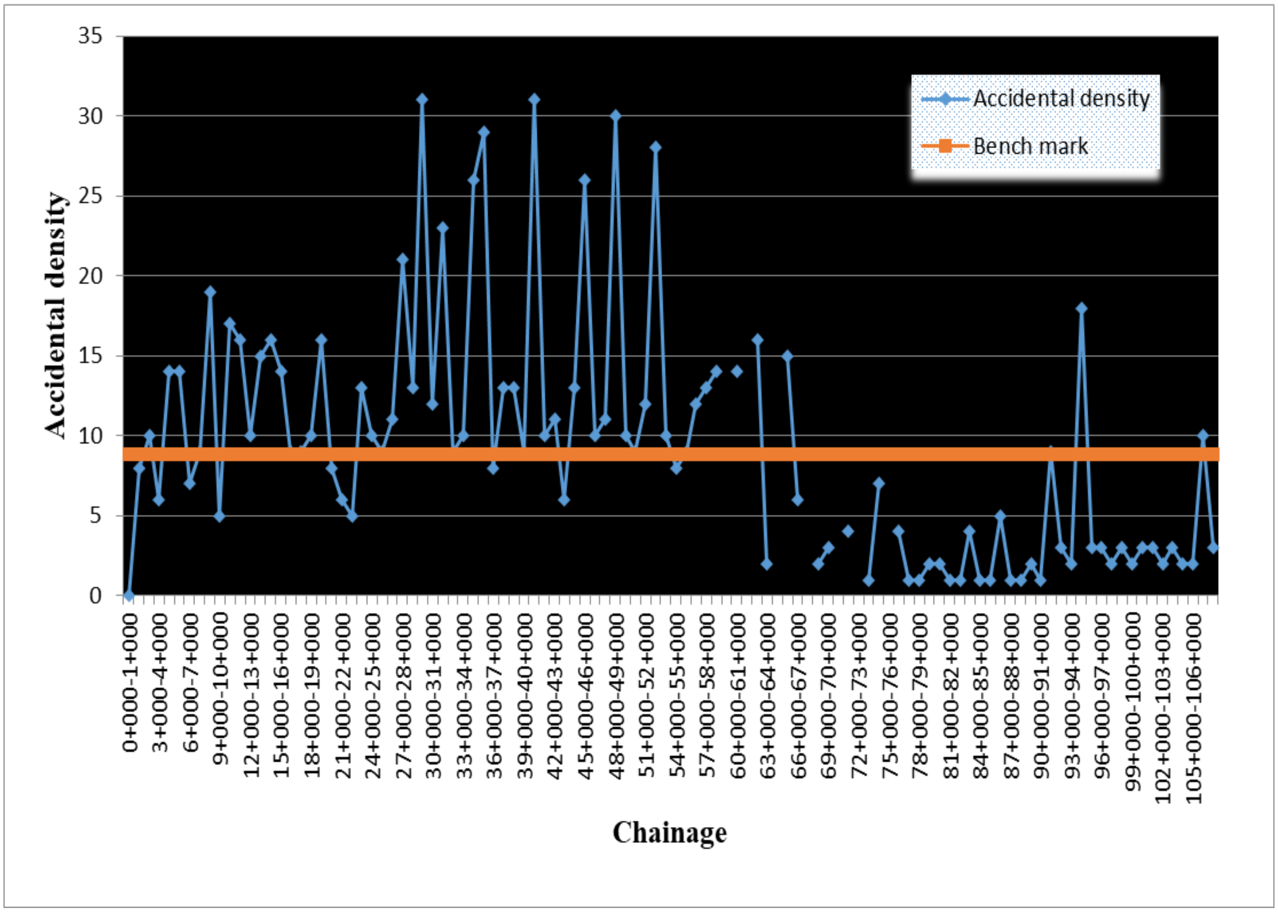


Fig.4. 18 Chainage Vs accidental density

The above graph shows the relationship between the actual chainage and accidental density. According to the graph the locations (chainages) with accidental density value greater than accidental density bench mark value (8.85) are considered to be blackspot. These are locations which are found above the bench mark line on the graph.

The next segment is from Fitche (108+000KM) to Gohatsion/Qarreegohaa (199+237KM). As what done for the first segment, the accidental density for each chainage in this segment and bench mark accidental density should be calculated. After comparing the two values together it is simple to identify the blackspot locations. Accidental data which is formed in tabulated form is given in the appendix. **(APPENDIX B3)**

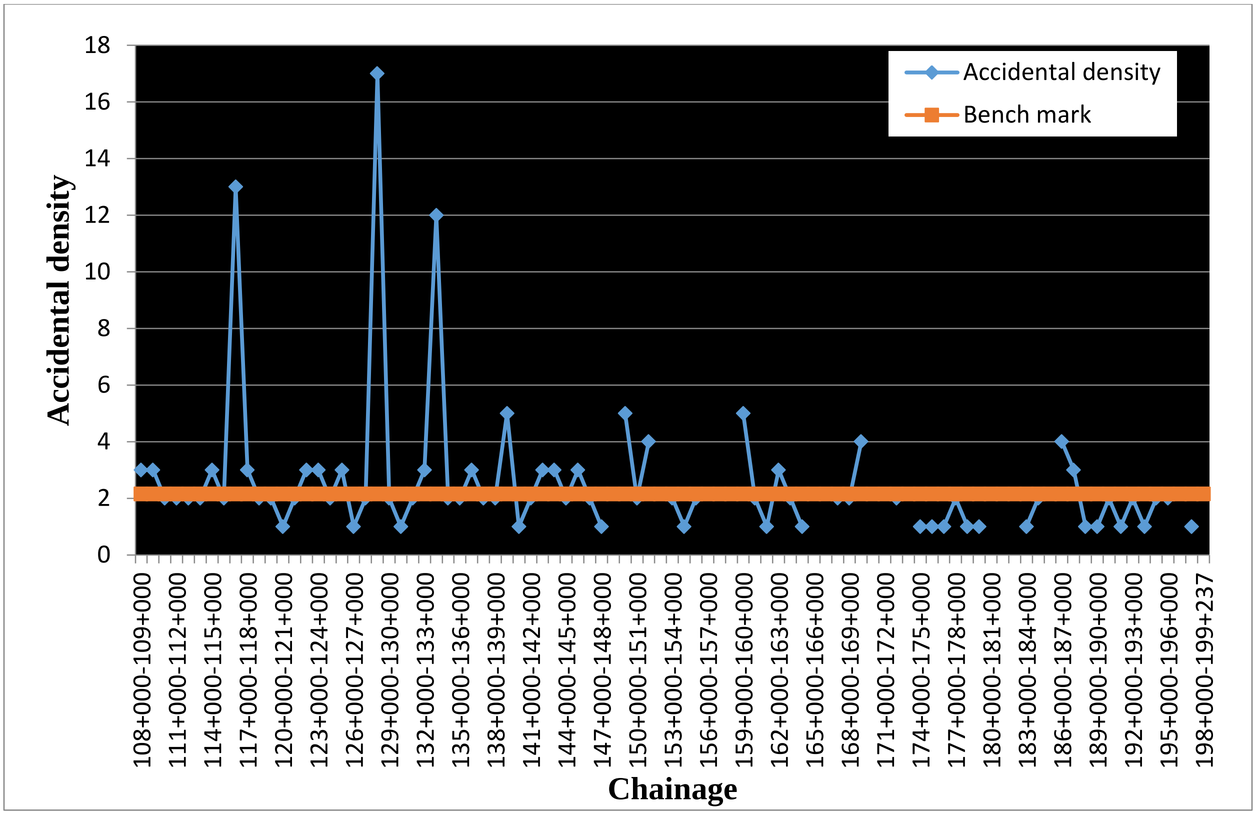


Fig.4. 19 Chainage Vs accidental density of (108+000 to 199+237KM)

The above graph illustrates the locations (chainages) with accidental density value greater than accidental density bench mark values (2.15) are considered to be blackspot. These are locations which are found above the bench mark line on the graph.

4.3.3 Analysis of questionnaires

The formation of questionnaire is needed to incorporate the idea of different road user regarding the traffic accident happened and happening on the road on the study area. It is the society who is affected by the accident and it is the government officials (concerned body) that have the responsibility to identify the problem, take the necessary measure and finally keep the safety of the road user as whole. So, it is mandatory to include all the affected category of population into the study. Accordingly, the questionnaire is distributed to residents, drivers and traffic policemen. It is intentionally distributed to these groups of society; because of the fact that it is believed they are very close to see the cause of traffic accident and its effect and the information gained may be supportive.

During the questionnaire sample size was taken first to represent the road user along the study area. Sample size is calculated using confidence level of 95%, variance of the population (p=50%) and maximum margin error of 5%.

n= $\frac{z2\ (1-p)p}{d2}$ where, n=number of sample size, z= is the critical value of the Normal distribution, p=variance of population and d=absolute error or precision.

For 95% confidence level, z=1.96

Hence, n= $(1.96^2*(1-0.5)*0.5)/0.05^2$ =384.16 ~385

The sampled groups are pre-defined and are non-probably (purposely) selected due to the reason that these groups are believed to have the information about what is asked in the questionnaire.

Table 4. 23 Quantity of sample group for questionnaire

S.N	Group of sample	Quantity
1	Traffic policemen	27
2	Drivers	104
3	Residents	254
Total		385

The 27 traffic policemen are selected from 6 woredas (Warra jaarsoo, Kuyyuu, Dagam, Giraar jaarsoo, Debre libanos & Wacaalee) and 3 towns (Fitche, Chancho & Sululta); 2 from each woreda and 5 from each town. The drivers comprise of drivers who drive between Addis Ababa and capital town of each woredas including the taxi drivers in Fitche, Chancho and Sululta.

Table 4. 24 General characteristics of respondents

Respondents		Traffic policemen		Drivers		Residents	
		Quantity	% tage	Quantity	% tage	Quantity	% tage
Sex	Male	20	74.07	104	100	173	68.11
	Female	7	25.93	0	0	81	31.89
Age	<18	0	0	0	0	30	11.81
	18-25	0	0	15	14.42	24	9.45
	25-35	12	44.44	58	55.77	67	26.38
	35-45	8	29.63	20	19.23	37	14.57
	>45	7	25.93	11	10.58	15	5.91
Level of Education	Illitrate	0	0.00	0	0	0	0.00
	Elementary	0	0.00	25	24.04	16	6.30
	Secondary	0	0.00	61	58.65	34	13.39

	school						
	Diploma	14	51.85	8	7.69	22	8.66
	TVET	4	14.81	6	6.00	42	16.54
	Degree and Above	9	33.33	4	3.85	59	23.23

Table 4. 25 Questionnaire response of Traffic policemen

N.S	Woreda/ town	Questions	Traffic policemen Response		
			Location	Reason	Measurement
1	Warra jaarsoo	1. Where do the accidents often occur? 2. What will be the reason for the occurrence? 3. What kind of	Bitoo Milkii	Speed,Grade,Horizontal curve radius	Speed limit sign, improve signing in horizontal curve radius
			Tulu milki school		
			Walee Cilaalloo		
			Abay gorge		
2	Kuyyuu		Goraa	Curve, Grade,speed,	Signing horizontal curve radius, Speed limit sign, superelevation
			UlaaUmmoo(Wuyyee gosee)		
			Laga Qallaa (ganda birrattee)		
			Iskaan iskaanii		
3	Dagam		Laga Silmi	Curve, sight distance, speed, Grade, Junction, sight distance	Avoiding obstructions, signing horizontal curve radius, Erecting Speed limit sign
			Hambiso 01 kebele		
			Ayane Gerba bridge		
			Dabala Boka		
			Jajabdu		
			Wasarbe		
			Walatu		
			East cement factory		
			Egdu/Ganchur		
4	Fitche		Absira Hotel	Grade	Improving vertical alignment
			Fitche Hospital		
			Waliya Hotel		
5	G/Jaarsoo		Laga Guri	Bridge width, Curve	Superelevation, Bridge widening
			Dankaka/Wartu		
			Massaalamaa Mikaa'ela		

		measurement should be taken to reduce the crash?	Gara Gudeta		
6	D/Libanos		Waadaa/Sallee Gursoo Massaalamaa Sillaasee Qasim school	Speed, Road surface	Erecting speed limit sign
7	Wachale		Laga Dubar Qoraan Magaalaa Keessa Gumaa/Sallee Laga Alaltuu	Speed,Bridge width, Curve	Erecting speed limit sign, Bridge widening, Improving horizontal alignment
8	Chancho		ERA camp Bacho Abbichuu Derba mazoria Kosobar Chancho river Laga leencaa	Curve, Junction, Grade, Speed	Improving horizontal curve alignment, Erecting speed limit sign, Improving vertical alignment
9	Sululta		10 kilo Ashewa Doro irbata Kajima Mizan Qimbirree Shufunnee	Sight distance, Curve, Grade, speed	Avoiding obstructions, signing horizontal curve radius, Erecting Speed limit sign

Table 4. 26 Questionnaire response of drivers

N.S	Woreda/ town	Questions	Driver's Response		
			Location	Reason	Measurement
1	Warra jaarsoo		Bitoo Milkii Walee Cilaalloo/keellaa Qalloo milkii	Bad pavement surface	Improving pavement surface

2	Kuyyuu	1. Where do the accidents often occur? 2. What will be the reason for the occurrence? 3. What kind of measurement should be taken to reduce the crash?	Misili irasu G/G bridge Laga Qallaa (ganda birrattee) Iskaan iskaanii	Grade,Curve	Improving horizontal alignment,Improving vertical alignment
3	Dagam		Laga Silmi Ayane Gerba bridge Dabala Boka Walatu East cement factory Egdu/Ganchur Jajabdu	Devil,Bridge width	Changing route, Widening bridge
4	Fitche		Torban ashee Kumando Fitche Hospital	Grade	Improving vertical alignment
5	G/Jaarsoo		Laga Guri Dankaka/Wartu Gaara Gudeta	Curve	Guard rails, Improve signing in horizontal curve radius
6	D/Libanos		Sallee Gursoo Qasim school Wakene	Junction,Curve,Bad pavement surface	Improving pavement surface, Improving Signing at junction and horizontal curve radius
7	Wachale		Laga Dubar Qoraan Waadaa Laga Alaltuu	Bridge width, Curve	Bridge widening, Guard rails
8	Chancho		ERA camp Derba mazoria Chancho river Laga leencaa	Grade, Junction, Bad pavement surface	Improving vertical alignment, Improving pavement surface

9	Sululta		10 kilo	Curve, Grade, Sight distance	Avoiding obstruction, Improving horizontal alignment, Improving vertical alignment,
			Doro irbata		
			Kajima		
			Mizan		
			Qimbirree		
			Coca		

Table 4. 27 Questionnaire response of residents

N.S	Woreda/ town	Questions	Response residents		
			Location	Reason	Measurement
1	Warra jaarsoo	1. Where do the accidents often occur? 2. What will be the reason for the occurrence? 3. What kind of measurement should be taken to reduce the crash?	Qalloo milkii	Grade, Rough pavement surface	Improving vertical alignment,Improving pavement surface
			Keellaa		
			Laga hantuutaa		
			Sakkee		
2	Kuyyuu		Misili irasu	Grade,Curve	Improving horizontal alignment,Improving vertical alignment
			Goraa		
			UlaaUmmoo		
			Ganda birrattee		
			Iskaan iskaanii		
3	Dagam		Laga Silmi	Devil,Sight distance,Bridge width	Avoiding obstruction,Improving horizontal alignment,Widening
			Hambiso 01 kebele		
			Ayane Gerba bridge		
			Dabala Boka		
			Jajabdu		
			East cement factory		
			Egdu/Ganchur		
			Warabe		
4	Fitche		Kumando	Grade	Improving vertical alignment
			Fitche Hospital		
			Torban ashee		
5	G/Jaarsoo		Laga Guri	Curve	Guard rails, Improve signing in horizontal
			Dankaka/Wartu		

			Chagal town exit when to Addis		curve radius
6	D/Libanos		Waadaa/Sallee	Junction,Curve, Bad pavement surface	Improving pavement surface, Improving Signing at junction and horizontal curve radius
			Gursoo		
			Massaalamaa Sillaasee		
			Wakene		
7	Wachale		Laga Dubar	Curve	Guard rails
			Qoraan		
			Gumaa		
			Laga Alaltuu		
8	Chancho		Gajoo	Junction, Bad pavement surface	Erecting appropriate sign, Improving pavement surface
			Gorfoo		
			Malima		
			Derba mazoria		
			Chancho river		
			Laga leencaa		
9	Sululta		Prime milk	Curve, Sight distance	Improving horizontal alignment, Avoiding obstruction,
			Ashewa		
			Kajima		
			Mizan		
			Wasarbi mazoria		
			Leather factory		

4.3.4 Mapping of Accident Using GIS

It is known that the traffic crash data recorded by traffic police is not geo referenced to map all the points where all recorded crash is occurred. It was very tiresome to determine even the nearest locations where crash is happened for 3 years' data by cooperating with traffic police. Since it is difficult to geo reference all the reported crash data throughout the study period, few crash data are mapped with the help of Woreda and Town traffic policemen. After determining blackspot locations using Rate Quality Control Method (i.e. Accident rate, Accident frequency, Severity index), Accident Density Method and support of Some stakeholder questionnaire a lot of work is executed with traffic policemen by going to where crashes happened frequently to capture the coordinates of the places in order for mapping. Moreover, most of the time is spent with traffic policemen at office using Google Earth Pro to locate the blackspots. The blackspot locations which are identified using the above mentioned method and the aid of Traffic policemen information is marked on Google Earth Pro and file on Google earth pro is saved in KML format. File saved in KML format is converted in to layer using ArcGIS software by adding open street base map and accident blackspot mapping has been executed finally.

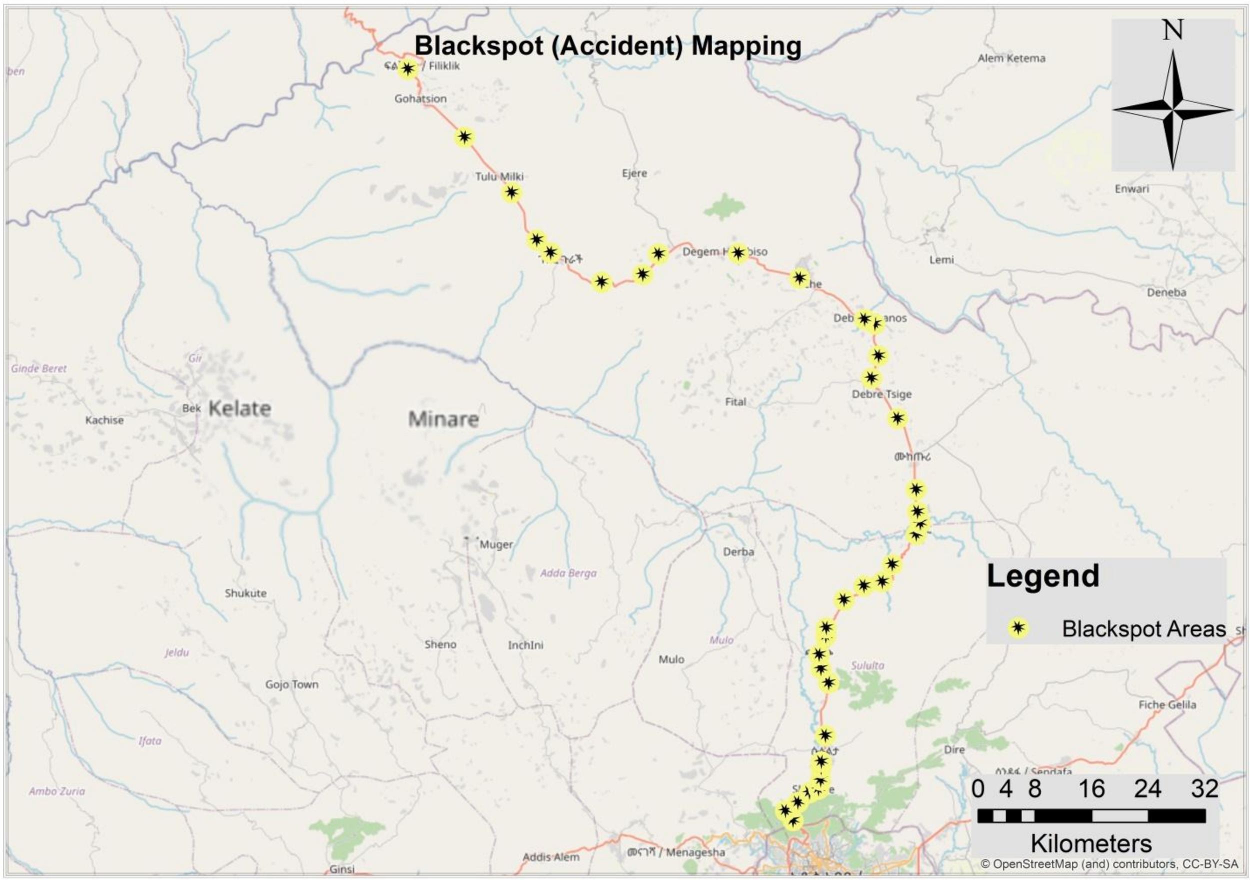


Fig.4. 20 Blackspot (Accident) Mapping Using ArcGIS

4.4 Blackspot Analysis

4.4.1 Geometric Parameters of the Road at Blackspot Locations

Geometric parameters of the road play an essential role in defining the operation of the traffic efficiency of any road way. Key geometric design parameters that influence traffic operations include cross section effects (lane width, number of lanes, shoulder width, median width and type) and alignment effects (horizontal alignment i.e. horizontal curve and super elevation & vertical curves, gradient, climbing lane and vertical clearances).

The existing dimensions of the geometric parameters of the road at the blackspot locations has been measured and compared with ERA Geometric Design Manual (Two-Lane Two way rural roads DC7 Paved) as presented below for each blackspot locations along the study area.

1. 10Kilo (between 3+000 and 4+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 21 10Kilo Blackspot area

Table 4. 28 Observed values Vs ERA standard values of 10kilo blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65+	3.5/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walk way 2.5 m	No proper shoulder
5		Horizontal radius (m)	80	500
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	80 crest
8		Maximum gradient (%)	6/8	-1.37
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	11.7

NB: The value for vertical curve is written by preceding minimum crest vertical curve (k) followed by minimum sag vertical curve. In addition, the value for gradient is written maximum desirable gradient first and followed by maximum absolute gradient.

In the same way bridge width is of two types; one is bridge which is constructed in rural area (7.3m width) and the second is bridge which is found in town section that is provided with additional 3m width of segregated pedestrian lane.

2. Wasarbi mazoria (between 4+000 and 5+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 22 Wasarbi mazoria Blackspot area

Table 4. 29 Observed values Vs ERA standard values of Warbi mazoria blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	88.76
2		Lane width (m)	3.65+	3.48/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walk way 2.5 m	No proper shoulder
5		Horizontal radius (m)	80	500
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	62 crest
8		Maximum gradient (%)	6/8	-0.97
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	12.1

3. Qimbirree (between 7+000 and 8+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 23 Qimbirree Blackspot area

Table 4. 30 Observed values Vs ERA standard values of Qimbirree blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Mountainous	Design speed (km/hr)	50	96.77
		Lane width (m)	3.65	3.6/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walk way 2.5 m	No proper shoulder
5		Horizontal radius (m)	95	2000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	104 crest
8		Maximum gradient (%)	6/8	0.47(below standard)
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	9.7

4. Shufunne (between 9+000 and 10+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 24 Shufune Blackspot area

Table 4. 31 Observed values Vs ERA standard values of Shuffunnee blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Flat	Design speed (km/hr)	50	74.29
2		Lane width (m)	3.65+	3.4/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walkway 2.5 m	No proper shoulder
5		Minimum horizontal radius (m)	780	6000
6		Max.Super elevation (%)	4	4
7		Vertical curve (Crest/sag)	10/7	50 sag
8		Maximum gradient (%)	6/8	0.6
9		Bridge width (m)	7.3+	NA
10		Min.Clear zone from outer road edge (m)	15	8.5

5. Doro irbata (between 10+000 and 11+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 25 Doro Irbata Blackspot area

Table 4. 32 Observed values Vs ERA standard values of Doro Irbata blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	75
		Lane width (m)	3.65+	3.52/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walkway 2.5 m	No proper Shoulder
5		Minimum horizontal radius (m)	515	1000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	99 sag
8		Maximum gradient (%)	6/8	1.62
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	14

6. Ashewa (between 12+000 and 13+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 26 Ashewa Blackspot area

Table 4. 33 Observed values Vs ERA standard values of Ashewa blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65+	3.6/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walkway 2.5m	No proper shoulder
5		Horizontal radius (m)	80	600
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	40 sag
8		Gradient (%)	6/8	4.33
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.5

7. Prime Milk (between 13+000 and 14+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 27 Prime Milk Blackspot area

Table 4. 34 Observed values Vs ERA standard values of Prime Milk blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Flat	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65+	3.61
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walkway 2.5m	No proper shouder
5		Horizontal radius (m)	780	4000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	27 sag
8		Maximum gradient (%)	6/8	0.26(Below standard)
9		Bridge width (m)	7.3+	NA
10		Min.Clear zone from outer road edge (m)	15	15+

8. Kajima (between 14+000 and 15+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 28 Kajima Blackspot area

Table 4. 35 Observed values Vs ERA standard values of Kajima blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	74.01
2		Lane width (m)	3.65+	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walkway 2.5m	No proper shoulder
5		Horizontal radius (m)	515	2000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	34 sag
8		Maximum gradient (%)	6/8	7
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	9.4

9. Leather Factory (between 18+000 and 19+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 29 Leather factory Blackspot area

Table 4. 36 Observed values Vs ERA standard values of Leather Factory blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	74.47
2		Lane width (m)	3.65+	3.3
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walkway 2.5m	No proper shoulder
5		Horizontal radius (m)	515	5000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	89 sag
8		Maximum gradient (%)	6/8	1.59
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

10. Gajo (between 26+000 and 27+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 30 Gajo Blackspot area

Table 4. 37 Observed values Vs ERA standard values of Gajoo blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	74.94
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	No proper shoulder
5		Horizontal radius (m)	410	200
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	83 sag
8		Gradient (%)	5/7	5.62
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

11. Kosoba (between 28+000 and 29+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 31 Kosoba Blackspot area

Table 4. 38 Observed values Vs ERA standard values of Kosoba blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	74.13
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.4
5		Horizontal radius (m)	410	NA
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	20.628
8		Gradient (%)	5/7	-4.08
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.5

12. Derba mazoria (between 30+000 and 31+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 32 Derba mazoria Blackspot area

Table 4. 39 Observed values Vs ERA standard values of Derba Mazoria blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	50	88.76
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walkway 2.5m	3.5m Parking lane & 2.5m walkway
5		Horizontal radius (m)	80	NA
6		Max.Super elevation (%)	NA	NA
7		Vertical curve (crest/sag)	10/7	41.719 Sag
8		Gradient (%)	6/8	9.68
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	10.9

13. Mesalemiya (between 33+000 and 34+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 33 Mesalemiya Blackspot area

Table 4. 40 Observed values Vs ERA standard values of Mesalemiya blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	96.77
2		Lane width (m)	3.65	3.45
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.7
5		Horizontal radius (m)	410	600
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	8 Sag
8		Gradient (%)	5/7	0 (below standard)
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	14.3

14. Chancho river (between 35+000 and 36+000 from the boundary of Addis Ababa and OSZSF)

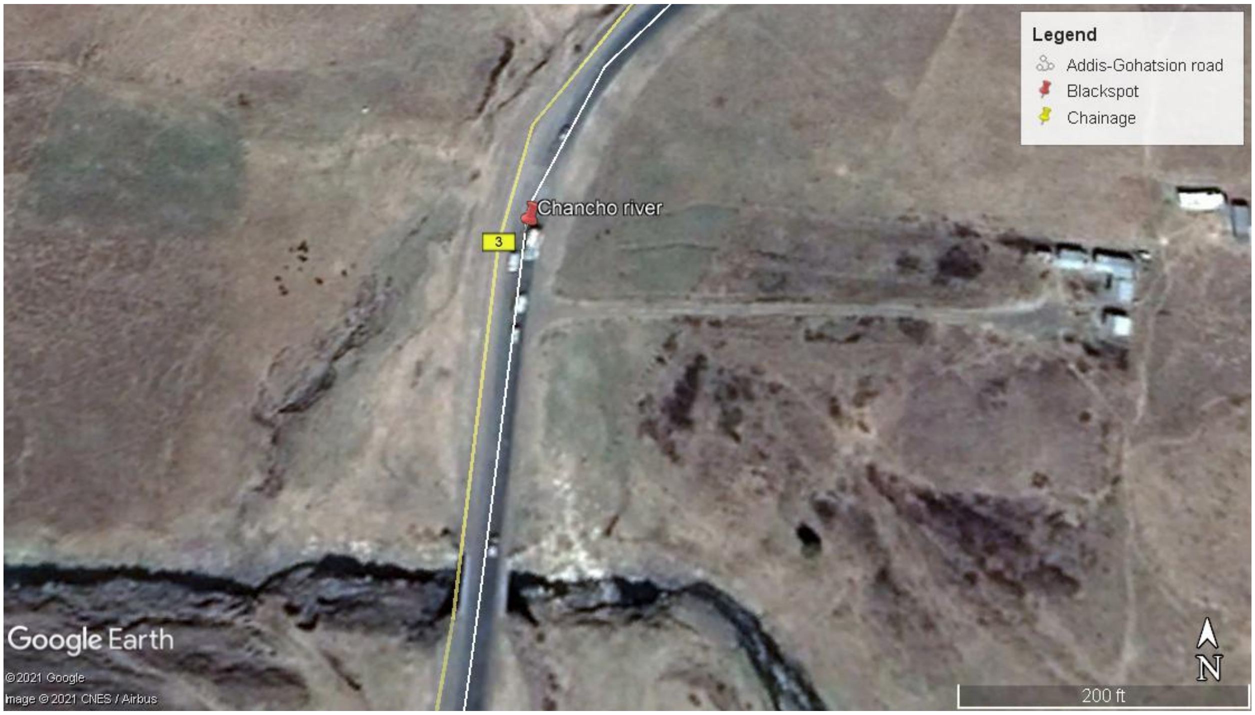


Fig.4. 34 Chancho river Blackspot area

Table 4. 41 Observed values Vs ERA standard values of Chancho river blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	74.29
2		Lane width (m)	3.65	3.62
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.3
5		Horizontal radius (m)	410	620
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	25.74 Sag
8		Gradient (%)	5/7	6.28
9		Bridge width (m)	7.3/10.3	7.3
10		Min.Clear zone from outer road edge (m)	15	15+

15. Laga Leencaa (between 40+000 and 41+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 35 Laga Leencaa Blackspot area

Table 4. 42 Observed values Vs ERA standard values of Laga Leencaa blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	75
2		Lane width (m)	3.65	3.63
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.4
5		Horizontal radius (m)	410	NA
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	25.915 Sag
8		Gradient (%)	5/7	1.64
9		Bridge width (m)	7.3/10.3	7.3
10		Min.Clear zone from outer road edge (m)	15	15+

16. Abbichuu (between 44+000 and 45+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 36 Abbichuu Blackspot area

Table 4. 43 Observed values Vs ERA standard values of Abbichuu blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Rolling	Design speed (km/hr)	100	74.13
2		Lane width (m)	3.65	3.62
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.3
5		Horizontal radius (m)	410	250
6		Max.Super elevation (%)	8	5.5
7		Vertical curve (crest/sag)	100/25	47.499 Sag
8		Gradient (%)	5/7	-0.4 (Below standard)
9		Bridge width (m)	7.3/10.3	7.25
10		Min.Clear zone from outer road edge (m)	15	15+

17. Gorfoo (between 47+000 and 48+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 37 Gorfoo Blackspot area

Table 4. 44 Observed values Vs ERA standard values of Gorfoo blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Mountanious	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	120
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	55/18	18.906 crest
8		Gradient (%)	7/9	4.12
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

18. Bacho (between 51+000 and 52+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 38 Bacho Blackspot area

Table 4. 45 Observed values Vs ERA standard values of Bacho blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Flat	Design speed (km/hr)	120	74.01
2		Lane width (m)	3.65	3.54
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.9
5		Horizontal radius (m)	610	4000
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	185/36	2195.281 Sag
8		Gradient (%)	3/5	2.19
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

19. Laga Roobaa (between 57+000 and 58+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 39 Laga Roobaa Blackspot area

Table 4. 46 Observed values Vs ERA standard values of Laga roobaa blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Flat	Design speed (km/hr)	120	74.47
2		Lane width (m)	3.65	3.6
3		Number of lanes	2	2
4		Shoulder width (m)	3	No proper shoulder
5		Horizontal radius (m)	610	500
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	185/36	116.423 Sag
8		Gradient (%)	3/5	-.45
9		Bridge width (m)	7.3/10.3	7.2
10		Min.Clear zone from outer road edge (m)	15	15+

20. Dubar river (between 59+000 and 60+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 40 Dubar river Blackspot area

Table 4. 47 Observed values Vs ERA standard values of Dubar river blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	74.94
2		Lane width (m)	3.65	3.6
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.3
5		Horizontal radius (m)	410	800
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	108.84 Sag
8		Gradient (%)	5/7	0.93
9		Bridge width (m)	7.3/10.3	7
10		Min.Clear zone from outer road edge (m)	15	15+

21. Koran (between 61+000 and 62+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 41 Koran Blackspot area

Table 4. 48 Observed values Vs ERA standard values of Koran blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1		Design speed (km/hr)	120	74.13
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.6
5		Horizontal radius (m)	610	10000
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	185/36	278.401 Sag
8		Gradient (%)	3/5	0.23(Below standard)
9		Bridge width (m)	7.3/10.3	NA
10	Flat	Min.Clear zone from outer road edge (m)	15	13.9

22. Wada (between 64+000 and 65+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 42 Wada Blackspot area

Table 4. 49 Observed values Vs ERA standard values of Wada blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Flat	Design speed (km/hr)	120	88.76
2		Lane width (m)	3.65	3.58
3		Number of lanes	2	2
4		Shoulder width (m)	3	No proper shoulder
5		Horizontal radius (m)	610	600
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	185/36	73.904 Sag
8		Gradient (%)	3/5	0.88
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.7

23. Sallee (between 75+000 and 76+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 43 Sallee Blackspot area

Table 4. 50 Observed values Vs ERA standard values of Sallee blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	96.77
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.4
5		Horizontal radius (m)	410	460
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	86.064 crest
8		Gradient (%)	5/7	0.2 (below standard)
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

24. Gurso (between 82+000 and 83+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 44 Gurso Blackspot area

Table 4. 51 Observed values Vs ERA standard values of Gurso blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Mountanious	Design speed (km/hr)	50	74.29
2		Lane width (m)	3.65	3.57
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	110
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	55/18	11.939 crest
8		Gradient (%)	7/9	-7.29
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	14.8

25. Qasim school (between 85+000 and 86+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 45 Qasim School Blackspot area

Table 4. 52 Observed values Vs ERA standard values of Qasim school blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	75
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.98
5		Horizontal radius (m)	410	150
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	53.786 Sag
8		Gradient (%)	5/7	1.76
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	14.9

26. Wartu/Chagal (between 90+000 and 91+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 46 Wartu/Chagal Blackspot area

Table 4. 53 Observed values Vs ERA standard values of Wartu/Chagal blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed value/Provided
1	Mountanious	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	150
6		Max.Super elevation (%)	8	4
7		Vertical curve (crest/sag)	55/18	34.311 Sag
8		Gradient (%)	7/9	4.75
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.7

27. Laga guurii (between 93+000 and 94+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 47 Laga Guurii Blackspot area

Table 4. 54 Observed values Vs ERA standard values of Laga guurii blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Mountanious	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	800
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	55/18	85.361
8		Gradient (%)	7/9	5.2
9		Bridge width (m)	7.3	7.3
10		Min.Clear zone from outer road edge (m)	15	15+

28. Torban Ashee (between 105+000 and 106+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 48 Torban Ashe Blackspot area

Table 4. 55 Observed values Vs ERA standard values of Torban Ashee blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	50	74.01
2		Lane width (m)	3.65+	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5m & Walk way 2.5m	No parking lane& No walkway
5		Horizontal radius (m)	80	NA
6		Max.Super elevation (%)	8	NA
7		Vertical curve (crest/sag)	10/7	301.826
8		Gradient (%)	6/8	9.2
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.8

29. Laga Silmii (between 115+000 and 116+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 49 Laga Silmii Blackspot area

Table 4. 56 Observed values Vs ERA standard values of Laga Silmii blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Mountanious	Design speed (km/hr)	50	74.47
2		Lane width (m)	3.65	3.45
		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	NA
6		Max.Super elevation (%)	8	NA
7		Vertical curve (crest/sag)	55/18	39.286 crest
8		Gradient (%)	7/9	-4.96
9		Bridge width (m)	7.3	7.2
10		Min.Clear zone from outer road edge (m)	15	15+

30. Eegduu (between 127+000 and 128+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 50 Eegduu Blackspot area

Table 4. 57 Observed values Vs ERA standard values of Eegduu blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Mountainous	Design speed (km/hr)	50	74.94
2		Lane width (m)	3.65	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	280	600
6		Max.Super elevation (%)	8	4.5
7		Vertical curve (crest/sag)	55/18	21.944 Sag
8		Gradient (%)	7/9	-3.03
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	15+

31. Hambiso 01kebele (between 132+000 and 133+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 51 Hambiso 01 Kebele Blackspot area

Table 4. 58 Observed values Vs ERA standard values of Hambiso 01 kebele blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Flat	Design speed (km/hr)	50	74.13
2		Lane width (m)	3.65+	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	Parking 3.5m & Walkway 2.5m	No parking & No walkway
5		Horizontal radius (m)	80	490
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	10/7	119.192 Crest
8		Gradient (%)	6/8	0.06
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.9

32. Laga kala (between 138+000 and 139+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 52 Laga Kala Blackspot area

Table 4. 59 Observed values Vs ERA standard values of Laga kala blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	88.76
2		Lane width (m)	3.65	3.48
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.6
5		Horizontal radius (m)	410	550
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	100/25	60.025 Sag
8		Gradient (%)	5/7	0.07
9		Bridge width (m)	7.3/10.3	7.2
10		Min.Clear zone from outer road edge (m)	15	14.3

33. Garba Guracha bridge (between 148+000 and 149+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 53 Garba Guracha Bridge Blackspot area

Table 4. 60 Observed values Vs ERA standard values of Garba Guracha bridge blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	50	96.77
2		Lane width (m)	3.65+	3.62
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walk way 2.5 m	No proper parking lane & walkway
5		Horizontal radius (m)	80	NA
6		Max.Super elevation (%)	8	NA
7		Vertical curve (crest/sag)	10/7	157.266
8		Gradient (%)	6/8	-2.51
9		Bridge width (m)	7.3/10.3	7.3
10		Min.Clear zone from outer road edge (m)	15	14.6

34. Misilii Iraasuu (between 150+000 and 151+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 54 Misilii Iraasuu Blackspot area

Table 4. 61 Observed values Vs ERA standard values of Misilii Iraasuu blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	74.29
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.3
5		Horizontal radius (m)	410	NA
6		Max.Super elevation (%)	8	NA
7		Vertical curve (crest/sag)	100/25	136.394
8		Gradient (%)	5/7	6.65
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	13.7

35. Bitoo Milkii (between 158+000 and 159+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 55 Bitoo Milkii Blackspot area

Table 4. 62 Observed values Vs ERA standard values of Bitoo Milkii blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Rolling	Design speed (km/hr)	100	75
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	3	1.9
5		Horizontal radius (m)	410	NA
6		Max.Super elevation (%)	8	NA
7		Vertical curve (crest/sag)	100/25	205.681
8		Gradient (%)	5/7	-0.11(Below standard)
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	14.9

36. Walee Chilalo (between 168+000 and 169+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 56 Walee Chilalo Blackspot area

Table 4. 63 Observed values Vs ERA standard values of Walee Chilalo blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Flat	Design speed (km/hr)	120	74.13
2		Lane width (m)	3.65	3.5
3		Number of lanes	2	2
4		Shoulder width (m)	3	2.6
5		Horizontal radius (m)	610	800
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	185/36	16.303 Sag
8		Gradient (%)	3/5	0.31(below standard)
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	10.5

37. Abay gorge (between 185+000 and 186+000 from the boundary of Addis Ababa and OSZSF)

Fig.4. 57 Abay Gorge Blackspot area

Table 4. 64 Observed values Vs ERA standard values of Abay gorge blackspot geometric parameters

N.S	Terrain type	Roadway element	ERA Standard value	Observed/ Provided value
1	Escarpment	Design speed (km/hr)	70	74.13
2		Lane width (m)	3.65	3.65
3		Number of lanes	2	2
4		Shoulder width (m)	0.5-2.5	No proper shoulder
5		Horizontal radius (m)	175	35
6		Max.Super elevation (%)	8	8
7		Vertical curve (crest/sag)	30/12	147.135
8		Gradient (%)	7/9	-4.14
9		Bridge width (m)	7.3/10.3	NA
10		Min.Clear zone from outer road edge (m)	15	5

Table 4. 65 Summary of the observed/Provided road element value for the 37 blackspots

Blackspot locations	Lane width(m)	Number of lanes	Shoulder width(m)	Horizontal radius (m)	Max.super elevation (%)	Vertical curve (m)	Gradient (%)	Bridge width (m)	85^{th} Percentile speed (km/hr)	Min.clear zone (m)	Number of Accidents
BS1	3.5/BE	2	NPS	500	4	80 C	-1.37	NA	74.13	11.7	14
BS2	3.4/BE	2	NPS	500	4	62C	-0.19	NA	88.76	12.1	14
BS3	3.6/BE	2	NPS	2000	4	104C	0.17BS	NA	96.77	9.7	19
BS4	3.4/BE	2	NPS	600	4	50S	0.6	NA	74.29	8.5	17
BS5	3.52/BE	2	NPS	1000	4	99S	1.62	NA	75	14	16
BS6	3.6/BE	2	NPS	600	4	40S	4.33	NA	74.13	13.5	15
BS7	3.61	2	NPS	4000	4	28S	0.26BS	NA	74.13	15+	16
BS8	3.65	2	NPS	2000	4	34S	7	NA	74.01	9.4	14
BS9	3.3	2	NPS	5000	4	89S	1.59	NA	74.47	15+	16
BS10	3.65	2	NPS	200	8	83S	5.62	NA	74.94	15+	21
BS11	3.65	2	1.4	NA	8	20.628	-4.08	NA	74.13	13.5	31
BS12	3.65	2	3.5PL &2.5 WW	NA	NA	41.72S	9.68	NA	88.76	10.9	23
BS13	3.45	2	1.7	600	8	8S	0BS	NA	96.77	14.3	26
BS14	3.62	2	1.3	620	8	25.74S	6.28	7.3	74.29	15+	29
BS15	3.63	2	2.4	NA	8	25.92S	1.64	7.3	75	15+	31
BS16	3.62	2	2.3	250	5.5	47.5S	-0.4BS	7.2 5	74.13	15+	26
BS17	3.5	2	NPS	120	8	18.9C	4.12	NA	74.13	15+	30
BS18	3.54	2	1.9	4000	8	2195.2 8S	2.19	NA	74.01	15+	28
BS19	3.6	2	NPS		8	116.42 3S	-.45	7.2	74.47	15+	14
BS20	3.6	2	2.3	800	8	108.8S	0.93	7	74.94	15+	14
BS21	3.65	2	2.6	1000 0	8	278.4S	0.23	NA	74.13	13.9	16
BS22	3.58	2	NPS	600	8	73.9S	0.88	NA	88.76	13.7	15
BS23	3.65	2	2.4	460	8	86.1C	0.2Bs	NA	96.77	15+	4
BS24	3.57	2	NPS	110	8	11.9C	-7.29	NA	74.29	14.8	4
BS25	3.65	2	1.98	150	8	53.8S	1.76	NA	75	14.9	5
BS26	3.65	2	NPS	150	4	34.3S	4.75	NA	74.13	13.7	9
BS27	3.5	2	NPS	800	8	85.36	5.2	7.3	74.13	15+	18
BS28	3.5	2	NPL &NW W	NA	NA	301.8	9.2	NA	74.01	13.8	10
BS29	3.45	2	NPS	NA	NA	39.3C	-4.96	7.2	74.47	15+	13

BS30	3.5	2	NPS	600	4.5	21.9S	-3.03	NA	74.94	15+	17
BS31	3.5	2	NPL &NWW	490	8	119.192C	0.06	NA	74.13	13.9	12
BS32	3.48	2	1.6	550	8	60.03S	0.07	7.2	88.76	14.3	5
BS33	3.62	2	NPL &NWW	NA	NA	157.3	-2.51	7.3	96.77	14.6	5
BS34	3.65	2	2.3	NA	NA	136.4	6.65	NA	74.29	13.7	4
BS35	3.65	2	1.9	NA	NA	205.7	-0.11	NA	75	14.9	5
BS36	3.5	2	2.6	800	8	16.3S	0.31	NA	74.13	10.5	4
BS37	3.65	2	NPS	35	8	147.14	-4.14	NA	74.13	5	4

Where BE-Broken edge, NPS-No proper shoulder,C-Crest,Bs-Below Standard,S-Sag,NPL-No Parking Lane, NWW-No Walk Way, NA-Not Available/Not Applicable

4.4.2 Spot speed analysis at each identified blackspot locations

The vehicle speeds were computed by using the predetermined study length between two points and the elapsed time it took the vehicle to move through the course (as recorded on the stopwatch data form).

The vehicle speed is computed as V=L/T, Where V= Spot speed (km/hr), L=Length between the two points (km) & T=Time elapsed (hr).

Once each vehicle's speed is determined, speed percentiles are computed to evaluate/recommend the posted speed limit. The two speed percentiles most important to understand are the 50th and the 85th percentiles. The 50th percentile is the 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. The 50th percentile of speed represents the average speed of the traffic stream while the 85th percentile is the speed at which 85% of the observed vehicles are traveling at or below. The 85thpercentile of speed is normally assumed to be the highest safe speed for a roadway section; i.e. used for evaluating and/recommending posted speed limit based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe. Speed percentile is determined using frequency distribution table. In frequency distribution table, the frequency of vehicle is the number of vehicles recorded at each specified speed, while cumulative frequency is the sum of vehicles frequency starting from the first row to the last. Then percentage of cumulative frequency is calculated accordingly. The 50th and 85th percentiles spot speed is determined from cumulative percent column. The two percentiles (50th and 85th) are determined by interpolation as follows.

SD= $\frac{PD-Pmin}{Pmax-Pmin}\ ((Smax-Smin)+Smin)$

SD-Desired speed, Smax-Maximum speed, Smin-Minimum speed, PD-Desired percentile, Pmax-Maximum cumulative percentile, and Pmin-Minimum cumulative percentile.

I) Spot speed analysis at Qimbirree Blackspot (Sululta)

Table 4. 66 Spot speed Analysis at Qimbirree blackspot

Speed (km/hr)	Frequency	Cummulative frequency	Cummulative percent	Speed Percentile	
28.23	1	1	1		
36.38	1	2	2		
36.79	1	3	3		
36.95	2	5	5		
37.50	2	7	7		
38.76	1	8	8		
40.29	1	9	9		
44.33	1	10	10		
47.67	1	11	11		
47.97	1	12	12		
50.73	2	14	14		
52.51	1	15	15		
52.69	1	16	16		
53.00	2	18	18		
54.02	1	19	19		
54.55	2	21	21		
55.35	1	22	22		
55.81	1	23	23		
56.25	3	26	26		
57.18	2	28	28		
57.77	1	29	29		
57.92	1	30	30		
59.21	1	31	31		
59.37	2	33	33		
60.57	2	35	35		
60.89	1	36	36		
61.22	1	37	37		
61.56	2	39	39		
61.98	1	40	40		
62.33	1	41	41		
62.50	1	42	42		

62.67	2	44	44		
63.29	1	45	45		
63.56	1	46	46	63.93	50th
64.29	8	54	54		
64.75	2	56	56		
65.03	1	57	57		
65.41	1	58	58		
65.60	1	59	59		
65.89	1	60	60		
66.67	1	61	61		
67.06	1	62	62		
67.57	1	63	63		
68.60	1	64	64		
68.70	3	67	67		
69.02	2	69	69		
69.55	1	70	70		
69.88	1	71	71		
70.20	1	72	72		
70.53	2	74	74		
71.77	2	76	76		
72.12	2	78	78		
73.41	2	80	80	74.13	85th
75.00	11	91	91		
76.01	2	93	93		
77.99	1	94	94		
79.51	2	96	96		
84.43	2	98	98		
90.00	1	99	99		
112.50	1	100	100		

Sample Calculation:

SD= $\frac{PD-Pmin}{Pmax-Pmin}$ $((Smax - Smin) + Smin)$

S50th= ((50-46)/ (54-46)) *((64.29-63.56) +63.56) = 63.93 km/hr.

S85th = ((85-80)/ (91-80)) *((75-73.41) +73.41) = 73.13 km/hr.

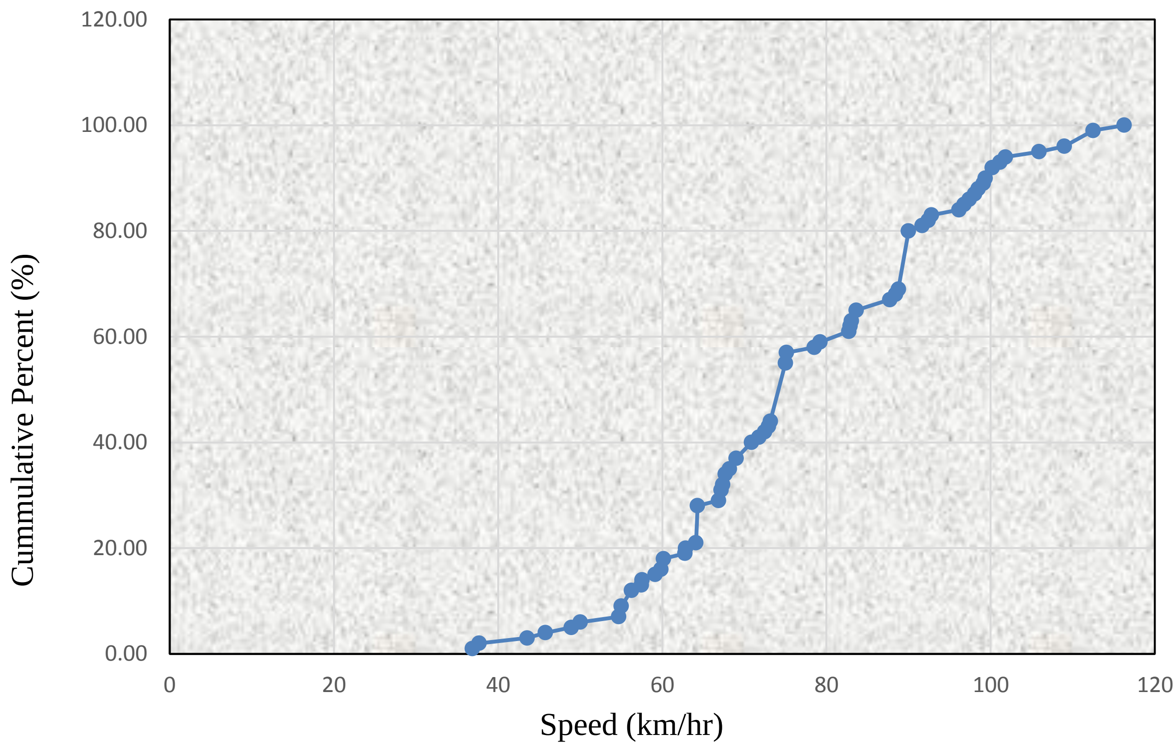


Fig.4. 58 Spot Speed Vs Cumulative Percent at Qimbirree black spot (BS3)

Spot speed analysis for all 37 blackspot locations are computed in same procedure.

Table 4. 67 Summary of Speed Percentile Along the whole length of road at each black spots

Black Spots Number	50th Percentile Speed	85th Percentile Speed	Black Spots Number	50th Percentile Speed	85th Percentile Speed
BS1	63.96	74.13	BS20	63.29	74.94
BS2	74.38	88.76	BS21	63.96	74.13
BS3	74.17	96.77	BS22	74.38	88.76
BS4	63.66	74.29	BS23	74.17	96.77
BS5	63.98	75	BS24	63.66	74.29
BS6	64.02	74.13	BS25	63.98	75
BS7	63.83	74.13	BS26	64.02	74.13
BS8	63.63	74.01	BS27	63.83	74.13

BS9	63.66	74.47	BS28	63.63	74.01
BS10	63.29	74.94	BS29	63.66	74.47
BS11	63.96	74.13	BS30	63.29	74.94
BS12	74.38	88.76	BS31	63.96	74.13
BS13	74.17	96.77	BS32	74.38	88.76
BS14	63.66	74.29	BS33	74.17	96.77
BS15	63.98	75	BS34	63.66	74.29
BS16	64.02	74.13	BS35	63.98	75
BS17	63.83	74.13	BS36	64.02	74.13
BS18	63.63	74.01	BS37	63.83	74.13
BS19	63.66	74.47			

4.4.3 Relationship of geometric parameters of blackspot locations with traffic accident

Even if there is no universally accepted definition of blackspot it is known that location with highly concentrated traffic accident is considered as blackspot. Highly concentrated record of traffic accident may happen due to several reasons like road, vehicles and road users. The concern area of this thesis is related to geometric parameters of road in causing traffic accident. The relationship between geometric parameters of road with numbers/frequency of traffic accidents at blackspot can be determined using different mechanisms like regression.

4.4.3.1 Regression Analysis Method

Regression analysis method describes the relationship between a set of independent variables and the dependent variable. It produces an equation where the coefficients represent the relationship between each independent variable. There are different types of regression depending on the nature of explanatory/independent variable and dependent variable. In this thesis case it is better to use multiple regression analysis method since the dependent variable is continuous. In multiple regression analysis method independent variable can be either continuous or dichotomous (ordinal /and nominal), while dependent variable should be continuous.

i) Assumptions in Multiple Regression Analysis

When you choose to analyze your data using multiple regression analysis method, the data to be analyzed should pass some assumptions to determine valid result. These are: -

I. The dependent variable should be measured on continuous scale
II. There should be two or more independent variables/predictor.
III. There should be independence of residuals/Autocorrelation (can be checked using durbin-watson statistics)

IV. There needs to be linear relationship between dependent variables and each of independent variables and between dependent variable and the independent variables collectively. (can be checked by creating scatterplots)

V. Your data needs to show homoscedasticity

VI. Your data must not show multicollinearity. Highly correlated independent variables leads to the problem with understanding which independent variable contributes to the variance explained in the dependent variable. (can be checked using collinearity diagnostics)

VII. There should be no highly influential points/outliers. (can be checked using cook's distance)

VIII. Error should be approximately normally distributed.

ii) Choice of Explanatory Variables

Number of lane is excluded from the short list of explanatory variables due to its constant nature throughout the given data. In addition, for further elimination of non-prevalent explanatory variables a correlation analysis was made using SPSS software package. As a result, the variable which was found to be highly correlated with other explanatory variable was removed from the study. On the other hand, independent explanatory variables that have less correlation with other independent variables were extracted and taken for further analyses.

As per the above stated explanation, the following presumed explanatory variables are selected for conducting the proposed research.

Table 4. 68 Explanatory Variables to be analyzed

No	Variable label	Description of the Variables	Variable types
1	LW	Lane Width (m)	Continuous (m)
2	ShW	Shoulder Width (m)	Categorical: 0-Insufficient shoulder width, 1-Sufficient shoulder width
3	H.Rad	Horizontal Radius (m)	Categorical:0-Insufficient horizontal Radius,1-Sufficient horizontal radius
4	E	Supper elevation (%)	Categorical: 0-Insufficient supper elevation, 1-Sufficient supper elevation
5	VC	Vertical Curve (m)	Categorical: 0-Insufficient vertical curve, 1-Sufficient vertical curve
6	G	Gradient (%)	Categorical: 0- Insufficient gradient, 1-Sufficient gradient
7	85^{th}PS	85^{th} Percentile Speed (km/hr)	Categorical: 0-Beyond limit, 1-within limit
8	MCZ	Minimum Clear Zone (m)	Continuous (m)

Variables like shoulder width, horizontal radius, supper elevation, vertical curve, gradient and 85^{th} percentile speed which seems to be continuous were made categorical in order for simplifying the complexity of mixed value of the variables for rural and urban sections both. The same value for one type of variable may have different interpretation for rural area section and urban section, since the standards for rural and urban sections are different. So, it was better to categorize the variables into categories to describe their respective values in correct way.

Table 4. 69 Contingency table of Explanatory Variables

Blackspot locations	Lane width(m)	Shoulder width(m)	Horizontal radius (m)	Max.super elevation (%)	Vertical curve (m)	Gradient (%)	85^{th} Percentile speed (km/hr)	Min.clear zone (m)	Number of Accidents
BS1	3.5/BE	NPS	500	4	80 C	-1.37	74.13	11.7	14
BS2	3.4/BE	NPS	500	4	62C	-0.19	88.76	12.1	14
BS3	3.6/BE	NPS	2000	4	104C	0.17Bs	96.77	9.7	19
BS4	3.4/BE	NPS	600	4	50S	0.6	74.29	8.5	17
BS5	3.52/BE	NPS	1000	4	99S	1.62	75	14	16
BS6	3.6/BE	NPS	600	4	40S	4.33	74.13	13.5	15
BS7	3.61	NPS	4000	4	28S	0.26Bs	74.13	15+	16
BS8	3.65	NPS	2000	4	34S	7	74.01	9.4	14
BS9	3.3	NPS	5000	4	89S	1.59	74.47	15+	16
BS10	3.65	NPS	200	8	83S	5.62	74.94	15+	21
BS11	3.65	1.4	NA	8	20.628	-4.08	74.13	13.5	31
BS12	3.65	3.5PL &2.5 WW	NA	NA	41.72S	9.68	88.76	10.9	23
BS13	3.45	1.7	600	8	8S	0Bs	96.77	14.3	26
BS14	3.62	1.3	620	8	25.74S	6.28	74.29	15+	29
BS15	3.63	2.4	200	8	25.92S	1.64	75	15+	31
BS16	3.62	2.3	250	5.5	47.5S	-0.4Bs	74.13	15+	26
BS17	3.5	NPS	120	8	18.9C	4.12	74.13	15+	30
BS18	3.54	1.9	4000	8	2195.2 8S	2.19	74.01	15+	28
BS19	3.6	NPS		8	116.42 3S	-.45	74.47	15+	14
BS20	3.6	2.3	800	8	108.8S	0.93	74.94	15+	14
BS21	3.65	2.6	1000 0	8	278.4S	0.23	74.13	13.9	16
BS22	3.58	NPS	600	8	73.9S	0.88	88.76	13.7	15
BS23	3.65	2.4	460	8	86.1C	0.2Bs	96.77	15+	4
BS24	3.57	NPS	110	8	11.9C	-7.29	74.29	14.8	4
BS25	3.65	1.98	150	8	53.8S	1.76	75	14.9	5
BS26	3.65	NPS	150	4	34.3S	4.75	74.13	13.7	9
BS27	3.5	NPS	800	8	85.36	5.2	74.13	15+	18

BS28	3.5	NPL &NWW	NA	NA	301.8	9.2	74.01	13.8	10
BS29	3.45	NPS	NA	NA	39.3C	-4.96	74.47	15+	13
BS30	3.5	NPS	600	4.5	21.9S	-3.03	74.94	15+	17
BS31	3.5	NPL &NWW	490	8	119.192C	0.06	74.13	13.9	12
BS32	3.48	1.6	550	8	60.03S	0.07	88.76	14.3	5
BS33	3.62	NPL &NWW	NA	NA	157.3	-2.51	96.77	14.6	5
BS34	3.65	2.3	NA	NA	136.4	6.65	74.29	13.7	4
BS35	3.65	1.9	NA	NA	205.7	-0.11	75	14.9	5
BS36	3.5	2.6	800	8	16.3S	0.31	74.13	10.5	4
BS37	3.65	NPS	35	8	147.14	-4.14	74.13	5	4

Where BE-Broken edge, NPS-No proper shoulder, C-Crest, Bs-Below Standard, S-Sag, NPL-No Parking Lane, NWW-No Walk Way,NA-Not Applicable

Table 4. 70 Coded road elements/geometric parameters for selected explanatory variables

Blackspot locations	Lane width(m)	Shoulder width(m)	Horizontal radius (m)	Max.super elevation (%)	Vertical curve (m)	Gradient (%)	85th Percentile speed (km/hr)	Min.clear zone (m)	Number of Accidents
BS1	3.5	0	1	1	1	1	0	11.7	14
BS2	3.4	0	1	1	1	1	0	12.1	14
BS3	3.6	0	1	1	1	0	0	9.7	19
BS4	3.4	0	0	1	1	1	0	8.5	17
BS5	3.52	0	1	1	1	1	0	14	16
BS6	3.6	0	1	1	1	1	0	13.5	15
BS7	3.61	0	1	1	1	0	0	15+	16
BS8	3.65	0	1	1	1	1	0	9.4	14
BS9	3.3	0	1	1	1	1	0	15+	16
BS10	3.65	0	0	1	1	1	1	15+	21
BS11	3.65	0	-	1	0	1	1	13.5	31
BS12	3.65	1	-	-	1	0	0	10.9	23
BS13	3.45	0	1	1	0	0	1	14.3	26
BS14	3.62	0	1	1	1	1	1	15+	29

BS15	3.63	0	-	1	1	1	1	15+	31
BS16	3.62	0	0	0	1	0	1	15+	26
BS17	3.5	0	0	1	0	1	0	15+	30
BS18	3.54	0	1	1	1	1	1	15+	28
BS19	3.6	0	0	1	1	1	1	15+	14
BS20	3.6	0	1	1	1	1	1	15+	14
BS21	3.65	0	1	1	1	0	1	13.9	16
BS22	3.58	0	0	1	1	1	1	13.7	15
BS23	3.65	0	1	1	0	0	1	15+	4
BS24	3.57	0	0	1	0	1	0	14.8	4
BS25	3.65	0	0	1	1	1	1	14.9	5
BS26	3.65	0	0	0	1	1	0	13.7	9
BS27	3.5	0	1	1	1	1	0	15+	18
BS28	3.5	0	-	-	1	0	0	13.8	10
BS29	3.45	0	-	-	0	1	0	15+	13
BS30	3.5	0	1	0	1	1	0	15+	17
BS31	3.5	0	1	1	1	1	0	13.9	12
BS32	3.48	0	1	1	0	1	1	14.3	5
BS33	3.62	0	-	-	1	1	0	14.6	5
BS34	3.65	0	-	-	1	1	1	13.7	4
BS35	3.65	0	-	-	1	0	1	14.9	5
BS36	3.5	0	1	1	0	0	1	10.5	4
BS37	3.65	0	0	1	1	1	0	5	4

After coding geometric parameters for the Explanatory variables the data is encoded to SPSS software for further analysis.

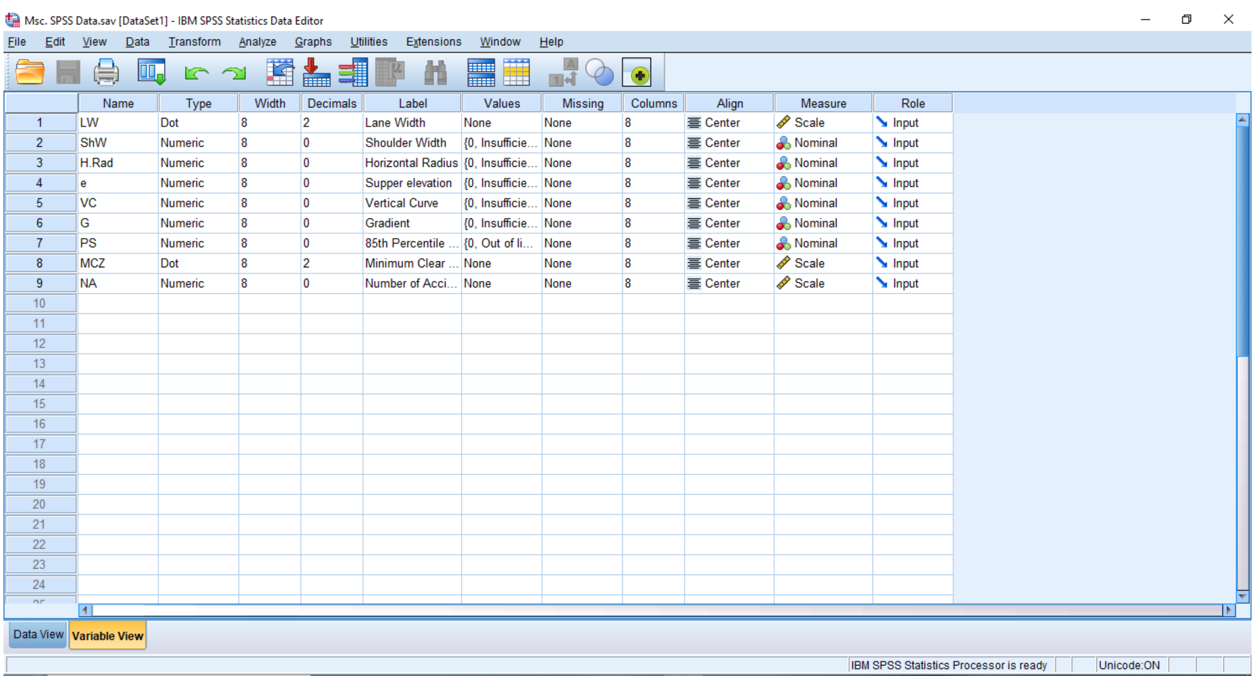


Fig.4. 59 Variable View for data Encoding

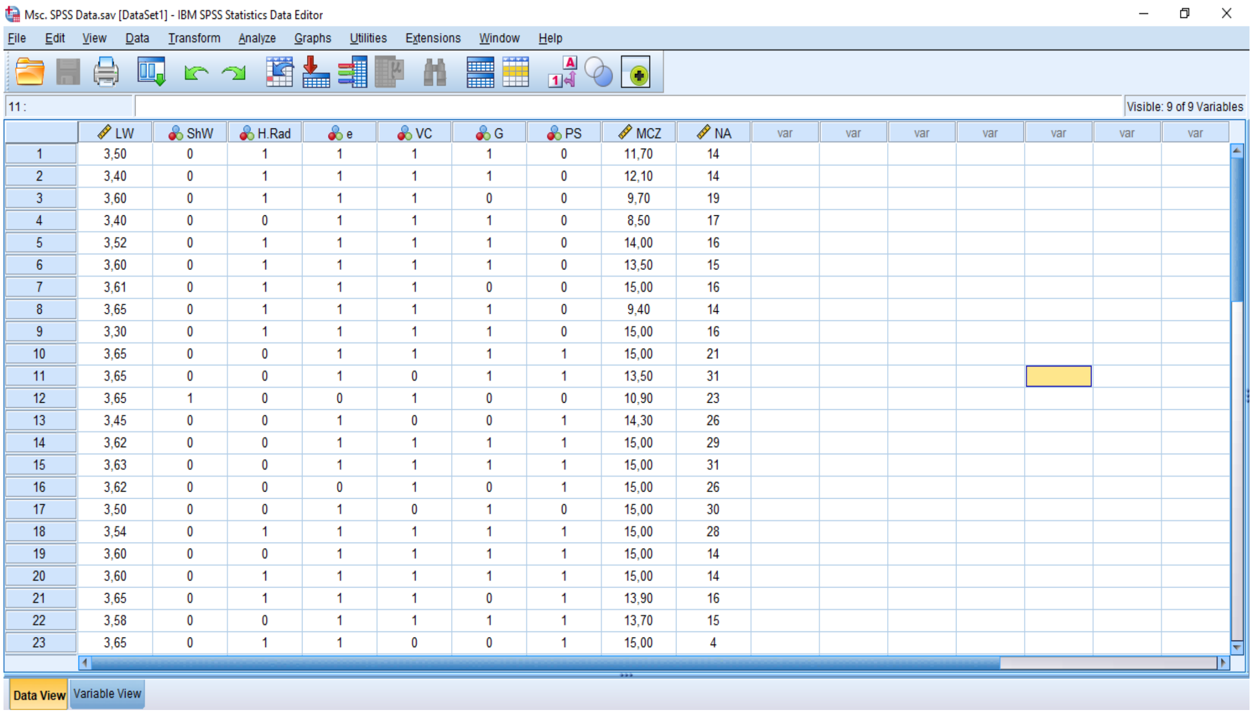
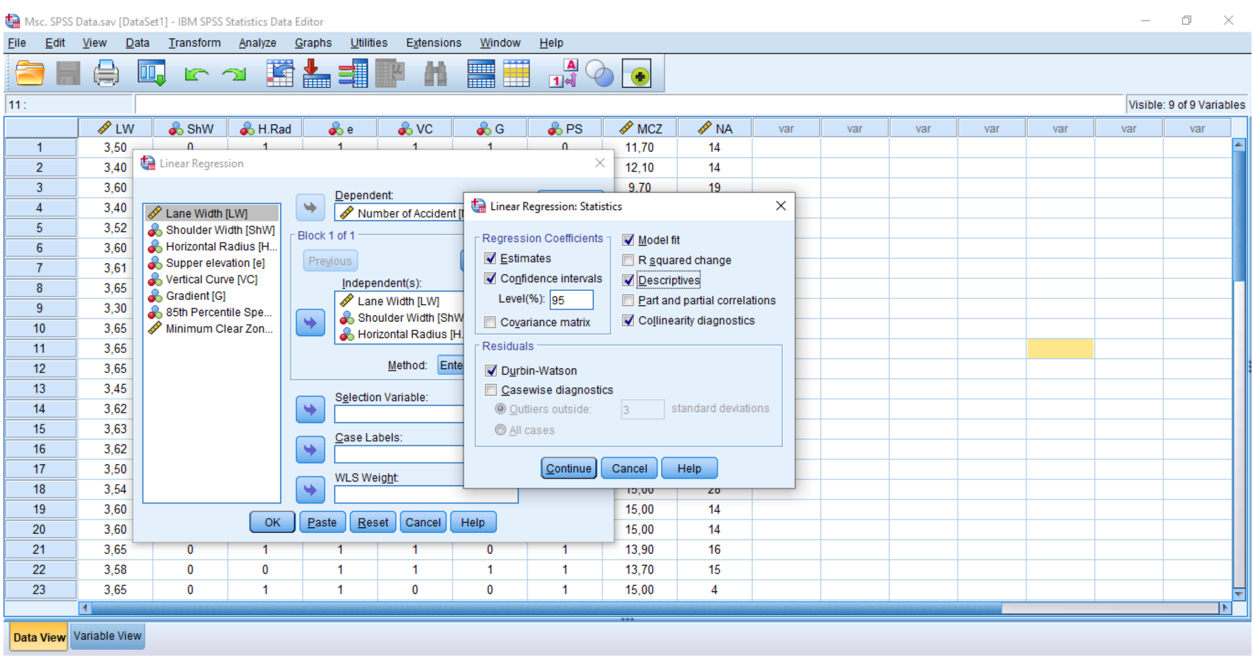


Fig.4. 60 Encoding coded data into SPSS Software (Data view)



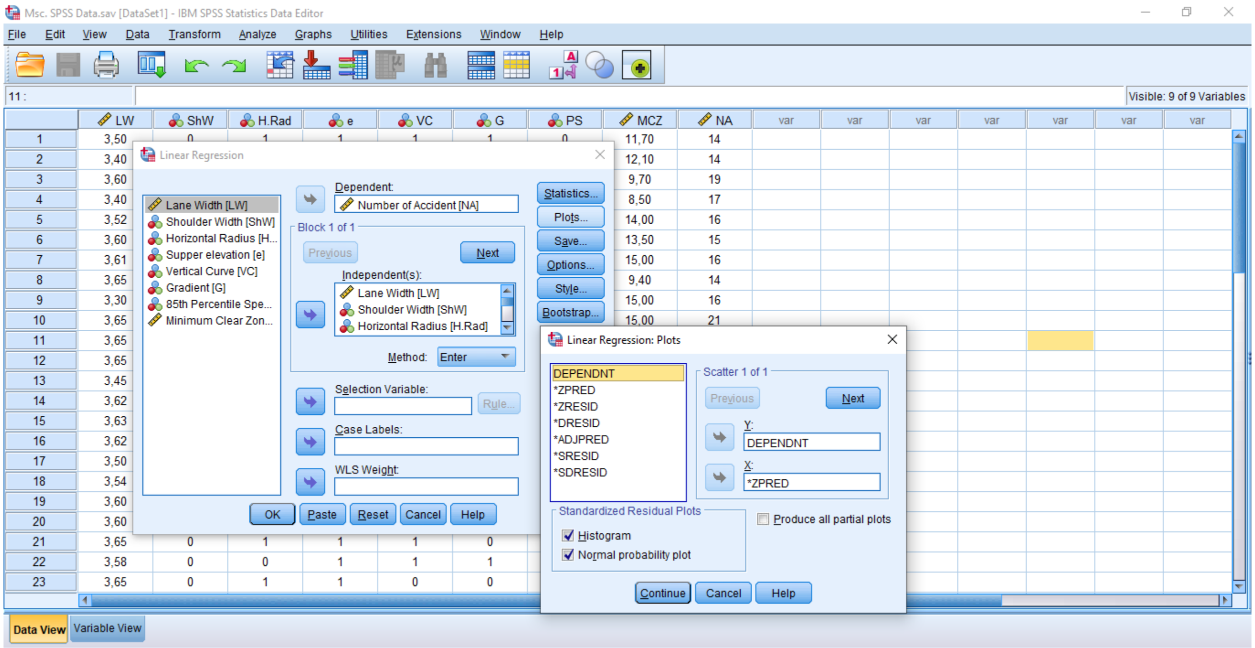


Fig.4. 61 Performing the Statistical analysis with SPSS

iii) SPSS Output

Table 4. 71 Correlation Coefficient

		Number of Accident	Lane Width	Shoulder Width	Horizontal Radius	Supper elevation	Vertical Curve	Gradient	85th Percentile Speed	Minimum Clear Zone
Pearson Correlation	Number of Accident	1.000	-0.055	0.155	-0.112	0.191	0.039	0.025	0.123	0.187
	Lane Width	-0.055	1.000	0.163	-0.291	-0.157	0.190	-0.170	0.364	-0.016
	Shoulder Width	0.155	0.163	1.000	-0.154	-0.294	0.088	-0.274	-0.154	-0.191
	Horizontal Radius	-0.112	-0.291	-0.154	1.000	0.396	0.089	-0.050	-0.197	-0.034
	Supper elevation	0.191	-0.157	-0.294	0.396	1.000	-0.145	0.222	0.143	-0.143
	Vertical Curve	0.039	0.190	0.088	0.089	-0.145	1.000	0.124	-0.174	-0.129
	Gradient	0.025	-0.170	-0.274	-0.050	0.222	0.124	1.000	-0.172	0.052
	85th Percentile Speed	0.123	0.364	-0.154	-0.197	0.143	-0.174	-0.172	1.000	0.342
	Minimum Clear Zone	0.187	-0.016	-0.191	-0.034	-0.143	-0.129	0.052	0.342	1.000
Sig. (1-tailed)	Number of Accident		0.373	0.179	0.255	0.129	0.409	0.441	0.234	0.133
	Lane Width	0.373		0.167	0.040	0.177	0.130	0.157	0.013	0.462
	Shoulder Width	0.179	0.167		0.182	0.039	0.303	0.050	0.182	0.129
	Horizontal Radius	0.255	0.040	0.182		0.008	0.300	0.386	0.121	0.421
	Supper elevation	0.129	0.177	0.039	0.008		0.196	0.093	0.198	0.199
	Vertical Curve	0.409	0.130	0.303	0.300	0.196		0.233	0.151	0.224
	Gradient	0.441	0.157	0.050	0.386	0.093	0.233		0.155	0.379
	85th Percentile Speed	0.234	0.013	0.182	0.121	0.198	0.151	0.155		0.019
	Minimum Clear Zone	0.133	0.462	0.129	0.421	0.199	0.224	0.379	0.019	
N	Number of Accident	37	37	37	37	37	37	37	37	37
	Lane Width	37	37	37	37	37	37	37	37	37
	Shoulder Width	37	37	37	37	37	37	37	37	37
	Horizontal Radius	37	37	37	37	37	37	37	37	37
	Supper elevation	37	37	37	37	37	37	37	37	37
	Vertical Curve	37	37	37	37	37	37	37	37	37
	Gradient	37	37	37	37	37	37	37	37	37
	85th Percentile Speed	37	37	37	37	37	37	37	37	37
	Minimum Clear Zone	37	37	37	37	37	37	37	37	37

In statistics correlation coefficients are the measure of strength and direction between two variables. The value ranges between -1 to +1. The (–ve) sign indicates inverse relationship between variables i.e.as the value of one variable increases, the value of the other variable decreases. On the other hand, (+ve) sign indicates the direct relationship of the variables i.e.as the value of one variable increases, the value of the other variable increases and vice versa. Highly correlated variables should be eliminated before further analysis of the data as it significantly influences the model to estimate the relationship between each independent variable and dependent variable.

The result of Pearson Correlation coefficient in Table 4.7: shows that the variables exhibit weak direct and inverse relationship. Hence, further processing of data continues without eliminating any variable.

Table 4. 72 Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.495[a]	0.245	0.030	8.312	0.245	1.137	8	28	0.370	0.944

a. Predictors: (Constant), Minimum Clear Zone, Lane Width, Gradient, Vertical Curve, Supper elevation, Shoulder Width, Horizontal Radius, 85th Percentile Speed

b. Dependent Variable: Number of Accident

Model Summary explains the strength of the relationship between the model and the dependent variable. R- Represents multiple correlation coefficients, one of measure of the quality of prediction of the dependent variable. R^2 (Coefficient of determination)-evaluates the scatter of the data points around the fitted regression line. Adjusted R-Squared- Used to compare the goodness-of-fit for regression model that comprises of different number of independent variables. The model explains 24.5% of variation in the dependent variable. On the other hand, the Durbin-Watson value of 0.944 indicates that the residuals are positively correlated.

Table 4. 73 ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	628.505	8	78.563	1.137	.370[b]
	Residual	1934.306	28	69.082		
	Total	2562.811	36			

a. Dependent Variable: Number of Accident

b. Predictors: (Constant), Minimum Clear Zone, Lane Width, Gradient, Vertical Curve, Supper elevation, Shoulder Width, Horizontal Radius, 85th Percentile Speed

The analysis of variance table is used to look at how well the explanatory variables as a whole can account for differences in the response variable. It is used to indicate how the variability in the dependent variable is partitioned between different independent variable components which it measures sum of squares. From table 4.72: the total sum of squares (the total variance in number of accident) is 2562.811. This can be divided into two parts.

The regression sum squares (628.505) which is the variability in the number of accidents that would be predicted on the basis of explanatory variables alone, and the residual sum squares (1934.306) which is the variation in the dependent variable that remains unexplained by the explanatory variables. The fraction of regression (explained sum of squares) to total sum of squares gives the value of R-squared i.e.628.505/2562.811= 0. 245. The sum of squares has associated degrees of freedom (df). For total sum of squares the df is one less than the total number of observations.i.e. 37-1=36. The regression sum of squares has one df for each explanatory variables in the model, while the residual df is the difference of total df and regression df. The fraction mean square of the regression to the mean square of the residuals is “F” test statistics. The value of F is compared with an F distribution with df of regression (8) and df of residuals (28). Hence, the overall model does not significantly explain the number of traffic accident, F (8, 28) =1.137, P=0.37.

Table 4. 74 Collinearity Statistics

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	49.388	67.184		0.735	0.468	-88.233	187.009					
	Lane Width	-15.998	18.496	-0.170	-0.865	0.394	-53.886	21.890	-0.055	-0.161	-0.142	0.695	1.438
	Shoulder Width	15.241	9.487	0.297	1.606	0.119	-4.193	34.674	0.155	0.291	0.264	0.789	1.268
	Horizontal Radius	-5.111	3.403	-0.306	-1.502	0.144	-12.080	1.859	-0.112	-0.273	-0.247	0.649	1.540
	Supper elevation	8.959	4.162	0.462	2.152	0.040	0.433	17.485	0.191	0.377	0.353	0.585	1.708
	Vertical Curve	3.902	3.674	0.193	1.062	0.297	-3.624	11.428	0.039	0.197	0.174	0.816	1.225
	Gradient	-1.473	3.604	-0.079	-0.409	0.686	-8.856	5.909	0.025	-0.077	-0.067	0.729	1.372
	85th Percentile Speed	0.239	3.631	0.014	0.066	0.948	-7.198	7.676	0.123	0.012	0.011	0.570	1.753
	Minimum Clear Zone	1.180	0.703	0.321	1.679	0.104	-0.259	2.619	0.187	0.303	0.276	0.737	1.357

a) Dependent Variable: Number of Accident

Measure of Variable Inflation Factor (VIF) indicates multicollinearity relationship among variables. If the value of VIF< 5 there is no multicollinearity, if VIF value is 5-10, there is some multicollinearity, & if VIF value is greater than 10 the multicollinearity assumption will be violated. Table 4.73: depicts that all VIF values of the variables are <5. Hence, there is no multicollinearity among variables. Additionally, the table indicates that all explanatory variables except supper elevation do not affect number of traffic accident significantly.

Table 4. 75 Residual Statistics

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	8.28	23.00	15.24	4.178	37
Residual	-15.203	16.350	0.000	7.330	37
Std. Predicted Value	-1.666	1.856	0.000	1.000	37
Std. Residual	-1.829	1.967	0.000	0.882	37

a. Dependent Variable: Number of Accident

Residual is the difference between the predicted values of dependent variable and the observed value (actual-predicted). Predicted values are points that fall on the predicted line for the given point on the x-axis. The observations are represented by circular dots, and the best fit or predicted regression line is represented by diagonal solid line. Negative residual indicates that the predicted value is too high, while positive residual indicates the predicted value was too low.

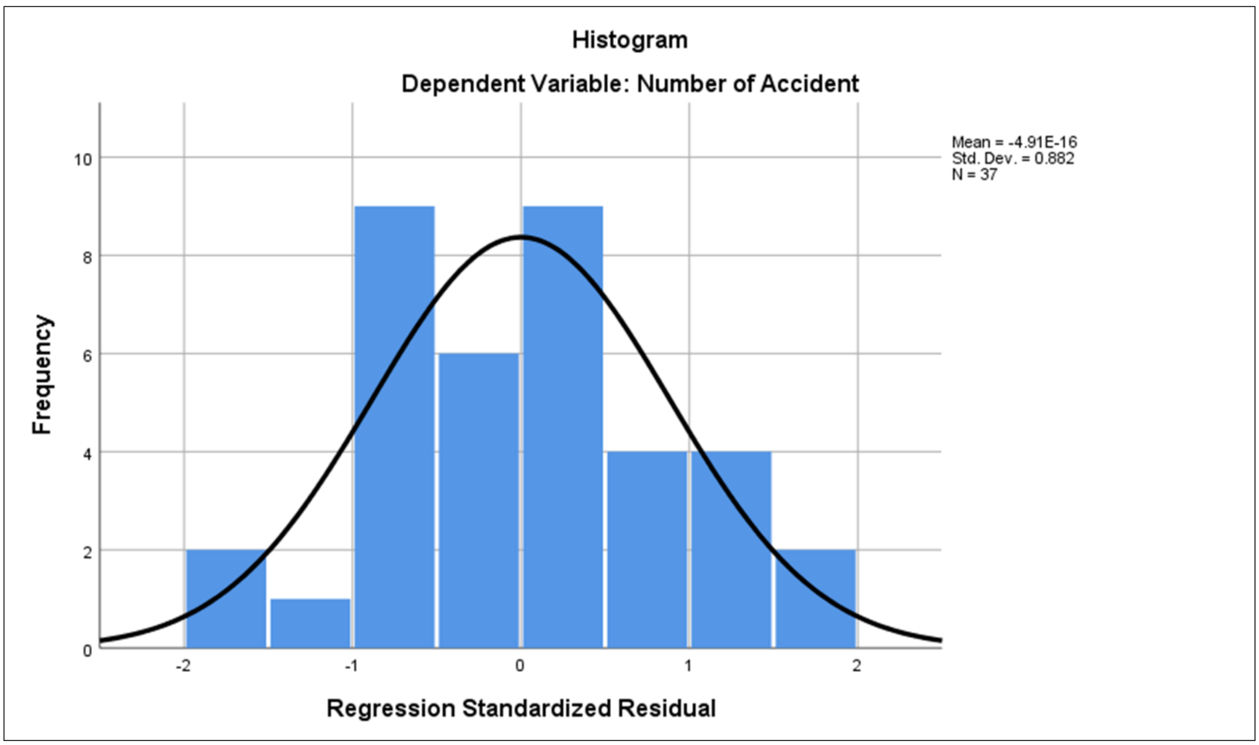


Fig.4. 62 Histogram of Standardized Residual

Histogram of the residuals roughly follows the shape the normal curve that is superimposed over them. Hence, it is consistent with the assumption of normality.

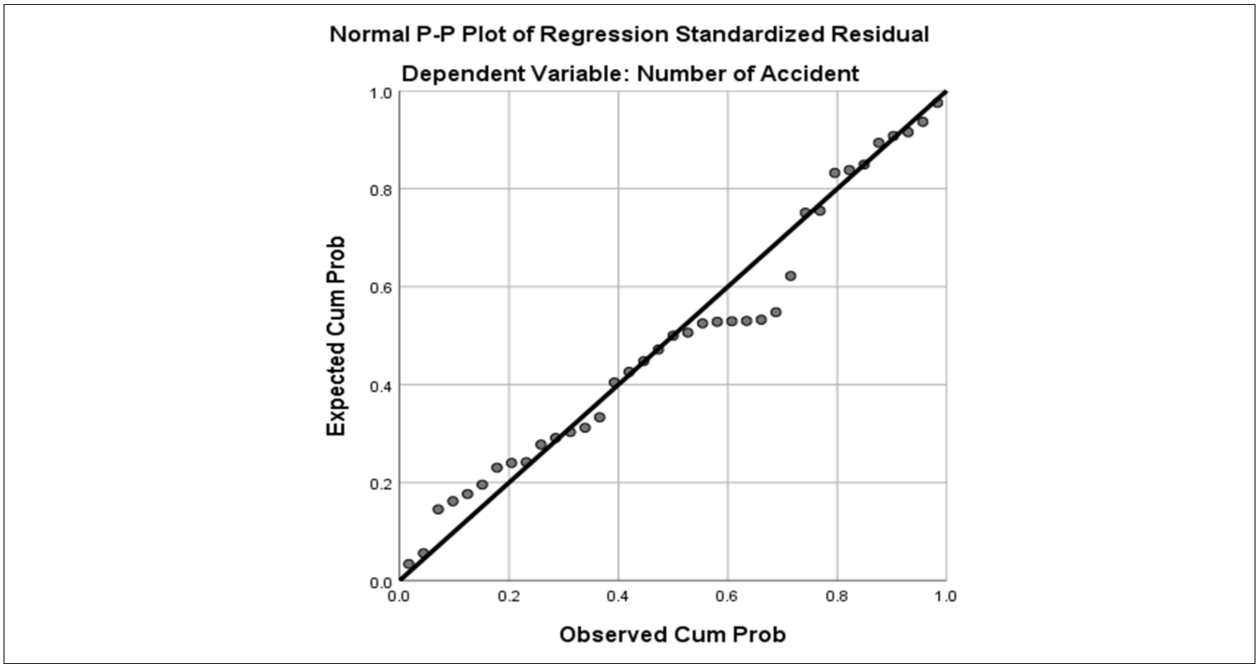


Fig.4. 63 Normal P-P plot of Regression Standardized Residual

Fig.4.61 depicts that the little circles follow the normality line (diagonal line), which in turn show the normality of our data. Hence, "normality" one of the assumptions of multiple regression is obeyed.

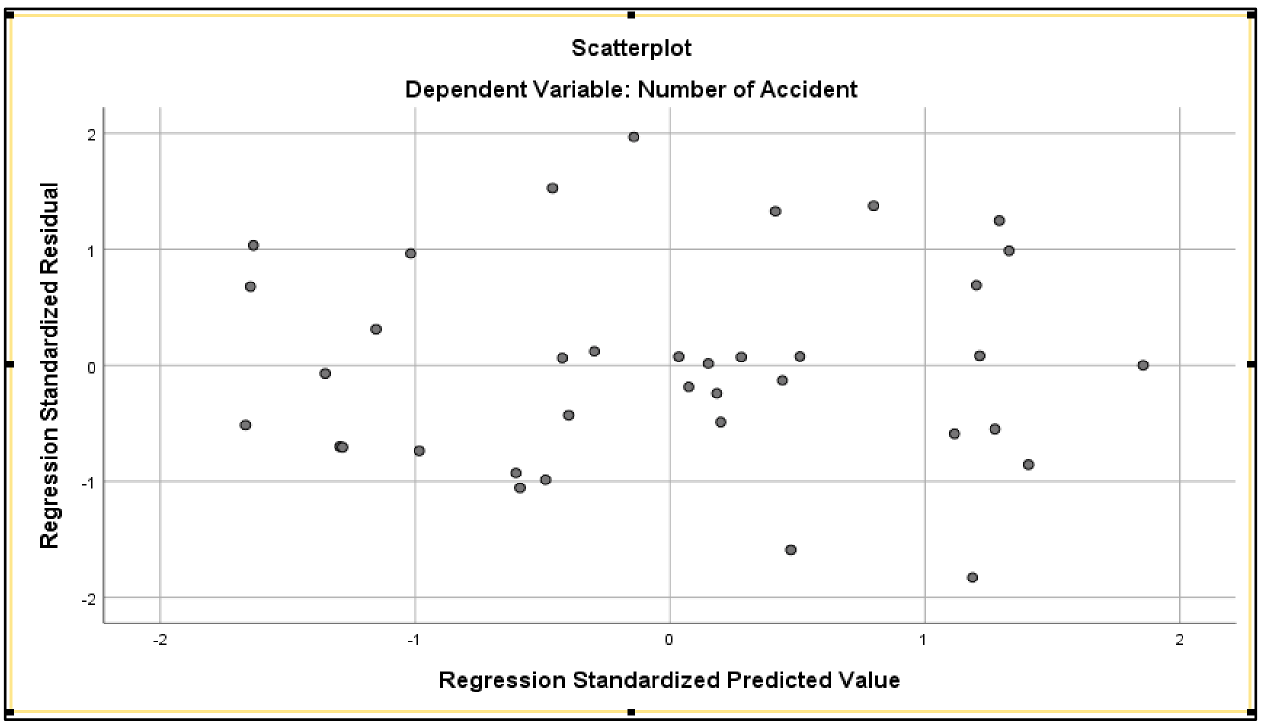


Fig.4. 64 Scatterplot of Regression Standardized Predicted Value

This scatterplot shows that the data do not have obvious pattern. It looks like it is shot out of the shotgun. There are points that equally distributed below and above zero on x-axis and to left and right of zero on y-axis. This shows that our data is homoscedastic.

As it is observed from the result, supper elevation is the significant parameters which influence number of crash recorded at each black spot locations. However, when talking about influence of supper elevation on number of accidents, operation speed of the vehicle where supper elevation is provided should be considered in addition to sufficiency of supper elevation. The following figure describes the speed limit set during the construction of the road, the 85th percentile speed determined during black spot identification and number of crashes recorded at each black spot locations for last three years.

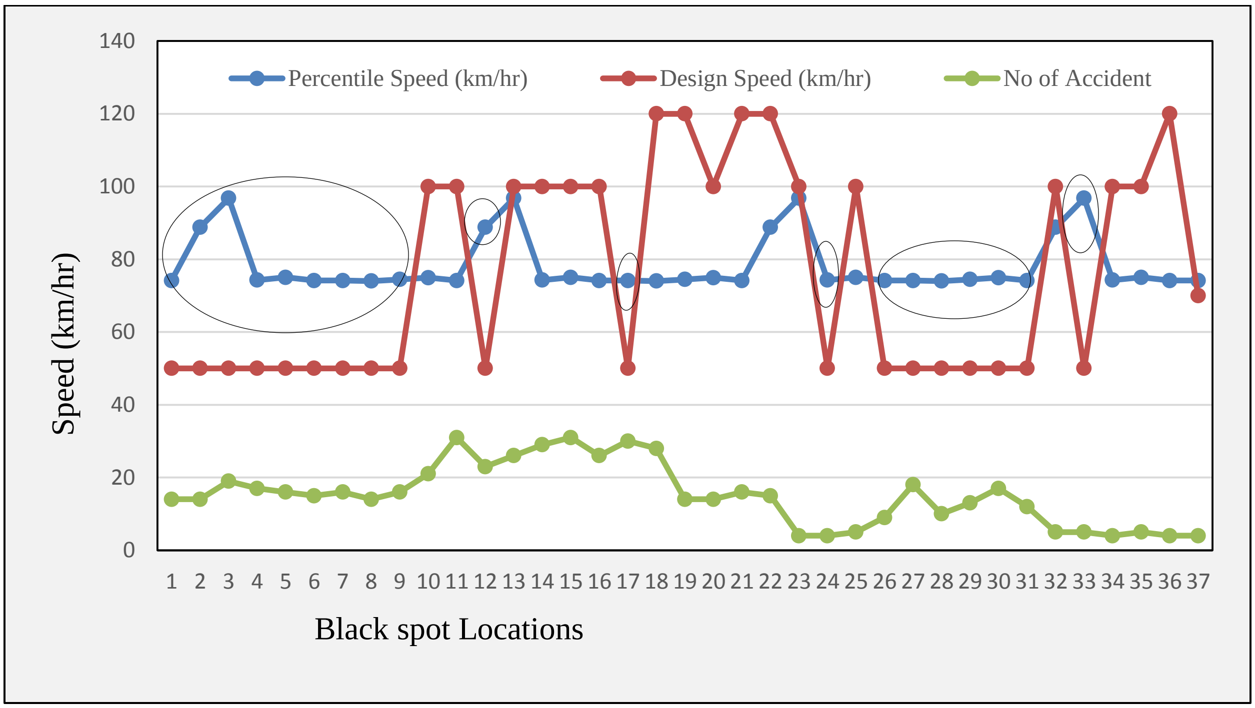


Fig.4. 65 Number of crash Vs Speed (Percentile Speed & Design Speed)

From the above figure, it is observed that at black encircled locations, vehicle's operating speed is higher than design speed. Since majority of the black spot locations are at horizontal curve, the probability of occurrence of crash due to over speeding is higher. Reducing of speed at these places will result in accident minimization and in turn erase the history of the location from black spot. Driving at design speed alone will not be a guarantee for the safest option. Abide by speed limit, speed should be even more reduced in response to different conditions like wet weather condition and where there is high pedestrian and cyclist traffic. By reducing speed, number of black spot will be reduced and cost incurred for application of counter measure is minimized.

CHAPTER-V

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research aimed to identify the blackspot locations along the Addis Ababa to Gohatsion road and finally to investigate the effect of road geometry on frequency of traffic accident. Based on qualitative and quantitative analysis of primary and secondary data obtained from six woredas and three town administration police stations and the Ethiopian Roads Administration, thirty-seven (37) blackspot locations could be identified along the study area and lastly mapped using GIS Software.

At these blackspot locations further analysis of the relationship between geometric design parameters of the road and number of traffic accident has been conducted by multiple regressions in SPSS, based on the observed/provided value in comparison with ERA Standard. The coefficients of the parameters really indicate that there is appropriate relationship between the geometric design parameters and the number of traffic accident which supports the theory in the literature review. Lane width and horizontal curve radius have inverse relationship with number of accidents. On the other hand, shoulder width, percentage of supper elevation, vertical curve radius, gradient, 85^{th} percentile speed and minimum clear zone shows direct relationship with number of traffic accidents.

According to the SPSS output of the overall model of accident prediction, the result revealed that the road geometric parameters do not significantly affect number of traffic accident. However, when looking at the parameters separately supper elevation significantly affected the number of traffic accidents. The fact that supper elevation significantly affected the number of traffic accident shows sufficient supper elevation should be provided.

This research is expected to show the way for scientific approach of differentiating factors which really affect the frequency of the traffic accident at some particular location to apply the appropriate and relevant countermeasure rather than following trial and error method.

5.2 Recommendations

The relationship between the geometric design parameters of the road and the road traffic accident should be accounted into consideration during design and construction of the road as traffic accident prevention mechanism. Even after identifying the location where the accidents happen very often, the accident reduction method should be followed. The following recommendations are forwarded to prevent further occurrence of the traffic accidents due to geometric parameters of the road.

i) Role of Government

a) **Road Safety Management**-Despite having very low road network density and vehicle ownership Ethiopia has the relatively high accident record which has been indicated as worst example by different authors. But based on the government policy emphasis, road network density is being expanded and the vehicle fleet is also increasing without accommodating the safety into consideration. So, both regional and national governments should develop clear road safety policy and legislations on how to manage safety of the entire road across the country in identifying black spots and applying counter measures and also should form the institutional organizations to every level for its implementation along with expanding road network density.

b) **Awareness Creation to major stakeholders**- Many drivers and road users and even concerned officials do not know why and how traffic accidents will happen. Due to lack of awareness many lost their live and beloved ones. Awareness should be given by concerned road safety management agencies and institutions of the country in collaboration with different national and international organizations which work on road safety.

-The first duty should be executing comprehensive studies for identifying blackspot locations along the entire road networks of the country so as to set respective best and economical countermeasures.

-After identification of blackspot locations appropriate and meaningful sign should be erected as warning mechanism in order for the driver's to be aware and adapt themselves to the prevailing condition.

c) **Data Recording System**- The research also revealed that the traffic accident data recording system of the police stations are very outdated and it lacks quality in providing accurate and necessary information unless it is aided with direct contact with traffic police men and ask everything one by one. So, it is recommended to form well-structured governmental organization using well-trained human resources and digitizing database system so as to access accurate data in detail. Digitization helps to get reliable data, save time, save resources and reduces bureaucracy to conduct the research easily. Likewise, when conducting research, researchers should not waste their time and resource in searching of data. Every stakeholder should follow modern data handling system.

Especially Ethiopian Roads Administration (Road Asset Management Directorate) should keep the as built data of the road it administers in well-organized manner and regional roads authority and transport bureaus should do the same.

d) **Enforcement**- After developing policy and laws and legislations the government should follow-up for their implementation. Even if, there are appropriate erection of warning signs at identified locations to take care of him and passenger/property the drivers are reluctant in obeying the traffic law where there are no traffic policemen. It is possible to counteract this problem in two ways. One, by community participation which is low cost. The government should aware the community to expose one who violated the laws for the sake of safe travel of the community themselves. Second and which is expensive is digitizing the road. Once the road is digitized everything will be under camera eye.

ii) Role of Intellectuals-

Intellectuals should organize different seminars, meetings, trainings and presenting their findings to the concerned body so as to early manage the problem.

iii) Role of NGOs

NGOs working on road safety in different countries are a necessary supplement and extension to the government officials. NGOs in the country should cooperate with international NGOs working on road safety to: -

- Promote the road safety education
- Disseminate information for the road users' correct behavior in traffic situation
- Coordinate the voluntary and private traffic safety work
- Coordinate the voluntary and private road safety groups and different public sectors

-

5.3 Future Research Areas

The following research areas are proposed for future study:

- **Effects of Geometric Design Parameters of Ethiopian Road Networks on Traffic Safety**

The scope of the study was limited to single trunk road from Addis Ababa to Gohatsion due the limitation of time and budget constraint. At least it is better to incorporate other road networks of the same classification for better conclusion of the relationship between geometric design parameters and the road traffic accident.

- **Investigating the Major Causes of Ethiopian Road Traffic Accident**

The study focus only on the geometric design parameters of the road keeping other factors constant, while the traffic accident can happen due to the interaction of three main factors.i.e. road, road users and vehicle. Incorporating all these factors will help us to drive clear conclusion about the share of these factors in causing the road traffic accident to apply respective countermeasures without confusion.

- **Digitization of Data Recording and Storage System of Road Traffic Accident**

The very tiresome parts of conducting research on traffic safety is collecting data and getting reliable data. The traffic accident data recording and storage system is very outdated and need to be improved. The daily reporting format doesn't include details of each accident. The report, further, does not contain details of the road section and precise location of an accident. The location of an accident is reported broadly by district, Kebele and Woreda or the name of the surroundings. The information recorded could generally be adequate for crime investigation, but it is of limited use to other bodies requiring information for identifying the causes to apply appropriate remedial measures. Moreover, accident reporting lacks a significant level of consistency. Digitization will overcome all these problems including preserving of information for a long period of time in easily accessible manner. When digitization concept is fully applied the exact coordinate of each and every accident can be determined which can help to further study of the location to take appropriate countermeasure.

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APPENDIXES

APPENDIX A Formats Used for The Research

APPENDIX A1 Questionnaire format

APPENDIX A2 Sample Road Geometry Inspection Check list at each blackspot locations

APPENDIX A3 Traffic Volume Counting Format

APPENDIX A4 Spot Speed Recording Format

APPENDIX B Accident Analysis to Identify Blackspot

APPENDIX B1 Accident Rate Calculation

APPENDIX B2 Accident Severity Value Calculation

APPENDIX B3 Accident Density Calculation

APPENDIX C Sample Spot Speed Calculation

APPENDIX D Output of Multiple Regressions Using SPSS

APPENDIX A1- Questionnaire format

Questionnaire form for residents, passengers, drivers, traffic police man and other concerned authorities to get the required information for conducting thesis on the title" Investigating The Effects of Road Geometry On Accident Black Spots of Addis Ababa to Gohatsion Trunk Road"

Section I: Personal Details

1. Age category: Less than18 ☐, 18-24 ☐ , 25-34☐ ,35-44 ☐ , Greater than 45☐
2. Sex: Male ☐ , Female☐
3. Level of education: Illiterate☐ Elementary☐ , Secondary☐ , Diploma ☐, TVET☐ , Degree & above ☐
4. Which category of road user you are?
   a) Resident/pedestria ☐
   b) Passenger ☐
   c) Driver ☐
   d) Traffic police man☐
   e) Other ☐

Section II: Questions

Q.1. If your answer for personal detail 4 is a, where do the traffic accidents often occur around your surrounding?

- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..

If your answer for personal detail 4 is b, c & d, where do the traffic accidents often occur along the road Addis Ababa to Gohatsion?

- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..

Q.2. Because of what reason do you think it occurs around these areas you have mentioned on Q.1?

- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..

Q.3. For personal detail c and d, what measures to be taken do you think is appropriate for the future to reduce the crash happening along this road at different places?

- ✓ ………………………….. ✓ …………………………..
- ✓ ………………………….. ✓ …………………………..

Waraqaa qorannoo mata dureen“Daandii Guddaa Finfinnee Hanga Gohaatsiyoon Jirutti Dhiibbaa Ji’oomeetriin Karaa Iddoowwan Balaan Itti Heddumatanitti Qabu Qorachuu” jedhu hojjechuuf guca gaaffii fi deebii jiraattota, imaltoota,konkolaachistoota, poolisoota tiraafikaa fi qaama dhimmi ilaalatuuf qophaa’e

Kutaa I: Odeeffannoo dhuunfaa

1. Umrii: 18 gadi☐ , 18-24 ☐ , 25-34 ☐ ,35-44☐ 45 ol ☐
2. Saala: Dhiira ☐ , Shamara ☐
3. Sadarkaa barnootaa: Kan hin baranne☐, Sad.1[ffaa] ☐, Sad.2[ffaa] ☐ , Diiploomaa☐ , Teeknika☐ , Digrii & isaa ol☐
4. Ati fayyadamtoota karaa isaan kam keessatti ramadamta?
   a) Jirataa/lafoo deemaa ☐
   b) Imalaa ☐
   c) Konkolaachisaa ☐
   d) Poolisii tiraafikaa ☐
   e) Kan biraa ☐

Kutaa II: Gaaffiiwwan

Q.1. Yoo deebiin kee kutaa I, lakk 4 a ta’e, naannawa ati jirtutti yeroo baay’ee balaan konkolaataa iddoo kam kamitti mudata?

- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..

Yoo deebiin kee kutaa I, lakk 4 b,c & d ta’e, daandii Finfinnee hanga Gohaatsiyoon jiru kanarratti yeroo baay’ee balaan konkolaataa iddoo kam kamitti mudata?

- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..

Q.2. Sababbii maalitiif iddoowwan ati gaaffii tokkoffaarratti eerte kanatti balaan yeroo baay’ee mudata jettee yaadda?

- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..
- ✓ …………………………..

Q.3. Warra kutaa I lakk 4 c fi d jala jirtaniif: Tarkaanfiin akkamii yoo fudhatame balaawwan konkolaataa daandii kana iddoo gara garaatti ga’an kun hir’achuu danda’u jettee yaadda?

APPENDIX A2 Sample Road Geometry Inspection Check list at each blackspot locations

N.S	Terrain type	Roadway element	ERA Standard value	Observed/Provided value
1	Mountainous	Design speed (km/hr)	50	96.77
		Lane width (m)	3.65	3.6/Broken edge
3		Number of lanes	2	2
4		Shoulder width (m)	Parking lane 3.5 m & Walk way 2.5 m	No proper shoulder
5		Horizontal radius (m)	95	2000
6		Max.Super elevation (%)	4	4
7		Vertical curve (crest/sag)	10/7	104 crest
8		Maximum gradient (%)	6/8	0.47(below standard)
9		Bridge width (m)	7.3	NA
10		Min.Clear zone from outer road edge (m)	15	9.7

APPENDIX A3 Traffic Volume Counting Format

Date: ________________ Direction: ________________________

Station: ________________ Start time ________________________

Surveyor: ________________ End Time ________________________

Traffic	Tally	Total	Remark
CAR			
L/ Rover			
Small bus (≤ 27 Seats)			
Large bus (> 27 Seats)			
Small track (<3.5 Tons)			
Medium trucks (3.5 - 7.5 Tons)			
Heavy trucks (7.5 - 12 tons)			
Truck and Trailer (> 12 Tons)			

NB: Count Should be every 15minutes

APPENDIX A4 Spot Speed Recording Format

Date :____

Station :____

Direction :____

Surveyor :____

N.S	Vehicle type	Intering time	Exiting time	Time elapsed	Time in sec	Speed (km/hr)	Remark
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							

APPENDIX B Accident Analysis to Identify Blackspot

APPENDIX B1 Accident Rate Calculation

Station/ Section(j) km	Number of accidents (Aj)	Number of Vehicle km (mj)	Accident rate on section j (Rj)	Critical value of accident rate (Rc)	Name of the places
0+000	0	2.68	0.000	5.055	
1+000	8	2.68	2.985	5.055	
2+000	10	2.68	3.731	5.055	
3+000	6	2.68	2.239	5.055	
4+000	14	2.68	5.224	5.055	*10 kilo
5+000	14	2.68	5.224	5.055	*Wasarbii
6+000	7	2.68	2.612	5.055	
7+000	9	2.68	3.358	5.055	
8+000	19	2.68	7.090	5.055	*Qimbirree
9+000	5	2.68	1.866	5.055	
10+000	17	2.68	6.343	5.055	*Shuffunnee
11+000	16	2.68	5.970	5.055	*Doro irbata
12+000	10	2.68	3.731	5.055	
13+000	15	2.68	5.597	5.055	*Ashewa
14+000	16	2.68	5.970	5.055	*Prime milk
15+000	14	2.68	5.224	5.055	*Kajima
16+000	9	2.68	3.358	5.055	
17+000	9	2.68	3.358	5.055	
18+000	10	2.68	3.731	5.055	
19+000	16	2.68	5.970	5.055	*Leather factory
20+000	8	2.68	2.985	5.055	
21+000	6	2.68	2.239	5.055	
22+000	5	2.68	1.866	5.055	
23+000	13	2.68	4.851	5.055	
24+000	10	2.68	3.731	5.055	
25+000	9	2.68	3.358	5.055	
26+000	11	2.68	4.104	5.055	Malima
27+000	21	2.68	7.836	5.055	*Gajoo
28+000	13	2.68	4.851	5.055	
29+000	31	2.68	11.567	5.055	kosobar
30+000	12	2.68	4.478	5.055	

31+000	23	2.68	8.582	5.055	Derba mazoria
32+000	9	2.68	3.358	5.055	
33+000	10	2.68	3.731	5.055	stadium
34+000	26	2.68	9.701	5.055	*Mesalemiya
35+000	29	2.68	10.821	5.055	*laga chancho
36+000	8	2.68	2.985	5.055	
37+000	13	2.68	4.851	5.055	Guto
38+000	13	2.68	4.851	5.055	
39+000	9	2.68	3.358	5.055	
40+000	31	2.68	11.567	5.055	laga leencaa
41+000	10	2.68	3.731	5.055	Mooyyee gajoo
42+000	11	2.68	4.104	5.055	
43+000	6	2.68	2.239	5.055	
44+000	13	2.68	4.851	5.055	
45+000	26	2.68	9.701	5.055	Abbichuu
46+000	10	2.68	3.731	5.055	
47+000	11	2.68	4.104	5.055	
48+000	30	2.68	11.194	5.055	*Gorfoo
49+000	10	2.68	3.731	5.055	
50+000	9	2.68	3.358	5.055	
51+000	12	2.68	4.478	5.055	
52+000	28	2.68	10.448	5.055	Bacho
53+000	10	2.68	3.731	5.055	
54+000	8	2.68	2.985	5.055	Waajjituu
55+000	9	2.68	3.358	5.055	
56+000	12	2.68	4.478	5.055	
57+000	13	2.68	4.851	5.055	
58+000	14	2.68	5.224	5.055	*Laga roobaa
59+000		2.68	0.000	5.055	
60+000	14	2.68	5.224	5.055	*Dubar river
61+000		2.68	0.000	5.055	
62+000	16	2.68	5.970	5.055	*Koran
63+000	2	2.68	0.746	5.055	
64+000		2.68	0.000	5.055	
65+000	15	2.68	5.597	5.055	*Wada
66+000	6	2.68	2.239	5.055	
67+000		2.68	0.000	5.055	
68+000	2	2.68	0.746	5.055	
69+000	3	2.68	1.119	5.055	
70+000		2.68	0.000	5.055	

71+000	4	2.68	1.493	5.055	
72+000		2.68	0.000	5.055	
73+000	1	2.68	0.373	5.055	
74+000	7	2.68	2.612	5.055	
75+000		2.68	0.000	5.055	
76+000	4	2.68	1.493	5.055	*Sallee
77+000	1	2.68	0.373	5.055	
78+000	1	2.68	0.373	5.055	
79+000	2	2.68	0.746	5.055	
80+000	2	2.68	0.746	5.055	
81+000	1	2.68	0.373	5.055	
82+000	1	2.68	0.373	5.055	
83+000	4	2.68	1.493	5.055	*Gurso
84+000	1	2.68	0.373	5.055	
85+000	1	2.68	0.373	5.055	
86+000	5	2.68	1.866	5.055	*Qasim school
87+000	1	2.68	0.373	5.055	Wakene tuli
88+000	1	2.68	0.373	5.055	Wakene
89+000	2	2.68	0.746	5.055	Wushagedel
90+000	1	2.68	0.373	5.055	
91+000	9	2.68	3.358	5.055	*Dhankaka/wartu
92+000	3	2.68	1.119	5.055	Chagal town
93+000	2	2.68	0.746	5.055	
94+000	18	2.68	6.716	5.055	*Laga guurii
95+000	3	2.68	1.119	5.055	
96+000	3	2.68	1.119	5.055	
97+000	2	2.68	0.746	5.055	
98+000	3	2.68	1.119	5.055	
99+000	2	2.68	0.746	5.055	
100+000	3	2.68	1.119	5.055	
101+000	3	2.68	1.119	5.055	
102+000	2	2.68	0.746	5.055	
103+000	3	2.68	1.119	5.055	Commando
104+000	2	2.68	0.746	5.055	Bus station
105+000	2	2.68	0.746	5.055	Fitche hospital
106+000	10	2.68	3.731	5.055	*Torban Ashee
107+000	3	2.68	1.119	5.055	
108+000	3	2.68	1.119	5.055	
109+000	3	1.73	1.734	2.022	
110+000	2	1.73	1.156	2.022	
111+000	2	1.73	1.156	2.022	

112+000	2	1.73	1.156	2.022	
113+000	2	1.73	1.156	2.022	
114+000	3	1.73	1.734	2.022	Church
115+000	2	1.73	1.156	2.022	
116+000	13	1.73	7.514	2.022	*Laga Silmii
117+000	3	1.73	1.734	2.022	
118+000	2	1.73	1.156	2.022	
119+000	2	1.73	1.156	2.022	
120+000	1	1.73	0.578	2.022	
121+000	2	1.73	1.156	2.022	
122+000	3	1.73	1.734	2.022	Jajjabduu
123+000	3	1.73	1.734	2.022	Ayane Garbi bridge
124+000	2	1.73	1.156	2.022	
125+000	3	1.73	1.734	2.022	East cement
126+000	1	1.73	0.578	2.022	
127+000	2	1.73	1.156	2.022	
128+000	17	1.73	9.827	2.022	*Eegduu
129+000	2	1.73	1.156	2.022	
130+000	1	1.73	0.578	2.022	
131+000	2	1.73	1.156	2.022	
132+000	3	1.73	1.734	2.022	
133+000	12	1.73	6.936	2.022	*Hambiso 01 keb.
134+000	2	1.73	1.156	2.022	
135+000	2	1.73	1.156	2.022	
136+000	3	1.73	1.734	2.022	
137+000	2	1.73	1.156	2.022	
138+000	2	1.73	1.156	2.022	
139+000	5	1.73	2.890	2.022	*Laga qallaa
140+000	1	1.73	0.578	2.022	Ganda birrattee
141+000	2	1.73	1.156	2.022	ula
142+000	3	1.73	1.734	2.022	kesi
143+000	3	1.73	1.734	2.022	muka chita
144+000	2	1.73	1.156	2.022	Goraa
145+000	3	1.73	1.734	2.022	Lideta
146+000	2	1.73	1.156	2.022	Yetebaberut
147+000	1	1.73	0.578	2.022	G.G Preparatory
148+000		1.73	0.000	2.022	
149+000	5	1.73	2.890	2.022	*G/G River
150+000	2	1.73	1.156	2.022	Scan scan
151+000	4	1.73	2.312	2.022	*Misilii iraasuu
152+000		1.73	0.000	2.022	

153+000	2	1.73	1.156	2.022	Biriti junction
154+000	1	1.73	0.578	2.022	karekura school
155+000	2	1.73	1.156	2.022	Bargamo Hurrisaa
156+000		1.73	0.000	2.022	
157+000		1.73	0.000	2.022	
158+000		1.73	0.000	2.022	
159+000	5	1.73	2.890	2.022	*Bitoo milkii
160+000	2	1.73	1.156	2.022	
161+000	1	1.73	0.578	2.022	
162+000	3	1.73	1.734	2.022	old market
163+000	2	1.73	1.156	2.022	
164+000	1	1.73	0.578	2.022	Shooyii
165+000		1.73	0.000	2.022	
166+000		1.73	0.000	2.022	
167+000	2	1.73	1.156	2.022	Sakkee
168+000	2	1.73	1.156	2.022	Mesalemiya
169+000	4	1.73	2.312	2.022	*Walee cilalloo
170+000		1.73	0.000	2.022	
171+000		1.73	0.000	2.022	
172+000	2	1.73	1.156	2.022	Laga hantuutaa
173+000		1.73	0.000	2.022	
174+000	1	1.73	0.578	2.022	
175+000	1	1.73	0.578	2.022	
176+000	1	1.73	0.578	2.022	
177+000	2	1.73	1.156	2.022	
178+000	1	1.73	0.578	2.022	Goha land
179+000	1	1.73	0.578	2.022	
180+000		1.73	0.000	2.022	
181+000		1.73	0.000	2.022	
182+000		1.73	0.000	2.022	
183+000	1	1.73	0.578	2.022	
184+000	2	1.73	1.156	2.022	
185+000		1.73	0.000	2.022	
186+000	4	1.73	2.312	2.022	*Abay gorge
187+000	3	1.73	1.734	2.022	
188+000	1	1.73	0.578	2.022	
189+000	1	1.73	0.578	2.022	
190+000	2	1.73	1.156	2.022	
191+000	1	1.73	0.578	2.022	
192+000	2	1.73	1.156	2.022	
193+000	1	1.73	0.578	2.022	

194+000	2	1.73	1.156	2.022	
195+000	2	1.73	1.156	2.022	
196+000		1.73	0.000	2.022	
197+000	1	1.73	0.578	2.022	
197+237		1.73	0.000	2.022	

Legend:		
		Boundary between woredas
		Blackspot locations
		Fitche city Administration

APPENDIX B2 Accident Severity Value Calculation

N.S	Station/ Section(j) km	Fatal	Injury	PDO	Total	Severity (Si)	Name of the places
1	0+000	0	0	0	0	0.00	
2	1+000	1	2	5	8	20.00	
3	2+000	2	2	6	10	30.16	
4	3+000	1	2	3	6	19.91	
5	4+000	3	3	8	14	42.22	*10 kilo
6	5+000	3	3	8	14	42.22	*Wasarbii
7	6+000	1	2	4	7	21.11	
8	7+000	2	2	5	9	27.14	
9	8+000	4	4	11	19	57.30	*Qimbirree
10	9+000	1	1	3	5	15.08	
11	10+000	3	4	10	17	51.27	*Shuffunnee
12	11+000	3	4	9	16	48.25	*Doro irbata
13	12+000	2	2	6	10	30.16	
14	13+000	3	3	9	15	45.23	*Ashewa
15	14+000	3	4	9	16	48.25	*Prime milk
16	15+000	3	3	8	14	42.22	*Kajima
17	16+000	2	2	5	9	27.14	
18	17+000	2	2	5	9	27.14	
19	18+000	2	2	6	10	30.16	
20	19+000	3	4	9	16	48.25	*Leather factory
21	20+000	1	2	5	8	19.17	
22	21+000	1	1	3	6	18.09	
23	22+000	1	1	3	5	15.08	
24	23+000	3	3	7	13	39.20	
25	24+000	2	2	6	10	30.16	
26	25+000	2	2	5	9	27.14	
27	26+000	2	3	6	11	33.17	Malima
28	27+000	4	5	12	21	63.33	*Gajoo
29	28+000	3	3	7	13	39.20	
30	29+000	6	7	18	31	93.48	kosobar
31	30+000	2	3	7	12	36.19	
32	31+000	3	5	13	23	56.24	Derba mazoria
33	32+000	2	2	5	9	27.14	

34	33+000	1	2	7	10	22.98	stadium
35	34+000	5	6	15	26	78.41	*Mesalemiya
36	35+000	5	7	17	29	81.87	*laga chancho
37	36+000	1	2	5	8	19.17	
38	37+000	3	4	6	13	40.67	Guto
39	38+000	2	3	8	13	35.07	
40	39+000	2	2	5	9	27.14	
41	40+000	5	8	18	31	86.78	laga leencaa
42	41+000	2	2	6	10	30.16	Mooyyee gajoo
43	42+000	2	3	6	11	33.17	
44	43+000	1	2	3	6	19.91	
45	44+000	3	3	7	13	39.20	
46	45+000	5	6	15	26	78.41	Abbichuu
47	46+000	2	2	6	10	30.16	
48	47+000	2	3	6	11	33.17	
49	48+000	6	7	17	30	90.47	*Gorfoo
50	49+000	2	2	6	10	30.16	
51	50+000	2	2	5	9	27.14	
52	51+000	2	3	7	12	36.19	
53	52+000	5	7	16	28	84.44	Bacho
54	53+000	2	2	6	10	30.16	
55	54+000	1	2	5	8	19.17	Waajjituu
56	55+000	2	2	5	9	27.14	
57	56+000	2	3	7	12	36.19	
58	57+000	3	3	7	13	39.20	
59	58+000	3	3	8	14	42.22	*Laga roobaa
60	59+000	0	0	0		0.00	
61	60+000	3	3	8	14	42.22	*Dubar river
62	61+000	0	0	0		0.00	
63	62+000	3	4	9	16	48.25	*Koran
64	63+000	0	1	1	2	7.64	
65	64+000	0	0	0		0.00	
66	65+000	3	3	9	15	45.23	*Wada
67	66+000	1	1	4	6	18.65	
68	67+000	0	0	0		0.00	
69	68+000	1	0	1	2	11.54	
70	69+000	0	1	2	3	3.81	
71	70+000	0	0	0		0.00	
72	71+000	1	1	2	4	12.06	

73	72+000	0	0	0		0.00	
74	73+000	0	0	1	1	3.02	
75	74+000	1	2	4	7	21.11	
76	75+000	0	0	0		0.00	
77	76+000	1	1	2	4	12.06	*Sallee
78	77+000	0	0	1	1	3.02	
79	78+000	0	0	1	1	3.02	
80	79+000	0	1	1	2	7.64	
81	80+000	1	0	1	2	11.54	
82	81+000	0	0	1	1	3.02	
83	82+000	0	0	1	1	3.02	
84	83+000	1	1	2	4	12.06	*Gurso
85	84+000	0	0	1	1	3.02	
86	85+000	0	0	1	1	3.02	
87	86+000	1	1	3	5	15.08	*Qasim school
88	87+000	0	0	1	1	3.02	Wakene tuli
89	88+000	0	0	1	1	3.02	Wakene
90	89+000	0	1	1	2	7.64	Wushagedel
91	90+000	0	0	1	1	3.02	
92	91+000	2	2	5	9	27.14	*Dhankaka/wartu
93	92+000	0	1	2	3	3.81	Chagal town
94	93+000	0	1	1	2	7.64	
95	94+000	3	4	11	18	54.96	*Laga guurii
96	95+000	0	1	2	3	3.81	
97	96+000	1	0	2	3	6.95	
98	97+000	1	0	1	2	11.54	
99	98+000	0	1	2	3	3.81	
100	99+000	0	1	1	2	7.64	
101	100+000	0	1	2	3	3.81	
102	101+000	1	0	2	3	6.95	
103	102+000	0	1	1	2	7.64	
104	103+000	1	0	2	3	6.95	Commando
105	104+000	0	0	1	2	6.03	Bus station
106	105+000	1	0	1	2	11.54	Fitche hospital
107	106+000	2	2	6	10	30.16	*Torban Ashee
108	107+000	0	1	2	3	3.81	
109	108+000	1	0	2	3	6.95	
110	109+000	0	1	2	3	3.81	
111	110+000	1	0	1	2	11.54	

112	111+000	0	1	1	2	7.64	
113	112+000	0	1	1	2	7.64	
114	113+000	1	0	1	2	11.54	
115	114+000	0	1	2	3	3.81	Church
116	115+000	1	0	1	2	11.54	
117	116+000	3	3	7	13	39.20	*Laga Silmii
118	117+000	0	1	2	3	3.81	
119	118+000	0	1	1	2	7.64	
120	119+000	0	1	1	2	7.64	
121	120+000	0	0	1	1	3.02	
122	121+000	1	0	1	2	11.54	
123	122+000	1	0	2	3	6.95	Jajjabduu
124	123+000	0	1	2	3	3.81	Ayane Garbi bridge
125	124+000	0	1	1	2	7.64	
126	125+000	1	1	1	3	8.33	East cement
127	126+000	0	0	1	1	3.02	
128	127+000	1	0	1	2	11.54	
129	128+000	3	4	10	17	51.27	*Eegduu
130	129+000	1	0	1	2	11.54	
131	130+000	0	0	1	1	3.02	
132	131+000	1	0	1	2	11.54	
133	132+000	0	1	2	3	3.81	
134	133+000	2	3	7	12	36.19	*Hambiso 01 keb.
135	134+000	1	0	1	2	11.54	
136	135+000	1	0	1	2	11.54	
137	136+000	0	1	2	3	3.81	
138	137+000	0	1	1	2	4.15	
139	138+000	1	0	1	2	11.54	
140	139+000	1	1	3	5	15.08	*Laga qallaa
141	140+000	0	0	1	1	3.02	Ganda birrattee
142	141+000	0	1	1	2	7.64	ula
143	142+000	0	1	2	3	3.81	kesi
144	143+000	1	0	2	3	6.95	muka chita
145	144+000	1	0	1	2	11.54	Goraa
146	145+000	0	1	2	3	3.81	Lideta
147	146+000	1	0	1	2	11.54	Yetebaberut
148	147+000	0	0	1	1	3.02	G.G Preparatory
149	148+000	0	0	0		0.00	
150	149+000	1	1	3	5	15.08	*G/G River

151	150+000	1	0	1	2	11.54	Scan scan
152	151+000	1	1	2	4	12.06	*Misilii iraasuu
153	152+000	0	0	0		0.00	
154	153+000	0	1	1	2	7.64	Biriti junction
155	154+000	0	0	1	1	3.02	karekura school
156	155+000	0	1	1	2	7.64	Bargamo Hurrisaa
157	156+000	0	0	0		0.00	
158	157+000	0	0	0		0.00	
159	158+000	0	0	0		0.00	
160	159+000	1	1	3	5	15.08	*Bitoo milkii
161	160+000	1	0	1	2	11.54	
162	161+000	0	0	1	1	3.02	
163	162+000	0	1	2	3	3.81	old market
164	163+000	1	0	1	2	11.54	
165	164+000	0	0	1	1	3.02	Shooyii
166	165+000	0	0	0		0.00	
167	166+000	0	0	0		0.00	
168	167+000	1	0	1	2	11.54	Sakkee
169	168+000	0	1	1	2	7.64	Mesalemiya
170	169+000	1	1	2	4	12.06	*Walee cilalloo
171	170+000	0	0	0		0.00	
172	171+000	0	0	0		0.00	
173	172+000	1	0	1	2	11.54	Laga hantuutaa
174	173+000	0	0	0		0.00	
175	174+000	0	0	1	1	3.02	
176	175+000	0	0	1	1	3.02	
177	176+000	0	0	1	1	3.02	
178	177+000	1	0	1	2	11.54	
179	178+000	0	0	1	1	3.02	Goha land
180	179+000	0	0	1	1	3.02	
181	180+000	0	0	0		0.00	
182	181+000	0	0	0		0.00	
183	182+000	0	0	0		0.00	
184	183+000	0	0	1	1	3.02	
185	184+000	1	0	1	2	11.54	
186	185+000	0	0	0		0.00	
187	186+000	1	1	2	4	12.06	*Abay gorge
188	187+000	0	1	2	3	3.81	
189	188+000	0	0	1	1	3.02	

190	189+000	0	0	1	1	3.02	
191	190+000	1	0	1	2	11.54	
192	191+000	0	0	1	1	3.02	
193	192+000	0	1	1	2	7.64	
194	193+000	0	0	1	1	3.02	
195	194+000	1	0	1	2	11.54	
196	195+000	1	0	1	2	11.54	
197	196+000	0	0	0		0.00	
198	197+000	0	0	1	1	3.02	
199	197+237	0	0	0		0.00	

APPENDIX B3 Accident Density Calculation

N.S	Station/ Section(j) km	Number of accidents (Aj)	Accidental density	Name of the places
1	0+000-1+000	0	0	
2	1+000-2+000	8	8	
3	2+000-3+000	10	10	
4	3+000-4+000	6	6	
5	4+000-5+000	14	14	*10 kilo
6	5+000-6+000	14	14	*Wasarbii
7	6+000-7+000	7	7	
8	7+000-8+000	9	9	
9	8+000-9+000	19	19	*Qimbirree
10	9+000-10+000	5	5	
11	10+000-11+000	17	17	*Shuffunnee
12	11+000-12+000	16	16	*Doro irbata
13	12+000-13+000	10	10	
14	13+000-14+000	15	15	*Ashewa
15	14+000-15+000	16	16	*Prime milk
16	15+000-16+000	14	14	*Kajima
17	16+000-17+000	9	9	
18	17+000-18+000	9	9	
19	18+000-19+000	10	10	
20	19+000-20+000	16	16	*Leather factory
21	20+000-21+000	8	8	
22	21+000-22+000	6	6	
23	22+000-23+000	5	5	
24	23+000-24+000	13	13	
25	24+000-25+000	10	10	
26	25+000-26+000	9	9	
27	26+000-27+000	11	11	Malima
28	27+000-28+000	21	21	*Gajoo
29	28+000-29+000	13	13	
30	29+000-30+000	31	31	kosobar
31	30+000-31+000	12	12	
32	31+000-32+000	23	23	Derba mazoria
33	32+000-33+000	9	9	
34	33+000-34+000	10	10	stadium
35	34+000-35+000	26	26	*Mesalemiya

36	35+000-36+000	29	29	*laga chancho
37	36+000-37+000	8	8	
38	37+000-38+000	13	13	Guto
39	38+000-39+000	13	13	
40	39+000-40+000	9	9	
41	40+000-41+000	31	31	laga leencaa
42	41+000-42+000	10	10	Mooyyee gajoo
43	42+000-43+000	11	11	
44	43+000-44+000	6	6	
45	44+000-45+000	13	13	
46	45+000-46+000	26	26	Abbichuu
47	46+000-47+000	10	10	
48	47+000-48+000	11	11	
49	48+000-49+000	30	30	*Gorfoo
50	49+000-50+000	10	10	
51	50+000-51+000	9	9	
52	51+000-52+000	12	12	
53	52+000-53+000	28	28	Bacho
54	53+000-54+000	10	10	
55	54+000-55+000	8	8	Waajjituu
56	55+000-56+000	9	9	
57	56+000-57+000	12	12	
58	57+000-58+000	13	13	
59	58+000-59+000	14	14	*Laga roobaa
60	59+000-60+000			
61	60+000-61+000	14	14	*Dubar river
62	61+000-62+000			
63	62+000-63+000	16	16	*Koran
64	63+000-64+000	2	2	
65	64+000-65+000			
66	65+000-66+000	15	15	*Wada
67	66+000-67+000	6	6	
68	67+000-68+000			
69	68+000-69+000	2	2	
70	69+000-70+000	3	3	
71	70+000-71+000			
72	71+000-72+000	4	4	
73	72+000-73+000			
74	73+000-74+000	1	1	
75	74+000-75+000	7	7	
76	75+000-76+000			

77	76+000-77+000	4	4	*Sallee
78	77+000-78+000	1	1	
79	78+000-79+000	1	1	
80	79+000-80+000	2	2	
81	80+000-81+000	2	2	
82	81+000-82+000	1	1	
83	82+000-83+000	1	1	
84	83+000-84+000	4	4	*Gurso
85	84+000-85+000	1	1	
86	85+000-86+000	1	1	
87	86+000-87+000	5	5	*Qasim school
88	87+000-88+000	1	1	Wakene tuli
89	88+000-89+000	1	1	Wakene
90	89+000-90+000	2	2	Wushagedel
91	90+000-91+000	1	1	
92	91+000-92+000	9	9	*Dhankaka/wartu
93	92+000-93+000	3	3	Chagal town
94	93+000-94+000	2	2	
95	94+000-95+000	18	18	*Laga guurii
96	95+000-96+000	3	3	
97	96+000-97+000	3	3	
98	97+000-98+000	2	2	
99	98+000-99+000	3	3	
100	99+000-100+000	2	2	
101	100+000-101+000	3	3	
102	101+000-102+000	3	3	
103	102+000-103+000	2	2	
104	103+000-104+000	3	3	Commando
105	104+000-105+000	2	2	Bus station
106	105+000-106+000	2	2	Fitche hospital
107	106+000-107+000	10	10	*Torban Ashee
108	107+000-108+000	3	3	
109	108+000-109+000	3	3	
110	109+000-110+000	3	3	
111	110+000-111+000	2	2	
112	111+000-112+000	2	2	
113	112+000-113+000	2	2	
114	113+000-114+000	2	2	
115	114+000-115+000	3	3	Church
116	115+000-116+000	2	2	
117	116+000-117+000	13	13	*Laga Silmii

118	117+000-118+000	3	3	
119	118+000-119+000	2	2	
120	119+000-120+000	2	2	
121	120+000-121+000	1	1	
122	121+000-122+000	2	2	
123	122+000-123+000	3	3	Jajjabduu
124	123+000-124+000	3	3	Ayane Garbi bridge
125	124+000-125+000	2	2	
126	125+000-126+000	3	3	East cement
127	126+000-127+000	1	1	
128	127+000-128+000	2	2	
129	128+000-129+000	17	17	*Eegduu
130	129+000-130+000	2	2	
131	130+000-131+000	1	1	
132	131+000-132+000	2	2	
133	132+000-133+000	3	3	
134	133+000-134+000	12	12	*Hambiso 01 keb.
135	134+000-135+000	2	2	
136	135+000-136+000	2	2	
137	136+000-137+000	3	3	
138	137+000-138+000	2	2	
139	138+000-139+000	2	2	
140	139+000-140+000	5	5	*Laga qallaa
141	140+000-141+000	1	1	Ganda birrattee
142	141+000-142+000	2	2	ula
143	142+000-143+000	3	3	kesi
144	143+000-144+000	3	3	muka chita
145	144+000-145+000	2	2	Goraa
146	145+000-146+000	3	3	Lideta
147	146+000-147+000	2	2	Yetebaberut
148	147+000-148+000	1	1	G.G Preparatory
149	148+000-149+000			
150	149+000-150+000	5	5	*G/G River
151	150+000-151+000	2	2	Scan scan
152	151+000-152+000	4	4	*Misilii iraasuu
153	152+000-153+000			
154	153+000-154+000	2	2	Biriti junction
155	154+000-155+000	1	1	karekura school
156	155+000-156+000	2	2	Bargamo Hurrisaa
157	156+000-157+000			
158	157+000-158+000			

159	158+000-159+000			
160	159+000-160+000	5	5	*Bitoo milkii
161	160+000-161+000	2	2	
162	161+000-162+000	1	1	
163	162+000-163+000	3	3	old market
164	163+000-164+000	2	2	
165	164+000-165+000	1	1	Shooyii
166	165+000-166+000			
167	166+000-167+000			
168	167+000-168+000	2	2	Sakkee
169	168+000-169+000	2	2	Mesalemiya
170	169+000-170+000	4	4	*Walee cilalloo
171	170+000-171+000			
172	171+000-172+000			
173	172+000-173+000	2	2	Laga hantuutaa
174	173+000-174+000			
175	174+000-175+000	1	1	
176	175+000-176+000	1	1	
177	176+000-177+000	1	1	
178	177+000-178+000	2	2	
179	178+000-179+000	1	1	Goha land
180	179+000-180+000	1	1	
181	180+000-181+000			
182	181+000-182+000			
183	182+000-183+000			
184	183+000-184+000	1	1	
185	184+000-185+000	2	2	
186	185+000-186+000			
187	186+000-187+000	4	4	*Abay gorge
188	187+000-188+000	3	3	
189	188+000-189+000	1	1	
190	189+000-190+000	1	1	
191	190+000-191+000	2	2	
192	191+000-192+000	1	1	
193	192+000-193+000	2	2	
194	193+000-194+000	1	1	
195	194+000-195+000	2	2	
196	195+000-196+000	2	2	
197	196+000-197+000			
198	197+000-198+000	1	1	
199	198+000-199+237			

APPENDIX C Sample Spot Speed Calculation

Analysis of Spot Speed at Blackspot number 2 (BS2)

Speed (km/hr)	Frequency	Cummulative frequency	Cummulative percent	Speed Percentile	
30.12	1	1	1.00		
39.58	1	2	2.00		
40.07	1	3	3.00		
40.25	2	5	5.00		
40.91	2	7	7.00		
42.41	1	8	8.00		
44.25	1	9	9.00		
49.18	1	10	10.00		
53.32	1	11	11.00		
53.7	2	13	13.00		
57.18	2	15	15.00		
59.45	1	16	16.00		
59.68	1	17	17.00		
60.08	2	19	19.00		
61.39	1	20	20.00		
62.07	2	22	22.00		
63.11	1	23	23.00		
63.74	1	24	24.00		
64.29	3	27	27.00		
65.5	2	29	29.00		
66.27	1	30	30.00		
66.47	1	31	31.00		
68.18	1	32	32.00		
68.39	2	34	34.00		
69.98	2	36	36.00		
70.42	1	37	37.00		
70.87	1	38	38.00		
71.32	2	40	40.00		
71.88	1	41	41.00		
72.35	1	42	42.00		
72.58	1	43	43.00		
72.82	2	45	45.00		
73.65	1	46	46.00		

74.01	1	47	47.00	74.38	50th
75.00	8	55	55.00		
75.63	2	57	57.00		
76.01	1	58	58.00		
76.53	1	59	59.00		
76.79	1	60	60.00		
77.19	1	61	61.00		
78.26	1	62	62.00		
78.81	1	63	63.00		
79.51	1	64	64.00		
80.94	1	65	65.00		
81.08	3	68	68.00		
81.52	2	70	70.00		
82.27	1	71	71.00		
82.72	1	72	72.00		
83.18	1	73	73.00		
83.64	2	75	75.00		
85.39	2	77	77.00		
85.88	1	78	78.00		
87.72	2	80	80.00	88.76	85th
90.00	11	91	91.00		
91.46	2	93	93.00		
94.34	1	94	94.00		
96.57	2	96	96.00		
103.93	2	98	98.00		
112.5	1	99	99.00		
150	1	100	100.00		

APPENDIX D Output of Multiple Regressions Using SPSS

Descriptive Statistics			
	Mean	Std. Deviation	N
Number of Accident	15.24	8.437	37
Lane Width	3,5632	,08982	37
Shoulder Width	.03	.164	37
Horizontal Radius	.46	.505	37
Supper elevation	.76	.435	37
Vertical Curve	.78	.417	37
Gradient	.73	.450	37
85th Percentile Speed	.46	.505	37
Minimum Clear Zone	13,4946	2,29637	37

Correlations										
		Number of Accident	Lane Width	Shoulder Width	Horizontal Radius	Supper elevation	Vertical Curve	Gradient	85th Percentile Speed	Minimum Clear Zone
Pearson Correlation	Number of Accident	1.000	-.055	.155	-.112	.191	.039	.025	.123	.187
	Lane Width	-.055	1.000	.163	-.291	-.157	.190	-.170	.364	-.016
	Shoulder Width	.155	.163	1.000	-.154	-.294	.088	-.274	-.154	-.191
	Horizontal Radius	-.112	-.291	-.154	1.000	.396	.089	-.050	-.197	-.034
	Supper elevation	.191	-.157	-.294	.396	1.000	-.145	.222	.143	-.143
	Vertical Curve	.039	.190	.088	.089	-.145	1.000	.124	-.174	-.129
	Gradient	.025	-.170	-.274	-.050	.222	.124	1.000	-.172	.052
	85th Percentile Speed	.123	.364	-.154	-.197	.143	-.174	-.172	1.000	.342
	Minimum Clear Zone	.187	-.016	-.191	-.034	-.143	-.129	.052	.342	1.000
Sig. (1-tailed)	Number of Accident	.	.373	.179	.255	.129	.409	.441	.234	.133
	Lane Width	.373	.	.167	.040	.177	.130	.157	.013	.462
	Shoulder Width	.179	.167	.	.182	.039	.303	.050	.182	.129
	Horizontal Radius	.255	.040	.182	.	.008	.300	.386	.121	.421
	Supper elevation	.129	.177	.039	.008	.	.196	.093	.198	.199

	Vertical Curve	.409	.130	.303	.300	.196	.	.233	.151	.224
	Gradient	.441	.157	.050	.386	.093	.233	.	.155	.379
	85th Percentile Speed	.234	.013	.182	.121	.198	.151	.155	.	.019
	Minimum Clear Zone	.133	.462	.129	.421	.199	.224	.379	.019	.
N	Number of Accident	37	37	37	37	37	37	37	37	37
	Lane Width	37	37	37	37	37	37	37	37	37
	Shoulder Width	37	37	37	37	37	37	37	37	37
	Horizontal Radius	37	37	37	37	37	37	37	37	37
	Supper elevation	37	37	37	37	37	37	37	37	37
	Vertical Curve	37	37	37	37	37	37	37	37	37
	Gradient	37	37	37	37	37	37	37	37	37
	85th Percentile Speed	37	37	37	37	37	37	37	37	37
	Minimum Clear Zone	37	37	37	37	37	37	37	37	37

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Minimum Clear Zone, Lane Width, Gradient, Vertical Curve, Supper elevation, Shoulder Width, Horizontal Radius, 85th Percentile Speed[b]	.	Enter
a. Dependent Variable: Number of Accident			
b. All requested variables entered.			

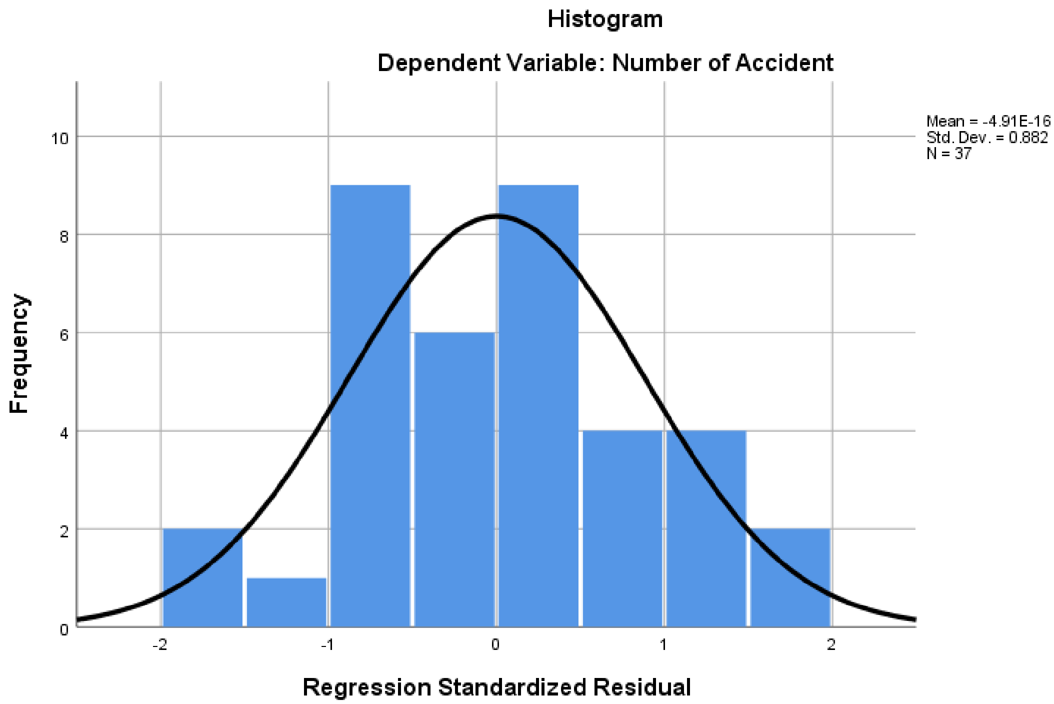
Model Summary[b]										
					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.495[a]	.245	.030	8.312	.245	1.137	8	28	.370	.944
a. Predictors: (Constant), Minimum Clear Zone, Lane Width, Gradient, Vertical Curve, Supper elevation, Shoulder Width, Horizontal Radius, 85th Percentile Speed										
b. Dependent Variable: Number of Accident										

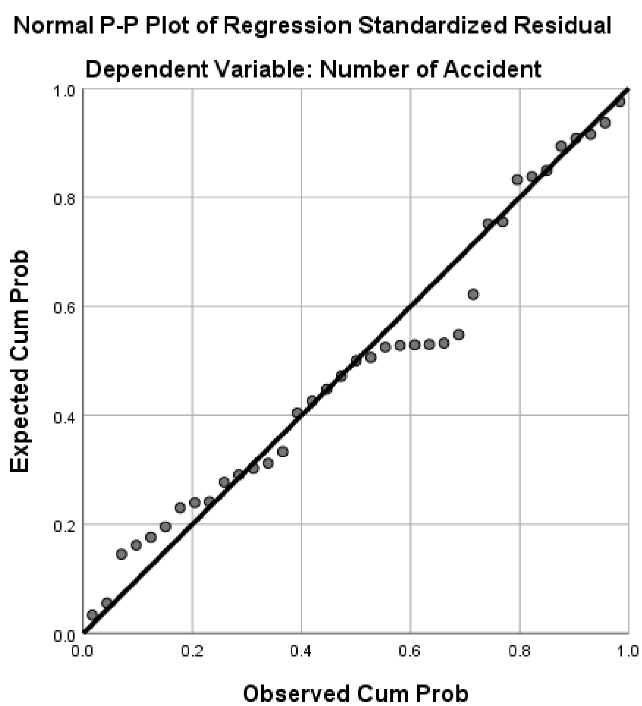
ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	628.505	8	78.563	1.137	.370[b]
	Residual	1934.306	28	69.082		
	Total	2562.811	36			
a. Dependent Variable: Number of Accident						
b. Predictors: (Constant), Minimum Clear Zone, Lane Width, Gradient, Vertical Curve, Supper elevation, Shoulder Width, Horizontal Radius, 85th Percentile Speed						

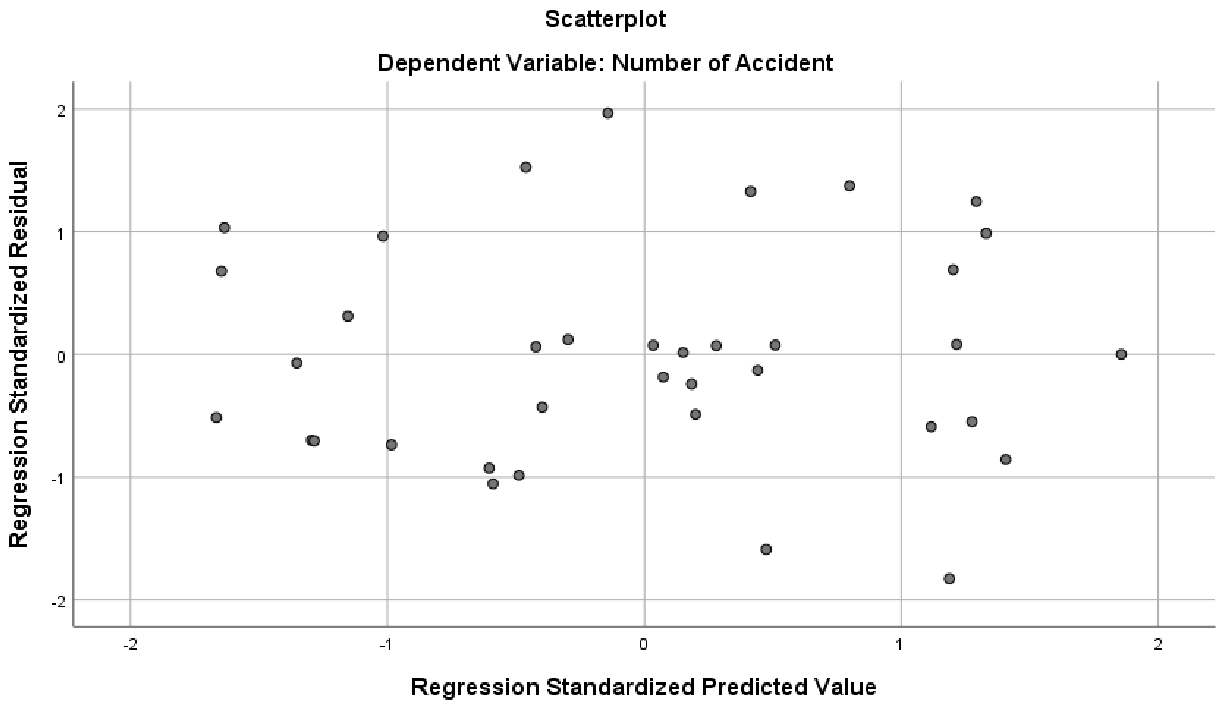
Coefficients[a]														
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	49.388	67.184		.735	.468	-88.233	187.009					
	Lane Width	-15.998	18.496	-.170	-.865	.394	-53.886	21.890	-.055	-.161	-.142	.695	1.438
	Shoulder Width	15.241	9.487	.297	1.606	.119	-4.193	34.674	.155	.291	.264	.789	1.268
	Horizontal Radius	-5.111	3.403	-.306	-1.502	.144	-12.080	1.859	-.112	-.273	-.247	.649	1.540
	Supper elevation	8.959	4.162	.462	2.152	.040	.433	17.485	.191	.377	.353	.585	1.708

	Vertical Curve	3.902	3.674	.193	1.062	.297	-3.624	11.428	.039	.197	.174	.816	1.225
	Gradient	-1.473	3.604	-.079	-.409	.686	-8.856	5.909	.025	-.077	-.067	.729	1.372
	85th Percentile Speed	.239	3.631	.014	.066	.948	-7.198	7.676	.123	.012	.011	.570	1.753
	Minimum Clear Zone	1.180	.703	.321	1.679	.104	-.259	2.619	.187	.303	.276	.737	1.357
a. Dependent Variable: Number of Accident													

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	8.28	23.00	15.24	4.178	37
Residual	-15.203	16.350	.000	7.330	37
Std. Predicted Value	-1.666	1.856	.000	1.000	37
Std. Residual	-1.829	1.967	.000	.882	37
a. Dependent Variable: Number of Accident					


Histogram
Dependent Variable: Number of Accident
Mean = -4.91E-16
Std. Dev. = 0.882
N = 37
Frequency
0
2
4
6
8
10
-2
-1
0
1
2
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Number of Accident
Expected Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob



Scatterplot
Dependent Variable: Number of Accident
Regression Standardized Residual
Regression Standardized Predicted Value
2
1
0
-1
-2
-2
-1
0
1
2