EVALUATION THE EFFECTS OF GEOMETRIC DESIGN PARAMETERS ON TRAFFIC CRASHES(A CASE STUDY: ALETA WONDO - BONA-DAYE ROAD SECTION)

MSc. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "Evaluation the Effects of Geometric Design Parameters on Traffic Crashes (A case study on AletaWondo - Bona -Daye Road Section) submitted in partial fulfillment of the requirements for the degree of **Masters of Science** with specialization in **Road and Transport Engineering,** the Graduate Program of the **School of Civil Engineering**, has been carried out by **Mr. DawitBeyeneAshango,**(ID No:**PGRo/006/10)** under our supervision. Accordingly, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the Final Master's Degree Open Defense, we certify that we have read and evaluated the thesis prepared by: **DawitBeyeneAshango**under the title **"**Evaluation the effects of Geometric Design Parameters on Traffic Crashes (A case study:AletaWondo - Bona- Daye Road section)and have recommended that it can be accepted as fulfilling the thesis requirement for the degree of **Masters of Science** in **Civil Engineering** with Specialization in **Road and Transport Engineering**.

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DECLARATION

I hereby declare that this MSc thesis entitled **"Evaluation the Effects of Geometric Design Parameters on Traffic Crashes(A case study on AletaWondo - Bona- Daye Road section)"** is my original work and has not been presented for a degree in any other university and all sources of materials used in its preparation have been duly acknowledged.

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ABBREVIATIONS

AADT: Average Annual Daily Traffic

ADT: Average Daily Traffic

CBD: Central Business District

ERA: Ethiopian Roads Authority

GDP: Gross Domestic Product

HPI: Highway Policy Information

HCM: Highway Capacity Manual

RTA: Road Traffic Accident

MH: Median Height

MT: Median Type

MW: Median Width

NA: Number of Access

NAC: Number of Access Control

NHC: Number of Horizontal Curves

NL: Number of Lanes

NVC: Number of Vertical Curves

PC: Police Commission

PCU: Passenger Cars Unit

PHV: Peak Hourly Volume

SH/SW: Shoulder or Sidewalk

SNNPR: Southern Nations Nationalities and Peoples Region

SZTPC: Sidama Zone Traffic Police Commission

WB: World Bank

WHO: World Health Organization

TWLTL: Two way-Left-Turn lanes

TPO: Traffic Police Office

TPC: Traffic Police Commission

WHO: World Health Organization

TWLTL: Two way - Left -Turn Lanes

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ABSTRACT

The problem of road crashes have been increasing in alarming rate and it is a serious problem all over the world, mainly in developing countries. Ethiopia's road accidents in terms of volumes, frequencies and severities are among the highest in the world. Specifically in Ethiopia,Sidama Zone under SNNPR has taken as one of leading road traffic crashes, particularly on Aletawondo - Bona - Daye road section. The objective of this study was to investigate the effect of road geometric design elements on road traffic crash occurrences at road segments on Aletawondo-Bona-Daye road section. In this study, data were collected regarding geometric characteristics; the number of crashes and traffic volume from twenty-nine (29) road sections which were selected based on the convenience sampling method. A total of 203 number of road accidents were collected from the woredas, Alatawondo and Daye town and Sidama Zone Police Commission over a period of five years, between 2013/14 and 2018/19. Regarding the analysis of the data, the Poisson Regression model and the Negative Binomial Regression models and Empirical Bayesian (EB) methods were utilized. The SPSS 20 software packages were applied to analyze the effects of variables. In addition to this, descriptive statistics was used to conclude the nature and characteristics of crash occurrences. A sum of 331 road crash data was gathered for five consecutive years comprising 47 fatal, 143 injuries and 141 property damages only for the general analysis in the study road section. The results of this study showed that there is a strong correlation between road geometric design elements and road crash occurrences. The modeling result indicated that gradient, median type, number of horizontal curves, number of vertical curves, number of lanes, sidewalk or shoulder width, number of access, number of access controls and average daily traffic are significantly affecting road crash occurrences. The general analysis in the road section reveals that most crashes occurred at road sections, painted two-way and one-way roads, particularly in rural residential and non-residential (forestry) areas. The EB result indicated that among 29 studies road sections, 13 sections were highly prone to accidents with PI values. The results of this study envisaged to support transport planners and road designers in consideration of road safety issue and sustainable road design standards and giving technical awareness for traffic policy on traffic data.

Keywords: Road geometric characteristics, Road crash occurrences, Negative Binomial Regression, Poisson Regression model and Empirical Bayesian (EB) method.

1. INTRODUCTION

1.1 Background

Generally, the main goal of transportation is stated as safe and efficient movement of people and goods from one place to another. Proper road design is a requirement for safe movement of traffic. Usually, drivers make fewer errors at geometric features that conform to their expectations. Deficiency in design can be described as a geometric feature or combination of features that has such a high driver workload requirement and those drivers may drive in an unsafe manner. This situation could lead to inappropriate driving maneuvers and/or an undesirable level of crashes. According to Fitzpatrick, K., and Collins, J.M. (2000), the roadway geometry, traffic conditions and roadside environment are the primary inputs to the driving task that determine the workload requirement of the driver. How quickly and how well these inputs are handled depend on driver expectancy and other human factors. Once these inputs are processed, they are translated into vehicle operations. When design deficiency on road exists that violates driver's expectation, the driver may adopt an inappropriate speed or inappropriate maneuvers, potentially leading to accidents.

Factors that cause road traffic crashes are categorized into road user factors, road characteristics factors, and vehicle factors. Hence, road factors are the scope of civil engineering professionals and considered as part of this study. It is very important for the highway to establish a harmony between all the three factors at the design stage of the highway. With standard road geometric design elements, it is possible to compensate for the other factors and thus decrease the number of road traffic crashes. Negative road engineering factors include where a road defect directly triggers a crash, where some element of the road environment misleads a road user and thereby creates an error (Dinesh et al., 2006).

The World Health Organization (WHO) and the World Bank (1999) reported that globally, road fatalities were expected to increase with a toll between 900,000 and 1.1 million in 2010. This figure is expected to reach between 1.1 million and 1.3 million in 2020. The trend of historical data shows that the total number of people killed in road crashes in developing world continues to increase. Considering this fact, many researchers listed in literature reviews have come up with the possible causes and effects of traffic accidents. The results of the studies indicated that drunk driving; vehicle mechanical failures, over speeding and others have been identified as some of the major causes of traffic accidents. According to WHO (2013), global status of road traffic accidents show that at least 1.3 million people are killed every year due to road crashes. Some 20-50 million people suffer with various forms of disabilities. The report also shows that 90% of road casualties were in low and middle-income countries. The same reports estimated that road traffic crashes are expected to be the 3rd leading cause of death worldwide by the year 2020, if rigorous and remarkable actions are not taken.

The report prepared on "The Global Burden of Disease", indicated that deaths from non-communicable diseases are expected to climb from 28.1 million in 1990 to 49.7 million by 2020 (an increase in absolute numbers of 77%). Road traffic crashes will contribute significantly to this rise. Concomitantly, the report show that road traffic injuries are expected to move from ninth place in 1990 to third place in the rank order of disease burden by 2020 (World Health Organization & World Bank, 1999).

Review of the magnitude of the problem revealed that 1.2 million people die due to road traffic crashes annually. On the average, in advanced and many developing countries, one out of every ten hospital beds is occupied by road traffic crash accident victims (National Road Safety of Developing Countries Council, 2010). The 1999 WHO publication on "Injury: A Leading Cause of the Global Burden of Disease," reported that road traffic crashes were the major causes of severe injuries in most countries and the leading injury-related cause of death among people aged 15-44 years. The WHO report also indicated that around 38.8 million people were injured by motor vehicle crashes in 1998. Out of the 5.8 million people who died of injuries, around 1.1 million (20%) died as result of injuries sustained by motor vehicle crashes. These facts reveal unacceptable levels of road traffic accidents and casualties.

The death rate presently stands near 70 per 10,000 vehicles. Of those killed, over half were pedestrians of which 20% were children under the age of 18. The economic loss due to road accident is also significant. Unless the trend is arrested, the social and economic problem of road traffic accidents will become more and more serious as the number of vehicle increases. In this regard, considering the importance of road safety, the Ethiopian government has requested the World Bank (WB) to review the road safety management capacity of the country. This review, based on benchmarked results of road safety management and the UN Global Plan guideline, were used for the development of national decade strategy for road safety (Minister of Transport, February, 2011). Despite all these efforts, the challenges of road traffic accident are still increasing from time to time.

Road safety is one among the serious problems in the world. According to the WHO (2015) Report, an approximated 1.25 million people are killed and up to 50 million injured worldwide every year; on average, 3,287 fatalities a day in road crashes. Additionally, road traffic crashes are the leading cause of death for adolescents aged 15 to 29, cost governments approximately 3 to 5% of GDP, and about 90% of the world's fatalities on the roads occurs in low and middle-income countries, which have only 54% of the world's registered vehicles.

Africa has one of the highest road traffic death rates in the world, with little difference in rates between those countries categorized as low-income (32.3 deaths per 100,000 populations per year). Whereas, the range of fatalities per 100,000 populations in countries of African region is not very wide, 70% of all the deaths in the Region occurred in the ten countries that account for 70% of the regional population: Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Nigeria, South Africa, and Tanzania (World Health Organization & World Bank, 1999).

Therefore, road traffic accident is becoming global and national problem and creating social and economic burden for countries. According to the World Health Organization Report, the economic costs of road crashes and injuries are estimated to be 1% of Gross Domestic Product (GDP) in low-income countries. Road traffic crashes cost developing countries a staggering 1–2% of their gross domestic product (William Eckersley et. al, Jan 21, 2010).

Ethiopia is one of the developing countries with high traffic accidents costing the country around 0.8% - 0.9% of the GDP for the past consecutive years (Ethiopian Federal Police Commission, 2008). Like any developing economies, Ethiopia has been experiencing large number of traffic accidents annually. To curb the problem, strong interventions and strategies are expected to deal with the challenges so as to reduce its impact by 50% at the end of 2020 (United Nations Global Plan for the Decade of Action for Road Safety 2011-2020).

The Southern Nations, Nationalities and Peoples Region (SNNPR)is one of the regions where severe road traffic accidents are caused in Ethiopia. Among the road sections in the region, a detailed study of road accidents on the main trunk road segment of the

AlataWondo - Bona- Daye road has been envisaged to give an opportunity to deal with pertinent problems. This is expected to provide rational remedial measures for the adverse effects of different road geometric parameters independently to minimize loss of life and property damages. Regarding this, a methodology was defined to better understand road geometric features that lead to traffic accidents through addressing the proposed questions using a post-accident approach to find correlations between road geometric parameters and traffic accidents by integrating with a statistical regression analysis method.

Horizontal curves have a large impact on the casualty crash risk. Single curves in the 200 m to 600 m range have been found to have the greatest risk. For instance, a sharp curve with a 100 m radius has a 5.5 times higher crash risk than a relatively straight section. Crash severity was found to be somewhat higher on milder curves; however, mainly due to the effect of higher speeds. Crash risk on curves is strongly associated with a high approach speed combined with a large speed change across the curve. For instance, a curve causing a speed reduction of 30 km/h from an approach speed of 100 km/h elevates the risk of a run-off-road casualty crash by 5.1 times. The same speed change but from an approach speed of 60 km/h will increase the risk by 3.1 times (Cardoso 2005).

On vertical grades, casualty crashes increase as the road grade increases, particularly on downhill grades, with a significant increase in the number of crashes and the severity of the crashes when the grade is greater than 6% (Austroads 2014). Sight distance along vertical curves affects the crash risk and it has been found that where the curve is deficient by greater than 40% compared to the design value, the risk increases by 40%, i.e. a relative risk of 1.40 (Austroads 2010).

Run-off-road events contribute to about a third of all fatal and serious injury crashes on rural roads (Victorian data based on Jurewicz et al. 2014). Design of road alignment and its delineation play a crucial role in helping drivers to stay on the road. When drivers make errors, or are impacted by events outside of their control (objects/animals on the road, actions of other drivers), design of the roadsides can have a significant contribution to improving safety on rural roads. Geometry of roadsides should be considered as part of any road design.

In view of the foregoing, this research usedNegativeBinomial and Poisson RegressionAnalysis modelsto determine the relationships between road geometry parameters and crash rate. Furthermore, the study examined the cases of collapses that are most influenced by the critical road parameters which means, it examined crash rates due to the deficiencies of road geometric design. The study concentrated on roadtraversing thetwo districts ofAlataWondo up to Tetichaintersection andTeticha intersection to Daye road sections including Bona at the middle. The length of the road is about 84.5 kilometers. In addition to the traffic accident related to geometric design, the study also focused on assessing the general characteristics of road traffic accidents, major causes and factors that are contributing to traffic accidents and their effects and the required countermeasures to reduce the severity of road traffic accidents that are specific to the deficiencies of geometric parameters.

This study identified and assessed the road traffic accidents spatially and temporally considering its relevance to planners, policy makers, stakeholders and the community as a whole. The research used different engineering techniques and design to ensure the geometric design and construction of road safety would become reliable in future. Finally, the research identified major geometric characteristics that influence road traffic crashes on the subject road section and forwarded recommendations to facilitate road safety in Ethiopia in general and in SNNPR in particular through the consideration of pertinent policy makers.

1.2. Statement of the problem

Most African countries have insufficient policies and strategies to protect vulnerable road users. Also, there is rarely traffic law enforcement, traffic regulation and post-crash treatment in most countries in the region (WHO, 2013). In Ethiopia, road traffic accident is a perennial problem, specifically on AlataWondo - Bona-Daye Road Section. However,causes of traffic crashes in Ethiopia are limited only to traffic police officials and are mostly reported as the problem of drivers and passengers with little consideration of geometric design parameters and experience about the effects of roads components on traffic safety. Geometric design inadequacy on existing roads lead to a potential traffic crashes, such as crashes happens at the sharp curves, layered pavement conditions and inconsistency sections along the road. Some of the primary road geometric design elements that can influence road crashes on highways are horizontal curvature, grade, shoulder and median (Mohammed, 2013). This incidence has long been adversely affecting the surrounding people through fatalities, injuries and property damages costing the area and the nation significant resources. Further, the trend of crashes is increasing on the road section from time to time.

The AlataWondo - Bona - Daye highway is one of the ruralpaved roads in Ethiopia and many of its sections are built on mountainous and escarpment terrain with significant road traffic accidents in the past five years, since the road started providing services. Despite this fact, there have been no assessment made on the accident level of the road and no study has been conducted to identify the causes of these traffic accidents. This study envisaged to fill the research gap on the area focusing on identifying the causes of traffic accidents regarding geometric parameters of the roads, location and then proposes possible measures that will help to minimize the level of traffic accidents on the study road.

This study is envisaged to close the gap by identifying contributions of road geometric parameters on the occurrence of road traffic crashes. If considered by relevant policy makers, this study is expected to contribute to the reduction human sufferings and social costs of the study area, including resources which are vital to the nation.

1.3 Objectives

1.3.1. General Objective

The main objective of this study is to analyze the effects of geometric road design elements on traffic crashes occurrence and crash severity by considering two-way ruralroads of study area.

1.3.2. Specific Objectives

The specific objectives of the study are:

- ✓ To characterize the geometric design parameters on AlataWondo - Bona - Daye two way rural trunk study road section;
- ✓ To investigate the nature and characteristics of road traffic crashes on AlataWondo - Bona-Daye roads section located in SNNPR;
- ✓ To analyze the effects of geometric design elements on theroad traffic crasheson AlataWondo - Bona-Daye road section by utilizing the Negative Binomial andPoissonRegression Analysis modelsand Empirical Bayesian (EB) method.

1.4 . Research Questions

The core goal of the study was the analysis of the effects of the road geometric characteristics that cause road accidentsonAlataWondo – Bona-Daye road section. Thestudy addressed issues with several research questions that promise to provide a better insight into the effects of road geometric elements on road crashes on the road section. In this regard, the main research questions are:

- ✓ What are the characteristics of geometric design parameters on Alatawondo-Bona-Daye road section?
- ✓ What is the nature and characteristics of road traffic crashes onAlataWondo -Bona - Daye road section?And
- ✓ What are the effects of geometric design parameters on traffic crashes occurrence rates?

1.5. Limitations and Scope of the Study

The study focused on the analysis of the effects of geometric design parameters on traffic crash occurrences on road sections of the Aletawondo- Bona - Daye (case study). The study used traffic data of the five years from 2014/15 to 2018/19 and for more precision one year 2013/14 data back addedfor analysis. The combinations of horizontal and vertical curves effects (was not detail analyzed), vehicle factors, human factors and pavement surface moisture conditions were not correlated with expected number of accidents. Therefore, recommended that further study should be conducted to get solution. Also road and its environment variable such as land use, posted speed, percentages of heavy vehicles and others were not incorporated. Moreover, the study used average daily traffic (ADT) on effects analysis for Negative binomial and Poisson regression models and average annually daily traffic (AADT) for more analysis of horizontal curves elements effects on traffic crashes through using Empirical Bayesian (EB) method as exposure variables. However, pedestrian volume is not incorporated on regression models for effectsanalysis. Additionally, a one-hour counting method was used to calculate peak hour volume (PHV).

1.6. Scope of the Study

The analysis has taken the influence of road geometric characteristics on the occurrence of road crashesonAlataWondo -Bona-Daye road section in SNNPR. Thus, the significances of the research findings are:

- ✓ To analyze and show the effects of geometric design parameters on traffic crashes;
- ✓ To introduce additional knowledge on highway engineering, on how to solve traffic safety problems on highwaysby using newly acquired knowledge during design and construction of roads;
- ✓ To provide support to road safety authorities, road designers and planners for consideration of proactive means before the occurrences of road accidents;
- ✓ It will significantly contribute in road safety aspects in Ethiopia since the problem is significant compared to many nations in the world; and

- ✓ The results of the study can help other researchers who willbe engaged in studies of related areas.

The above stated outputs of this research will may help for the sustainable safety on Ethiopian roads as much as for other countries in general and for the study road area in particular and for practical application of highway design safety manual with proper design of geometric parameters to mitigate traffic accidents through the country.

2. LITERATURE REVIEW

2.1. Introduction

There are different researches and traffic accident assessments that have been conducted at national and international levels. In this regard, Debela Deme (2016) stated that the possible major causes of accidents that are identified in the research included unethical operational behaviors of drivers (poor visibility and over speeding) that accounted for 59.8 percent the accidents. In terms of fatality, unethical driving of vehicles was the worst of all records. Particularly, geometric design is not a contributory factor to road accidents registered on Addis Ababa-Adama expressway so far, other than exacerbating the severity of accidents.

Glennon, J. C. and Harwood, D.W. (1978) stated that geometric features design consistency implies that the design or geometry of a road does not violate either the expectation of the drivers or the ability of the motorist to guide and control a vehicle in a safe manner. Keeping a roadway consistent in design is important because it is believed that drivers make fewer errors at geometric features that conform to their expectations than at features that violate their expectancies. Inconsistency in geometric design features can be defined as "a geometric feature or combination of adjacent features that have such unexpectedly high driver workload that motorists may be surprised and possibly drive in an unsafe manner (Post, T.Alexander, G. and Lunenfeld, H., 1981.)

A consistent alignment is important because of the relationship that exists between consistency and safety. The inconsistencies that exist on a roadway can produce a sudden change in the characteristic of the roadway which can surprise drivers and lead to speed errors. These design inconsistencies arise when the general character of alignment changes between segments of the roadway. A consistent alignment would ensure that "most drivers would be able to operate safely at their desired speed along the entire alignment as stated by Messer, C.J. (1980).

Geometric features design consistency refers to the conformance of the highway geometry to driver expectancy. Expectancy, in general, can be thought of as a set of possible probabilities regarding a given situation. Those probabilities are subjective and are based upon learnedand experienced events. An operational definition of expectancy with regard to transportation was stated by Ellisas driver expectancy relates to the observable, measurable features of the driving environment.

The World Health Organization(WHO) defined road traffic crash as "any crash involving a device designed primarily for, or being used at the time primarily for, conveying persons or goods from one place to another put the page no. on the reference". Alternatively, road crash are classified on the basis of the following conditions; the death of a person within 30 days of the crash; personal injury to the extent that the injured person was admitted to hospital; the crash occurred on any road/street, or any place open to public; the crash involved one or more road vehicles which were in motion at the time of the accident (WHO, 2004). Generally, road crash is an event which is unexpected, undersigned with an element or chance or probability or unfortunate result" and sometimes it is defined as "the occurrence which usually produces injury, death (fatal) or property damage (PDO)". Therefore, it is very essential studying on road geometric characteristics and its environment to reduce traffic crashes by incorporating safety-conscious design and planning of road network and beyond.

In most regions of the world, this epidemic of road traffic injuries is still increasing (WHO, 2009). The WHO (2004) study reports indicated that agerelateddiseases,drunk driving, technical failures of vehicles, over speeding and others are identified as some of the major causes of traffic accidents. The same reports estimated that road traffic crashes is expected to be the thirdleading cause of death worldwide by the year 2020, if rigorous and remarkable actions are not taken. The reports also show that ninety percent (90%) of road casualties were in low and middle-income countries. The historical trend shows that the total number of people killed in road crashes in developing world continues to increase (WHO, 2009).

Ethiopia is one of developing countries with high traffic accidents costing around 0.8% - 0.9% of the gross domestic product (GDP) for the past consecutive years (Ethiopian Federal Police Commission, 2008). Road traffic accident in Ethiopia is a serious problem. The death rate presently stands near 70 per 10,000 vehicles. To curb the problem, strong interventions and strategies are expected to deal with the challenges so as to reduce its impact by fifty percent (50%) at the end of 2020.In this regard, considering the importance of road safety, the Ethiopian government has requested the World Bank and its Global Road Safety Forum to review the road safety management capacity of the country. This review was used for the development of national decade strategy for road safety. Despite all these efforts, the challenges of road traffic accidents are still increasing from time to time. This indicates that studies made on the sector are not sufficient to address the challenges (Ethiopian Ministry of Transport, 2011).

Horizontal curves have a large impact on the casualty crash risk. Single curves in the 200 m to 600 m range have been found to have the greatest risk. For instance, a sharp curve with a 100 m radius has a 5.5 times higher crash risk than a relatively straight section. Crash severity was found to be somewhat higher on milder curves; however, mainly due to the effect of higher speeds. Crash risk on curves is strongly associated with a high approach speed combined with a large speed change across the curve. For instance, a curve causing a speed reduction of 30 km/h from an approach speed of 100 km/h elevates the risk of a run-off-road casualty crash by 5.1 times. The same speed change but from an approach speed of 60 km/h will increase the risk by 3.1 times (Cardoso 2005).

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Run-off-road events contribute to about a third of all fatal and serious injury crashes on rural roads (Victorian data based on Jurewicz et al. 2014). Design of road alignment and its delineation play a crucial role in helping drivers to stay on the road. When drivers make errors, or are impacted by events outside of their control (objects/animals on the road, actions of other drivers), design of the roadsides can have a significant contribution to improving safety on rural roads. Geometry of roadsides should be considered as part of any road design.

The above works were performed at international, national and regional levels, did not provide any comprehensive ideas with respect to coverage and assessment detailing the deficiencies of geometric parameters related to traffic accidents, even though the researchers have given a greater attention to vehicle factors, driver factors and road users information. With a geometrically good road design, it may be possible to compensate forthe other factors and thus decrease the number of traffic accidents.

Therefore, the analyses and investigations of the geometric deficiencies necessarily done in this research hardly determined the overall harmony among the other factorsat the design stage of a highway that cause traffic accidents on the constructed roads.

2.2. Factors Contributing to Road Traffic Crashes

According to the Interim National Road Safety Coordination Office, cited in Tulu (2015), the causes of road traffic accidents were identified as:

- Violation of speed limits;
- Insufficient enforcement;
- Lack of vehicle maintenance;
- Animal-drawn carts and animals that frequently use main highways;
- Lack of safety conscious regarding design and planning of road network;
- Disrespect to traffic rules and regulations;
- Lack of general safety awareness by pedestrians;
- Lack of medical facility in the area in general, in relation to accident severity.
- Poor knowledge of traffic rules and regulations; and
- Lack of driving skills.

These factors are common, especially in developing countries, and they need deep-rooted solutions since they are associated with road traffic crashes. Generally, the contribution in each set of circumstances falls into the three components of the road traffic system: road environment deficiencies, vehicle defects, and road user errors.

2.2.1 Driver Characteristics

According to Abbas (2004) that developed statistical models forecasting expected number of accidents and casualties indicated that the main categories contributing to accidents were considered as: drivers, pedestrians, vehicles, road and environmental related factors and others. The study depicted that driver-related factorswere the most highly contributing factors, due to loss of control of driving wheel, speeding, stoppage (i.e. sudden stopping).

Chanyukong and Jikuang (2010) investigated the association between the impact of speed and risk of pedestrian causalities regarding passenger vehicle collisions in China based on real world accident-data. They improved a multiple logistic regression model accepting impact and observedspeed. According to their findings, the risk of pedestrian fatality was found to be: 26% at 50-kmph, 50% at 58-kmph and 82% at 70-kmph. The pedestrians rarely survived at an impact speed of 80-kmph.

Nicholas et al. (2001) stated that the main components involved in run-off crashes are the drivers' inability to control both speed and direction. Especially, run-off vehicles occur when a driver is faced with a piece of unexpected (or unusual) information. Causes of this include; the driver's behavior, distractions, the influence of alcohol, drugs (or medication), drowsiness, fatigue, illness, or blackout, speeding, and failure to obey signs, signals or traffic police, which could be due to confusion or unfamiliarity with the roadway.

2.2.2 Vehicle Characteristics

Nicholas et al. (2001) stated that mechanical problems in vehicles are another important factor that contributes to road traffic crashes. Faulty brakes, worn tires, and other vehicle defects affect the controlling of a vehicle, especially at high speeds. Moreover, at high speeds, the tires may blow out leading to loss of control. Tire tread separation is another factor that leads to loss of control. The problems relating to heavy vehicles result from three characteristics: heavy vehicles are much heavier and larger in dimension compared with passenger cars and therefore experience instability and maneuverability problems. In addition, they have less effective acceleration capabilities than passenger cars and have greater difficulty maintaining speeds on upgrades, and this speed variation generates more instances of overtaking and the potential for head-on collisions with oncoming vehicles. Finally, they have a lower deceleration in response to braking than passenger cars, which increases the potential for severe rear-end crashes. In addition, Abbas (2004) included in his studies that tire burst, vehicle turn off the road and vehicle turn over, and crash due to mechanical failure are considered under vehicle-related factor.

2.2.3 Road Geometric Characteristics

The study conducted on the influence of road traffic management and geometric characteristics on traffic safety in rural roads developed two different statistical regression models using negative binomial regression method for black spot road segments and non-black spot road sections. The research found that the number of horizontal curves, number of lanes, number of vertical curves, and number of accesses and gradients per kilometer were found to be the main influencing road geometric related variables that significantly affect traffic safety (Tefera, 2015).

Nicholas et al. (2001) stated that the overtaking maneuver on multi-lane roads without the assistance of additional passing lanes is a complex driving task. It requires critical information-processing and decision-making skills, and a lengthy section of road to complete the maneuver. The rates of overtaking crashes are related to the provision and geometric design of passing lanes. When passing lanes are not provided on long sections of road lengths, there is increased potential for risky or misjudged overtaking maneuvers, particularly when sight distance is short. Also, it seems that design practices for passing lanes may not be appropriate for many drivers to pass slow traffic or multiple vehicles in a safe manner.

Moreover, previous studies examined the relationship of crash occurrences in terms of number of lanes, lane width, and presence of a median, median width, type of median, shoulder width, access density, speed limit, vertical grade, horizontal curvature, and weather condition. The relationship between safety on the highway and factors listed above is the primary focus in crash reduction and predictions (Deo, 2004). In addition, some of the primary geometric design elements that can affect road safety are carriageway, grade, horizontal curvature, shoulder, median, vertical curve (Iyinamet et al., 1997).

Douglas et al. (2000) concluded that geometric design elements play an important role in defining the traffic operational efficiency of any roadway and road traffic accidents. According to the investigation, the key geometric design elements that influence traffic operations and road traffic accidents are number of lanes, widths of lanes, the presence of width of shoulders and highway medians, and the horizontal and vertical alignment of the highways.

The study Conducted by Obaidat and Ramadan (2012) on the traffic accident at 28 hazardous on Amman - (Jordon) rural roads noticed that the logarithmic and linear models were the most important and realistic models that can be used to predict the relationship between the accident characters and dependent variables. According to their studies, the most important contributing factors to traffic accident in hazardous places were: number of vertical curves, median width, type of road surface, average running speed, posted speed, lighting, number of vehicles per hour, number of crossing facilities, and maximum and average degree of horizontal curves and percentage of trucks.

The number of the road crashes might vary due to the degree of access to the driveways that different land uses faced (Tulu et al., 2013).

.2.3.1 Road Alignments

According to Persaud et al. (2000) carried out a separate analysis for tangents and curves, the independent variables were traffic flow and road geometry, while the dependent variable was crash frequency. Regression models have compared the readings with standard readings of a generalized linear modeling. They used a dummy variable for "undulating (or) flat terrain. The Crash frequency for curves was found to increase with AADT, Section length (L) and curvature (1/R). The number of accidents for tangents per year increases with AADT and length. They showed a higher accident number on undulating terrain than on flat one.

Negative binomial distribution was used to anticipate crash frequency as a function of the degree of horizontal curvature, section length, lane, shoulder and median widths, AADT, and urban/rural designation. This study accounted for driver characters including age and sex. The outcomes have shown that crash frequency increases with AADT, section length and degree of horizontal curvature; whereas, frequency of accident decreases in comparison with lane, shoulder and median width according to Abdel and Essam (as cited in Kiran et al., 2017).

The relationship among highway geometrics, traffic-related elements, and motor-vehicle accident frequencies were investigated by Milton and Mannering (1998) and found that an increase in the annual daily traffic in the road section tends to increase in road crashes. Moreover, the research concluded that increments in a number of lanes tend to increase road crashes occurrence. The horizontal curve has a strong correlation with the frequency of accidents. They concluded that the radius of a horizontal curve is negatively correlated to road crashes. In addition, they confirmed that horizontal curve not caused by itself to increase accidents but dependent on large straight sections before the curves.

Hassan et al., as cited in Mohita (2014), studied on the effect of vertical alignment on driver perception of horizontal curves and found that perception of the driver of the road features ahead is an important human factor and should be addressed in road design. An erroneous perception of the road can lead to actions that may compromise traffic safety and poor coordination of horizontal and vertical alignments are believed to cause such wrong perceptions. Through statistical analysis, they suggested that the horizontal curvature looked consistently sharper when it overlapped with a crest curve and consistently flatter when it overlaps with a sag curve.

Past studies conducted by Ding and PEI (2000) on the study of Shenda Freeway shows, that accident rate and curve radius has a close relationship. Thus, accident rate reduces as the radius of the road increases; and the curves with the same or similar radius are safer than with different radius. A small radius, which is inserted into the long and straight line, is dangerous. The study concludes that modification of horizontal alignment is one of the effective countermeasures for highway accidents. Moreover, Glennon (1987) included the relationship of road crashes and curves that suggest that the average crash rate for curved road segments is three times that of tangents, and the average single vehicle's, run-off road crash rate is four times higher.

Sarbaz and Robert (2009) conducted a study on the effect of roadcurvature on accident rate and the outputs revealed that accident rate decreases with increasing radius of curves, for both right and left curves. The investigations also compared left turn and right turn curves road crashes. Accordingly, left turn curves have higher accident rate than right turn curves. Road sections with left curve and radius less than 100 meters have two times accident rate as compared to right curve radius less than 100 meters.

In addition, the study revealed that a road section with a left curve radius of less than 100 m has accident rates that are four times as high as those on a section with curve radius greater than 500 m. Road sections with a curvature of 5 to 10 degree have at least twice the crash rate of sections with a curvature of 1 to 5 degree. Furthermore, sections with a curvature of 10 to 15 degree have crash rates four times as great. Curve radius of 200m seems to be the point below which crash rate greatly increases (Cairney, 1998).

Anderson et al. (1999) conducted a study on relationship between mean crash rate and mean degree of curvature and found that horizontal curves that require speed reductions had higher crash rates than curves that do not require speed reductions. Curves requiring speed reductions are generally sharper than about 4 degreecorresponding to design speeds of less than 100 km/hr. and estimated 85^{th} percentile speeds less than drivers' desired speeds on long tangents (straights). They stated that mean crash rates were similar for degrees of curvature from 0.25 to 4 degree and, 4 degrees as a breakpoint, after which crash rates increased linearly for the remaining intervals 5 degrees and above.

Vertical curves variability's were studied as a general risk factor for road crashes. For example, a study of crashes on vertical curves with limited stopping sight distances inferred that the shorter the stopping sight distance, the greater the crash risk. Researchers also described that limited sight distance was not the key problem, rather, it seemed there was a major problem of vehicles stopping in the roadway to make a turn either into a driveway(or access), or turning at an intersection (Kay et al., 2000).

The study conducted by Sarbaz and Robert (2009) on effects of grades on accident rates implied that accident rate on a downgrade is slightly higher than on upgrades and upgrades have less effect on accident rate while accidents' rate increases with increasing downgrade. In addition, Iyinamet et al. (1997) studied and concluded that accident rate is highly increasing with increasing of road grades at the point of high slope section. Because emergency braking distance downgrade is longer than that of braking distance upgrade and as a result, more accident occurs at downgrade than upgrade.

The model developed by Gluck et al. (1999) concluded that an increase from 10 access points to 20 access points per mile would increase crash rates by roughly 30%. Moreover, Papayannoulis et al. (1999) found that most studies report an increase in accidents as a result of the increase in a number of driveways. They described that a road with 60 access points per mile would have tripled the accident rate compared to 10 access points per mile. Furthermore, Pardillo and Rubio (2003) concluded that access density is one of the highway variables that have the highest correlation with crash rates in Spain's roads network, and it influences mostly the rate of head-on and lateral collisions. High access density has a negative effect on road safety.

2.2.3.2 Cross-Sectional Elements

The effect of road cross-sectional elements on road traffic accident; roadway cross-section encompasses features on the travel portion of road used by vehicular traffics and the roadside according toZegeer et al. (1981) studied. Accordingly, the design of cross -sectional element influences the safety of the roadway. The portion of the road cross-section normally used for vehicles and pedestrian travel may serve multiple purposes, including future expansion and recovery room for errant vehicles. In addition, types and descriptions for the most Common elements of roadway cross section were given in the following ways; width of the lane, number of a lane, shoulder width, a pedestrian sidewalk in urban, median width, median type and bicycle lane.

Travel lanes: are those portions of the highway intended for use by general traffic. A fundamental feature of roadway cross section is the width of travel lane, which must be sufficient to accommodate the design vehicle, allow for imprecise steering maneuvers, and provide clearance for opposing flow in adjacent lanes. The selection of the number of lanes for a roadway is based primarily on projected traffic volume for the facility. **Sidewalks:** Walkways are paved (usually concrete) and separated from the street, generally by a curb and gutter. It is provided mainly in urban areas.

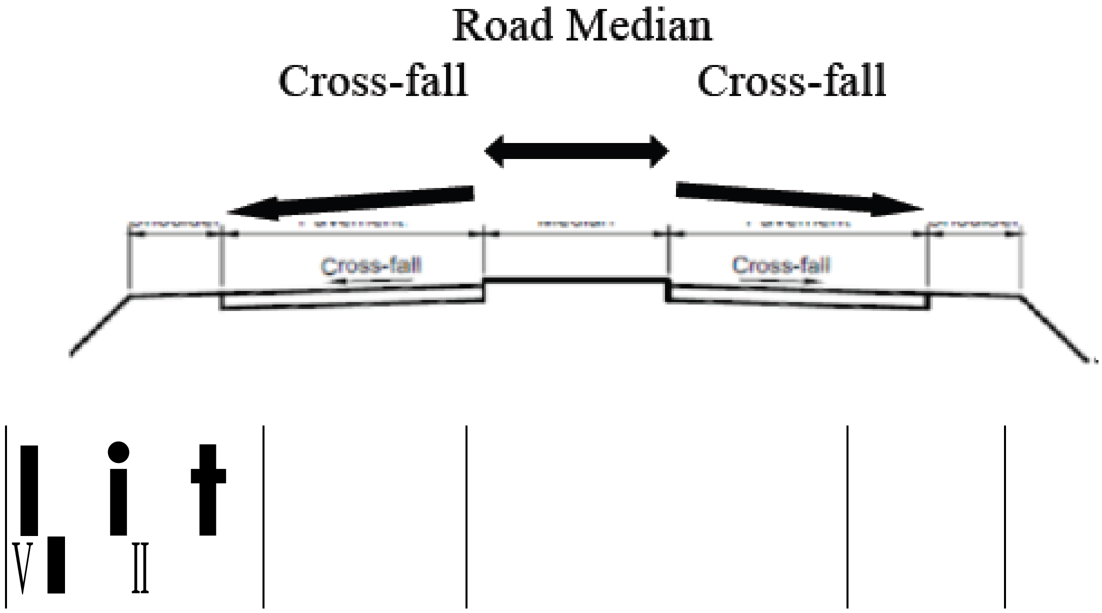
Pathway: Temporary or permanent walkways that may or may not be placed near a roadway and are usually made of asphalt or gravel.

Shoulder: is the portion of the highway immediately adjacent to, and outside of the lanes. In rural or suburban areas where sidewalks and pathways are not feasible, gravel or paved highway shoulder is provided an area for pedestrians to walk next to the roadway. Shoulder is used for emergency stopping, for parking of stopped vehicles, and for lateral support of Sub-base, base and surface course of travel lanes.

Median: is a continuous space, landscapes, or concrete structures installed in the middle of a roadway for the purpose of separating opposing traffic. Medians are categorized as traversable or non-traversable. Traversable medians are middle lanes mostly known as two-way-left-turn lanes (TWLTL) that are used by left turning traffic to access land-uses. Non-traversable medians are landscapes, slabs, short concrete walls, or barriers intended to prevent left turning traffic from directly accessing land uses. Curbed concrete or asphalt slabs are the most common types of non-traversable medians on urban arterials and they are known as raised medians. The raised medians are usually used in access management programs to replace TWLTL for the purpose of improving safety and mobility.

Moreover, medians can be categorized into undivided roadway, which is not effective as an access management measure, two way left turn lane (TWLTL) and raised median. Accordingly, the TWLTLs and raised medians are safer than the undivided roadways since road traffic conflicts due to the left turns are reduced from the through traffic lanes. According to Xuecai (2010), TWLTLs improve the operational flexibility by providing a refugee area for vehicles to turn left from both directions. Raised medians limit access and reduce conflict points by separating traffic flow in opposite directions. Figure 2.2 below shows common types of medians (Xuecai, X., 2010).

Since drivers on undivided roadways and TWLTLs can make left turns at any point on a roadway, most of the crashes for these two median types are related to left turns. Directional raised medians are used to control left-turn movements. They specify the location for switching from one side of major roadways to the other. Directional raised medians are installed to replace the undivided roadways and TWLTLs because raised medians utilize separate left-turn lanes to limit the locations for making left turns and then reduce the traffic conflicts



(a)Undivided Median (b) TWLTL

Figure 2.1: Common Types of Medians (Xuecai, X., 2010)

The study conducted by Girma (2004) on relating crash data with traffic volume and the road characteristics by Poisson and negative binomial regression methods depicts that providing median was found prominent in multiple vehicle accident models as well as, pedestrian accident models.

Zegeer et al. (1981) the investigation was conducted on two-lane highway to relate the effect of cross-sectional elements of roads on road traffic crashes and the findings depict that lane and shoulder condition directly influenced runoff road and opposite direction fixed object, rollover, head-on, and sideswipe accident.

A study conducted by Tobey et al. (1983) on the safety effects of sidewalks revealed that sites with no sidewalks or pathways were the most hazardous for pedestrians. This indicates that crashes at sites without sidewalks are more than twice as likely to occur as expected. Thus, sites with no sidewalks were the most hazardous to pedestrians, and sites where sidewalks were present on both sides of the road were least hazardous.

In Sub-urban areas, arterials with raised curb medians were found to have significantly lower accident rates than TWLTLs for rear-end, right angle, and left-turn collisions. Raised-curb medians also were found to have significantly lower accident rates than undivided cross-sections for right-angle collisions.

Moreover, the investigation on safety performance for 11 corridors in Texas before and after the installation of access management techniques was done. The data collected in the study included crash rate, access density, traffic volume as well as the presence of 22 raised medians or TWLTLs. It was found that safety improvement was demonstrated on all the corridors after the installation of the raised median (Eisele and Frawley, 2005).

Timur (2010) conducted stated that reductions in high dangerous crashes such as angle and head on are larger compared to rear end and sideswipe; segments with raised median have lower rates by 37.2 and 39.6% respectively.

A number of access points in rural and suburban areas would affect annual crash rate positively by increasing 0.11 to 0.18 per million vehicle miles on undivided highways and by 0.09 to 0.13 per million vehicle miles on highways with TWLTLs or non-traversable medians. In rural area increase the annual crash rate by 0.07 crashes per million vehicles miles on undivided highways, and 0.02 crashes per million Vehicle miles on highways with TWLTLs or no traversable medians Gluck et al. (1999).

The study conducted in states of Utah and Illinous by Knuiman et al. (1991) on relation of median width and highway accident rate at 982 section of highway (973.8mi) of roadway with 37,544 reported accident over period 5 years in Utah state and 2481 section (2081.3mi) roadway with 55,706 accidents within 4 years in Illinois states. Road section within media width ranging from zero (no median) to 110ft (33.6m) is examined in the study. The result from two states indicated that total accident and rate of specific types and severity decline when median width exceeds about 25 ft. (7.6m).

2.3 Regression Models

Regression analysis is a powerful statistical method that allows examining the relationship between two or more variables. All types of regression analysis at their core examine the influence of one or more independent variables on a dependent variable. Also, the process of performing a regression allows to confidently determining which factors matter most, which factors can be ignored, and how these factors influence each other. The essential terms in the regression are:

Dependent (response) variables: This is the main factor that the investigator is trying to understand or predict.

Independent (explanatory) variables: These are the factors that the researcher hypothesized an impact on the dependent variable (Ben, 2018)

A Study conducted on Safety performance functions incorporating design consistency variables by Alfonso and Lella (2015) stated that generalized linear modeling techniques were used to fit the models and a negative binomial distribution error structure was considered. Explanatory variables considered in the study were; design consistency, horizontal alignment, vertical alignment, sight distance, and roadside context. In addition, the researchers considered natural logarithm of the AADT as an aggregate measure of the traffic volume. They concluded that the ordinary linear model was not appropriate for predicting road traffic crashes because of accident frequency is discrete, and does not follow the normal distribution, which is one of the basic requirements of linear regression technique. Moreover, the variance in the accident frequency is not constant, but tends to increase as the flow increases. The number of accidents also cannot be negative while a normally distributed error structure implies a substantial probability of a negative number of accidents (road crash), especially when the flow is small and the expected number of traffic accidents will also come to small or zero, not negative.

The generalized Poisson regression and the negative binomial regression models have been used to describe count data. Generalized Poisson regression model has an advantage over the negative binomial regression model that it can be used to model count data with either over dispersion or under dispersion. While, the negative binomial regression model is suitable for cases with presence of greater variability (over dispersion).Berhanu (2004) did empirically demonstrated the superiority of the Poisson regression and negative binomial regression over the ordinary linear regression models in analyzing and modeling accident frequencies.

Lund Research Ltd (2015) stated that the Poisson regression technique is attractive in that there is only a single parameter to be estimated but it does have some limitations, especially when the variance of the dependent variable is constrained to be equal to the mean. Road traffic crash as a dependent variable was often found to have a variance greater than the mean, which can result in biased model coefficients and erroneous standard errors. To overcome this problem of over dispersion, the negative binomial regression model is recommended in addition to use a Poisson regression technique.

2.4 Empirical Bayesian Method (EB)

The use of the Empirical Bayesian (EB) method for crash prediction seems to have become widely accepted as one that the most unbiased estimate of the expected crash frequency. The EB method increases the precision of crash frequency estimation and corrects for the regression to mean bias (Hauer et al., 2002). The EB model assumes that the number of observed crashes on a 29 road sections is distributed according the Negative Binomial and Poison distribution on all considered geometric design parameters effects on traffic crashes of study road section. Among those geometric design parameters horizontal curves (HC) consists another its own sub-parameters and those also contributes effects on traffic crashes occurrence and EB method used for more detail analysis on those horizontal curves parameters effects on crashes. Using a weight factor, the historical crash record and on the reliability of the crash prediction models. TheBayesian adjusted/ estimated number of crash involvement per year is expressed as a combination of the estimated/predicted number of crashes and the observed number of crashes as follows, (Highway Safety Manual (HSM), 2008).

Hauer and Persaud (1984) suggest an Empirical Bayesian (EB) method for identification of high crash locations. The EB method attempts overcome the difficulties with some of the conventional techniques. The EB method controls the randomness of crash data by using an estimate of the long - term mean number of crashes at a location. This method is used for predicting crashes in the future and then ranking based on the predicted number of crashes. An estimate of the long - term mean number of crashes at a location is obtained by combining its crash count (in the most recent years) with the expected annual number of crashes at that location (based on the crash history of sites with similar characteristics) according to study of Persuad et al., 1999.

The term “black spot or dangerous road section” is used to describe locations that have a higher than average crash rate and has been a standard safety engineering methodology for over 30 years. The identification, analysis and treatment of black spots are widely regarded as an effective approach to road crash prevention (Elvik, R., 1997).

2.5 Possible Engineering Countermeasures

In the planning, design, and maintenance of the road network, four particular elements affecting road safety have been identified Dinesh et al. (2006). These elements are:

- Remedial action at high-risk crash sites;
- Safety improvements to existing roads section;
- The incorporation of safety features in the design of new roads;
- Safety-awareness in the planning of new road networks.

The accident rate was high before safety measures were taken on both upgrade and downgrade but significantly higher accident rate on downgrade than upgrade. However, after safety measures were taken for the highway by increasing two directional lanes, remedial measures were taken to upgrade, and downgrade, and accidents decreased. Again, after installing a speed limit signs, the accidents decreased and kept stable in absolve relatively (Iyinam et al., 2000).

The study conducted in Ethiopia depicts that pedestrians' facilities are not provided adequate manner that exposes pedestrians walking along roads where there are no footpaths, having to cross where there are no facilities, and being at risk at night due to a lack of adequate lighting. While the full provision of pedestrian infrastructure is prohibitively expensive for existing roads, it is possible to incorporate footpaths and crossing points into new roads without a large additional cost. For existing roads, the focus should be placed on locations where pedestrian numbers and risk are highest. For example, pedestrian crashes have often been observed to cluster in urban areas (Tulu, 2015)

At present, engineering treatments for pedestrians are not common practice in DCs, as there is a lack of awareness of the wider economic benefit of these measures, so this area has unexplored potential. One way of addressing this need is through the development of planning guides or manuals for pedestrian facilities in DCs. Pedestrian safety audits on existing and new roads should be conducted (Harwood et al., 2014).

The enforcement of compressive and clear legislation with appropriate penalties and creating public awareness can be critical for reducing road traffic crashes and enforcement of road traffic safety law needs to be both improved and sustained. Addressing road safety in a compressive manner necessitates the involvement of multiple sectors such as health, transport and police. A coordinated action between the sectors can bring the solution of road traffic crashes by development and implementation of multi sectorial strategy with sufficient finance for planned action to achieve within a specified period (WHO, 2009).

In general, the influence of road characteristics on road safety has been studied in developed countries that it is shared significant contribution to road crashes. However, in developing countries, the effect of road characteristics and its significance on road safety is not well investigated. Regards to this, the study aims to investigate on the effect of road geometric design elements on road traffic crash occurrence at road segments in AlataWondo – Bona – Daye road section.

3. MATERIALS AND METHODS

3.1 Introduction

Data required for researches can be either secondary which is acquired through available documents or primary which is original and collected through field surveys. In the case of this research, both secondary and primary data were collected.

Analysis of the effect of road geometric design elements on road traffic crash occurrences were conducted at different road segments of two lane trunk rural road in this study. A road section is a segment of a road between two traffic data measured or identified parts of roads from certain point to the next end of study areas. The safety and mobility in the mid segments are influenced by access management techniques, roadway characteristics, traffic flow, and land use (Xuecai, 2010).

This chapter deals with the description of the methodology followed for conducting different techniques to analysesandidentify the effect of geometric design parameters on the safety of selected road sections to develop regression model for two lane trunk roads. It comprises an outline of the general steps followed, methodology of study sections, sources of data and data collection used in this work. The research was achieved by a combination of literature review, and geometric design asbuilt data obtained from the Ethiopian Roads Authority (ERA), field survey to measure existed geometric parameters and traffic accident data obtained from the traffic police office of the subject woredas and town administrations, those included in the study area.

3.2. Characteristics of Traffic Accidentson AlataWondo –Bona – Daye Road.

Among the different paved roads with high traffic flow in Southern Ethiopia, AletaWondo - Bona- Daye road section connect Ethiopia with Kenya through Oromia region along AletaWondo – Kibremengist - Shakisho Trunk road. The study road traverses areas of high traffic and pedestrian movements where high income inhabitants are dominantly living and active trades are circulating. Consequently, more trade activities, more car ownership and pedestrian volumes were generated but resulted in high traffic crashes. The AletaWondo – Bona - Daye road section traverses different administrative areas that are six (6) rural woredas and two (2) town administrations those located in Sidama Zone. All traffic crashes in these areas have been considered in the study based on traffic surveys of 2019 in each woredas and city administration. The six (6) woredas and two (2) town admirations are shown in table 3.1;

Table 3.1: Woredas, Towns and Coverage under the Study Area by Author (2019)

No	Names of Woredas and Administration Places	Coverages and Percentages	
		Coverage (km)	%
1	Dalle	7	8.3
2	AletaWondo	19	22.5
3	AletaWondoTownAdministration	3.7	4.4
4	Hulla (HagereSelam)	15.7	18.6
5	Burssa	6.1	7.2
6	Bona	17.3	20.4
7	Bansa	12.5	14.8
8	Daye Town Administration	3.2	3.8
Total		84.5	100

The figures 3.1 and 3.2 graphically illustrated traffic crash frequency and distributiongeneral in SNNPR andparticular in Sidama Zone respectively.

Crash Distributions in SNNPR

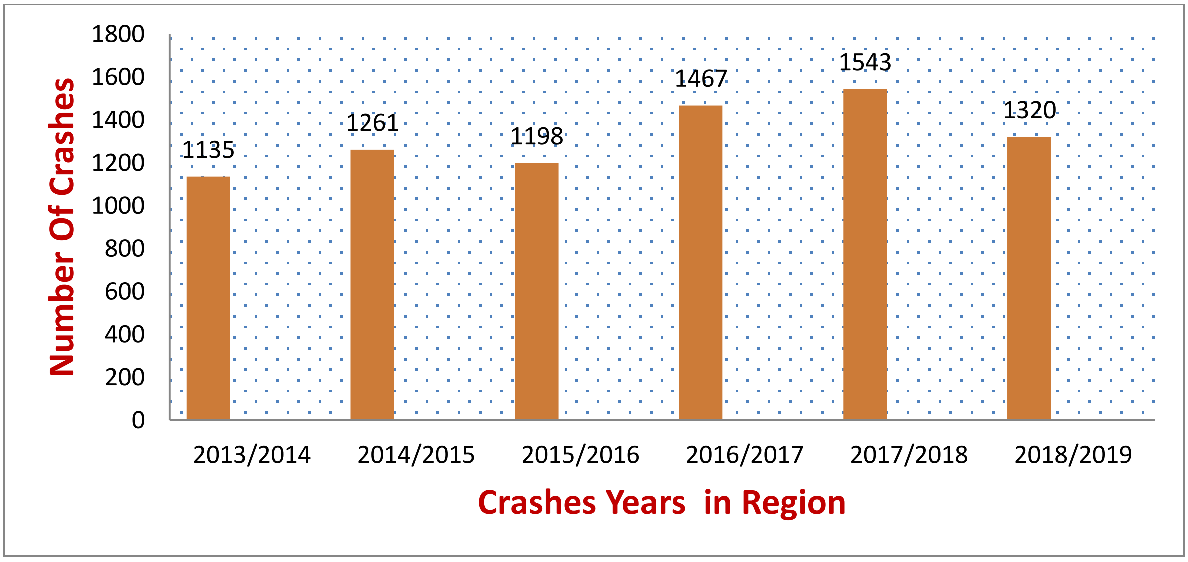


Figure 3.1: Road Traffic Crash Frequency in SNNPR

Source: SNNPRPC (2013/14-2018/19).

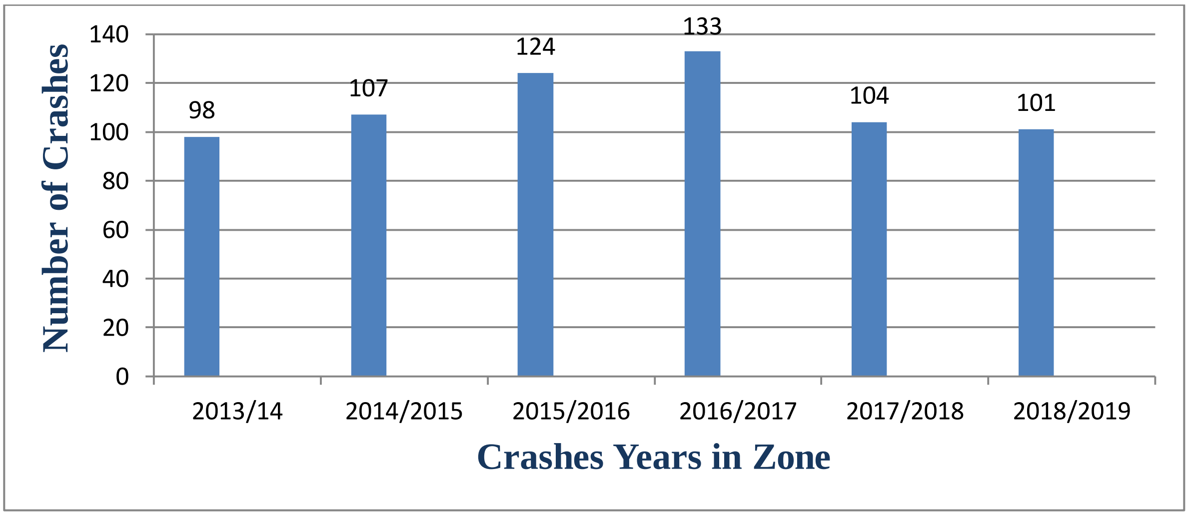


Figure 3.2: Road Traffic Crash Frequency in Sidama Zone

Source: SZTPC (2013/14- 2018/19 G.C.) or (2006 – 2011 E.C).

Table 3.2: Crash distributions in Aletawondo – Bona – Daye road section in (2006 to 2011 E.c)

S.no	Names of Woredas and Towns	Total Traffic Crashes in woredas or city administrations in each study year (E.c)						Total Traffic Crashes in the Study Area						Percentage of Traffic crashes (%)					
		2006	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011
1.	Dalle	4	3	4	5	4	4	3	2	2	4	1	2	75	66.6	50	80	25	50
2.	Aleta .W	11	9	13	14	8	9	8	7	6	11	5	6	72.7	77.7	45	78	62	66
3.	Hulla	7	8	11	10	6	5	5	4	5	9	4	4	71	75	45	90	66	79
4.	Bursa	3	6	4	4	4	3	0	5	2	3	4	2	0	81	0	50	100	66.6
5.	Bona	5	7	10	8	7	6	5	6	5	5	7	4	100	71	50	62	90	66
6.	Bansa	7	12	7	8	6	5	6	9	3	7	4	4	84	75	42	87	66	80
7.	AletaW. town	6	5	8	7	7	5	5	5	4	4	5	3	83	100	50	57	71	60
8.	Daye	3	4	4	3	3	2	3	3	2	3	2	2	100	75	50	100	66	100
Tot		46	54	61	59	45	39	35	41	29	46	32	27	64.8	75.9	47.5	77.9	71	69

Source: woredas police commission, AlataWondo and Daye Town road traffic statistics office and re arranged by Author

According to the SNNPRTPC Report of 2017/18, a total of 9,301 traffic accidents occurred in the Region in 2016/17.The most accidents occurred in GamoGofa, Hadiya,Sidama zones and Hawassa city. About 11.2% of the total accidents occurred in the Sidama Zone which is one of the 14 zones in the Region. Road traffic crash in the zone resulted in significant losses of human and economic resources. Between years 2013/14 and 2018/19, a total of 667 road traffic accidents occurred in Sidama Zone with about 915 fatalities. This indicates, death rate due to road crashes have significantly increased among pedestrians and passengers from time to time. The majority of fatalities were pedestrians (83%) followed by passengers (8.5%), and drivers (4%) as traffic commission reported.

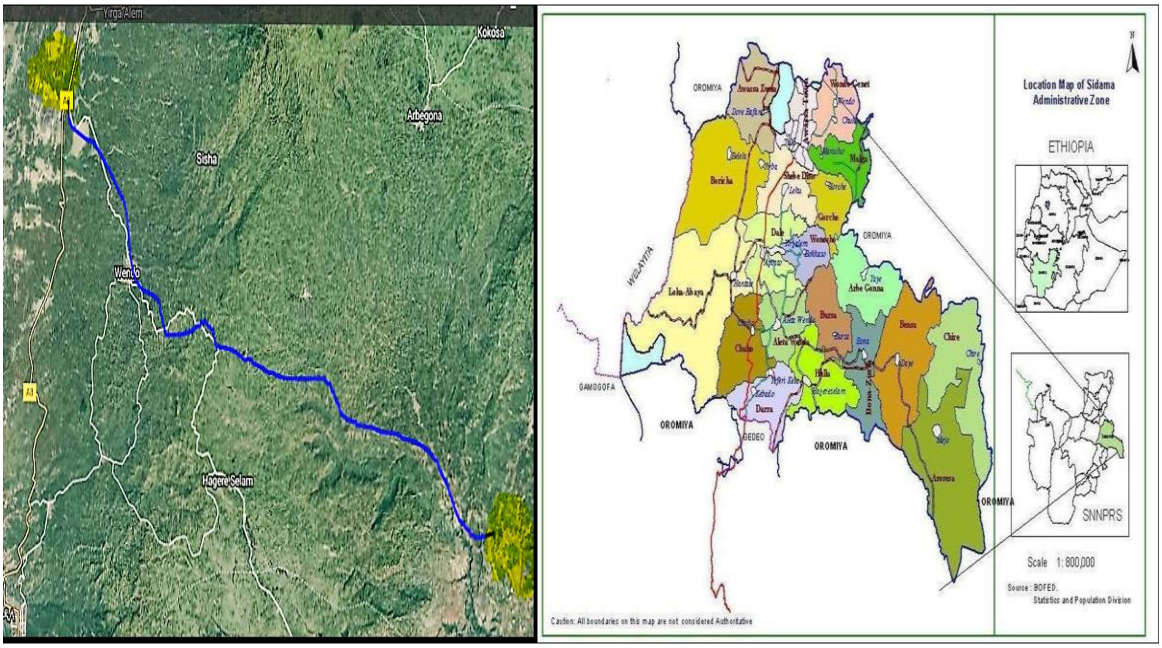
According to SZTPC (2018/19) Report, out of the total 667 road accidents mentioned above, 210 (31.5%) happened on AlataWondo - Bona - Daye road section which was significantly high compared to other roads in the Zone. The 2018/19 Report showed that this was due high movement of vehicles that resulted from significant economic activities in the region and the traffic on Hawassa - Dilla - Yabello- Moyale and Hawassa-Aletawondo- KibreMengist- Shakisso road routes towards Kenya and in neighboring Oromia Region.

3 .3.Description of the study area

3.3.1. Location of the study area.

The study area is located in Southern Nations and Nationalities and Peoples Region (SNNPR) in Sidama zone at an approximately 327 km south of Addis Ababa, the capital city of Ethiopia. The whole length of the study road is 84.5 km. Geographically, it is bounded between 975,000m and 995,000m North latitude and 670,000m and 705,000m East longitudeexpress direction which is $6^0$35N 38^0 20E from Aletawondo to 6^0 30N 38^0 50E Daye.

The study road branches offthe Hawassa to Moyale trunk road at 53 km from Hawassaand then directed towards the AletaWondo-Negele main road. The geometric design study starts from the intersection from Hawassa - Moyale road and continues along the AletaWondo - Bona - Daye road with a total length of 84.5 km.Figure: below shows the satellite map of the study road.



LEGEND: The blue line between the two yellow points shows the study road.
Figure: 3.3: Satellite map of the study road(by Author 2019)

Similarly, Figure 3.4: showed the satellite map of the AletaWondo - Bona - Daye road as provided by Author (2019).

Figure: 3.4: Satellite map of AletaWondo - Bona-Daye road section byAuthor(2019)

3.3.2 Physiography of the study area.

The study road is stretched between AletaWondoworedas and Daye towns with a total length of approximately 84.5 kilometers. The terrains of the area consist of flat, mountainous and escarpments type. The road sections under the study traverse two districts namely the fromthe intersection with Hawassa - Moyale main road to AlataWondo town and then from AlataWondo town to Daye with a two-lane rural trunk highway.

3.3.3 Sampling Method and Sample Size Determination

The approach used in the study is convenience-sampling method.Convenience sampling is a specific type of non-random sampling method that relies on data collection from population. The method is not complicated and is cost-effective.

The sample size wascalculated based on the following formula (Office of Highway Policy

$$n = \frac{(Cv)^2 (Z)^2}{(d)^2}$$

……………………………………………………………………………Equation(1)

20Information, 2010).

Where;

n: Required sample size;

Cv: Estimate of variance (at low variance = 0.1);

d: Desired precision rate or acceptable margin of error for proportion being estimated (=0.05); and

Z: Value of the standard normal statistic for an alpha confidence interval of two-sided = 1.96, 95%.

Based on above, the sample size was determined as follows ; $[(0.1)^2(1.96)^2]/(0.05)^2 = 15.36$

According to this sample size determination, aminimum sample size of 15 road segments wascollected.However, 29 representative sample sizes of road segments for the study conjugated with traffic data were identified and relevant data were collected from road networks locatedin AletaWondo - Bona - Daye roadsections. Selected road segmentsand data collection as clearly shown in Figure below.

Figure 3.5: Selected road sections Google map image.

Source: Google Map Web site (By Author 2019).

3.3.4 Road Geometric Characteristics and Variables

Geometric design elements play an important role in defining the traffic operational efficiency of any roadway. Some of primary geometric design elements included in the study were: number and width of lanes, the presence and widths of shoulders and highway medians,gradients, horizontal and vertical alignments. Super elevation, passing sight distances, stopping sight distances transition curves and road surface conditions directly or indirectly depend on primary geometric design elements or variables. Yingxue (1994) statedthat equation of traverse super elevation value (I) can be deduced by balance force act on vehicles when traveling on horizontal curve as expressed by the following equation:

$$\mathbf{I=\frac{V2}{127R}-U} \quad \text{………………………………………………….......Equation(2)}$$

Where

I: super elevation;

R: radius of curvature (horizontal alignment)

V: design speed; andU: transverse slope(gradient

Basically for this study used road geometric characteristics variables are:

- Length of sample road section (L);
- Gradient (%);
- Horizontal curves (NHC);
- Vertical curves (NVC);
- Number of lanes(NL);
- Surface widths (SW);
- Median type (MT);
- Median height (MH);
- Median width (MW); and
- Shoulder or sidewalk (SH/SW)widths.

Table below shows the geometric characteristics and variable of the study road

Table 3.3: Road Geometric Characteristics and Variables

No.	Road sections		Variable (X)Road Geometric Elements									
	Start (Local Name)	End (Local Name)	L (m)	G (%)	NVC	NHC	NL	SW (m)	MT	MH (m)	MW (m)	SH/SW (m)
1.	Dilla intersection	MegeraQuary	2150	2	2	5	2	9	P	0	0.11	1.5
2.	MegeraQuary	Wara Betel Area	1730	3	2	4	2	7	P	0	0.11	1.5
3.	Wara Betel	DongoraIlmate	1870	2	3	3	2	7	P	0	0.11	1.0
4.	DongoraIlmate	DongoraGidiwo	2420	5	3	4	2	7	P	0	0.11	1.0
5.	DongoraGidiwo	Kola River Area	1920	4	3	4	2	7	P	0	0.11	1.2
6.	Kola River Area	Terchamuslim mekabir	2510	5	4	5	2	7	P	0	0.11	1.0
7.	Terchamuslim mekabir	AletaWondo high school	1580	3	2	5	2	7.5	P	0	0.11	1.0

8.	AletaWondo high school	Bultuma	1820	3.5	2	4	4	15.8	R	0.24	0.32	2.5
9.	Bultuma	Mogissa	3470	5	9	6	2	9	P	0	0.11	1.0
10.	Mogissa	GarbichoKill a	4130	6	6	7	2	7	P	0	0.11	0.75
11.	GarbichoKilla	Fiinchawa	4720	6.5	5	9	2	7	P	0	0.11	0.75
12.	Fiinchawa	LegeseKidan esefer	3460	7	4	8	2	7.5	P	0	0.11	0.75
13.	LegeseKidane sefer	KibreMengis t intersection	2520	5.5	5	4	2	9	P	0	0.11	0.75
14.	KibreMengist intersection	Teticha	3570	2.5	4	5	2	7.5	P	0	0.1	1.0
15.	Teticha	NejuSefer	3210	5	5	5	2	7	P	0	0.1	1.5
16.	NejuSefer	Gidicho	4200	6.5	6	7	2	7	P	0	0.1	1.0
17.	Gidicho	Catholic church area	3720	5	3	6	2	7	P	0	0.1	1.5
18.	Catholic church area	Tugo	2810	4	2	4	2	7	P	0	0.11	1.0
19.	Tugo	OlonsoQeka	3830	5	4	4	2	7	P	0	0.1	1.0
20.	OlonsoQeka	OlonsoHore	3670	5.5	4	5	2	7	P	0	0.1	0.75
21.	OlonsoHore	BashiroDallo (Ererte river area)	3910	4	5	4	2	7	P	0	0.1	1.5
22.	BashiroDallo /Ererte river area	Bona Gibrina area	3,780	5.5	4	5	2	9	P	0	0.1	1.0
23.	Bona Gibrina area	Worancha	3,170	3	2	6	2	14	P	0	0.15	2
24.	Worancha	Gellana River	2,560	5.5	4	4	2	10	P	0	0.11	1.0
25.	Gellana River	Calba	2,930	5.5	5	5	2	7	P	0	0.11	1.0
26.	Calba	Bansa Ware	2,410	4	4	3	2	7	P	0	0.1	1.0
27.	Bansa Ware	Sada Ware	2,040	3	2	4	2	10.5	P	0	0.1	0.5
28.	Sada Ware	Daye Campus	2,070	2.5	3	3	2	7	P	0	0.11	0.5
29.	Daye Campus	Bonora River	2,320	3.5	3	4	2	14	P	0	0.2	2.0
	Total		8450									

N.B: L: Length; NHC: Number of Horizontal Curves; G (%): Gradient, NVC: Number of Vertical Curves; SW: Surface Widths; NL: Number of Lanes; MT: Median Types; MH: Median Height; MW: Median Width, R: Raised, P: Painted, SH: Shoulder, SW: Side walk.

Source: As built data from Ethiopian Roads Authority and some primary data collected from the selected road section by the author, 2019

3.3.5 Sample calculations of ADT traffic data for certain selected road sections

According to ERA Geometric design manual 2013 traffic volume for basic design purposes is based on the number of two(or more)axled motorized vehicles. For a two-lane two way road in a given terrain with an hourly flow of 15%(percent) of ADT after conversion of all type vehicles in to passenger cars unit (PCU)value and peak hourly flow taken from 6:30am-7:30am in the study area and weakly count were repeated on the selected road sections.Table 3.4 showedvehicles and corresponding passenger car equivalent values (PCUs).

Table 3.4: Vehicles and corresponding PCU Values

No.	Vehicle	PCU Value
1.	Passenger car	1.0
2.	Standard bus	2.0
3.	Min bus	1.5
4.	Truck	2.0
5.	Articulated truck	3.0
6.	Motor cycle (2&3 wheels)	0.5

Source: High way Capacity Manual (HCM) 2010

Sample 1:'Dilla intersection to Meggaraquary site'' road section traffic counts and ADT calculations for peak hour of local traffic from 6:30 A.M -7:30 A.M in table 3.5:

Table 3.5: Sample countedADT traffic volume of ''Dilla intersection to Meggaraquarysite''on the road section

Local count time	Cars	Standard buses	Min buses	Trucks	Articulated trucks	Motor cycles (2&3w	Total
6:30-6:45am	8	4	7	4	2	6	31
6:45-7:00am	9	2	8	4	1	10	34
7:00-7:15am	7	4	9	5	2	6	33
7:15-7:30am	10	3	9	6	0	4	32

Table 3.6: Sample counted ADT trafficsvolume PCU value of '' Dilla intersection to Meggaraquarysite''on the road section

Local count time	Cars *(1.0)	Standard buses*(2.0)	Min buses* (1.5)	Trucks *(2.0)	Articulated trucks *(3.0)	Motor cycles (2&3 wheels)*(0.5)	Total PCU
6:30-6:45am	9	8	10.5	8	6	3	44.5
6:45-7:00am	9	4	12	8	3	5	41
7:00-7:15am	7	8	13.5	10	6	3	47.5
7:15-7:30am	10	6	13.5	12	0	2	43.5

From the table 3.6, Peak hour duration is from 6:30-7:30am

Peak hour volume (PHV) = 47.5 + 41 + 44.5 + 43.5 = 176.5

15 minute maximum volume ($V_{15min,max}$) is 47.5

From formula, **ADT** =$\frac{\mathbf{PHV}}{\mathbf{K}}$= where **k** is rural hourly factor (15%) or 0.15

ADT =$\frac{\mathbf{PHV}}{\mathbf{K}}$= $\frac{176.5}{0.15}$ = 1177

Therefore the ADT at Dilla intersection to Meggeraquary road section is 1177.

Sample 2:''Aleta Wondo High School to Bultuma area'' road section traffic counts and ADT calculations for peak hour of local traffic from 6:30 A.M -7:30 A.M in table 3.7:

Table 3.7: Sample counted ADT traffic volume of ''AletaWondo High School to Bultumaarea''on the road section

Local count time	Cars	Standard buses	Min buses	Trucks	Articulated trucks	Motor cycles (2&3 wheels)
6:30-6:45am	8	6	10	4	3	11
6:45-7:00am	11	5	14	8	2	9
7:00-7:15am	10	3	6	4	2	15
7:15-7:30am	11	3	10	7	1	8

Table 3.8: Sample counted ADT trafficsvolume PCU value of ''AletaWondo High School to Bultumaarea'' on the road section

Local count time	Cars *(1.0)	Standard buses*(2.0)	Min buses*(1.5)	Trucks *(2.0)	Articulated trucks *(3.0)	Motor cycles (2&3 wheels)*(0.5)	Total PCU
6:30-6:45am	8	12	15	8	9	5.5	57.5
6:45-7:00am	11	10	21	16	6	4.5	68.5
7:00-7:15am	10	6	9	8	6	7.5	46.5
7:15-7:30am	11	6	15	14	13	4	63

From the above table, Peak hour duration is from 6:30-7:30am

Peak hour volume (PHV) = 57.5+ 68.5+ 46.5 + 63 = 235.5

15 minute maximum volume ($V_{15min,max}$) is 68.5

From formula, **ADT** = $\frac{PHV}{K}$ = where **k** is rural hourly factor (15%) or 0.15

$$ADT = \frac{PHV}{K} = \frac{235.5}{0.15} = 1570$$

Therefore, the ADT at Aletawondo high school toBultuma area road section is 1570

Table 3.9: Other Control Points and Dependent Variables measured on study road

No.	Variable (Y) Other Control Points				Variable (Z) Crash Severity			
|	Number of accesses	Number of access controls	Surface Types	ADT	Fatalities	Injuries	Property damages only	Total crash occurrence
1.	5	1	Paved	1,177	0	5	2	3
2.	7	0	Paved	1,096	1	4	1	3
3.	10	1	Paved	1,101	1	2	4	5
4.	13	0	Paved	1,223	2	5	4	6
5.	8	0	Paved	1,153	2	5	3	6
6.	11	0	Paved	1,041	1	7	4	5
7.	9	1	Paved	1,261	2	9	7	10
8.	16	2	Paved	1,570	3	13	6	9
9.	12	0	Paved	1,298	3	7	11	17
10.	7	0	Paved	1,013	2	5	11	13
11.	5	1	Paved	1,183	5	21	9	14
12.	7	2	Paved	1,101	3	4	13	15
13.	6	0	Paved	1,017	2	8	6	8
14.	9	0	Paved	1,198	1	2	2	4
15.	8	1	Paved	1,227	1	3	2	3
16.	11	0	Paved	1,021	2	1	4	7
17.	7	1	Paved	873	1	4	3	5
18.	5	0	Paved	912	0	3	3	4
19.	10	0	Paved	1,087	3	5	7	9
20.	8	2	Paved	785	2	2	9	11
21.	8	0	Paved	693	1	3	5	7
22.	6	0	Paved	956	0	4	3	4

23.	5	1	Paved	1,171	3	8	3	5
24.	7	0	Paved	803	2	3	4	6
25.	7	1	Paved	722	1	2	2	4
26.	5	0	Paved	917	2	0	5	7
27.	6	0	Paved	1,127	0	2	2	4
28.	5	1	Paved	1,060	1	4	2	3
29.	13	1	Paved	1,372	1	2	4	6
Sum	236	16		31,158	47	143	141	203

Source: Primary (Other Controls) and Secondary data (crash severity) on the road section by the Author, 2019

3.3.6 Data Collection

In this study two types of data were collected. The first one was road and road environment data and the second one was traffic volume data that was directly collected through measurement from the selected road sections such as average daily traffic (ADT) and average annual daily traffic (AADT) from Ethiopian Roads Authority (ERA) recorded for five study years. Further, data that Woredas' Police Commission and Daye and Alatawondo towns Traffic Police Stations used for official reporting of road traffic crashes at the end of the respective year were accounted for each crash severity (severe injury, slight injury and property damage) type occurred on the study road were specified. Traffic police also provided detail information data of the crashes such as; crash location, time, date, causes, road users involved in crashes, vehicle maneuver, road geometric characteristics and other necessary information.

3.3.7 Road Crash Data

Road traffic crash data were collected from all subjectworedas and fromtwo (AletaWondo and Daye) towns' administration Police Stationsbetween 2013/14 and August, 2018/19 that occurred at selected road sections. However, fatal crashes data and summarized crash data were collected from the SidamaZone Police Commission forthe same years. The crashes registered for five years were in hardcopy and thatincluded: time of day, day of the week, education, age and gender of drivers, driving experience, driver's relationship with vehicle, vehicle service years, vehicle type, vehicle ownership, road type, median and junction types, terrain, pavement type, pavement conditions, illumination, weather conditions, casualty type, causes for the crash and crash locations. The data gathered were prepared manually and transferred into an Excel file format for the crash frequency analysis.

3.3.8 Traffic Volume Data

Traffic volume data were used as input to undertake analysis. The average annual daily traffic (AADT) was taken from data recorded of Ethiopian Roads Authority (ERA) of five years from 2013/14 to 2018/19. The study also used local short-duration (peak hour) counts method from 6:30 a.m. to 7:30 a.m. for seven days from twenty-nine (29) selected road sections to estimate daily traffic. Vehicle types included in the study were: passengers cars, standard buses, min buses, small truck, medium truck, heavy truck, articulated truck, and motor cycle (2 and 3 wheels) in reference to the Highway Capacity Manual (HCM)2010 vehicle Classifications to convert all types of vehicles into passenger car units (PCU) for peak hour traffic volume calculations.The Ethiopian Roads Authority's (ERA's) Geometric Design Manual of 2013 was used to convert average daily traffic into a peak hour volume. The ADTs were multiplied by a K factor which is 0.15 (15%) in the case of two way rural paved roads. Therefore, to get ADT, peak hour volume was divided by K factor and is formulated as follows:

$$ADT=\frac{PHV}{K}$$

Where
ADT: Average Daily Traffic;
PHV: Peak Hour volume; and
K: hourly factor

3.3.9 Road and Road Environment Data

Road geometric characteristics such as road segment length, number of horizontal and vertical curves, number of downgrade and upgrade, number of lanes, surface width, median type, median width, median height, sidewalk width, were as built data from Ethiopian Roads Authority (ERA) of Shashemenedistrict road sections of AletaWondo-Bona-Daye. In addition, other road environment data such as number of access and access control, length of each sample of 29 road sections and surface type weremeasured actual measurement in the study area.Below shows checking surface width (around Gellane Riverarea).

Figure3.6: Checking Surface Widthlength (SW)(around Gellanariverarea); by Author, 2019

3.3.10 Candidate Variables Identification

The main target of getting effective parameters was to select influencing variables to analyze the effects of independents on depends. The effective explanatory and exposure variables that influence the road traffic crashes were evaluated throughstatistical analysis.Table 3.10 showed the independent candidate variables (major road alignment and cross-section) suggested for the crash prediction model. The main road characteristics used for the analysis are described in the following sections.

Horizontal curves: Horizontal curve is one of the major road alignments that influence road safety. The number of curves per section of road is counted for basic accident prediction variable. Moreover, both sharp and non-sharp horizontal curves are included in the study models.

Number of access (Access density):refers mainly to the number of driveways within a Roadway segment. Access density is one of the factors that has been pointed out as the determinant of accident rates on the highways. It includes cross roads and other accesses to residential areas, commercial centers, rural market entrance etc.

Access Control: Access control techniques include; traffic control devices, signs, guardrail, fences, and so on. It is used to improve traffic performance and safety on highways.

Road traffic crash frequency is defined as the number of crashes occurring within a specific jurisdiction, on a roadway section, or at an intersection. A number of road traffic crashes is used as a response variables (or dependent variables).

Traffic volume is the number of vehicles that pass a given point on the roadway in a specified period of time. The average of the seven days counts is considered as average daily traffic (ADT) which is primarily computed from peak hour volume and k factor and average annual daily traffic(AADT) in this study. The **K factor** is defined as the proportion of averagedaily traffic occurring in an hour. This factor is used for designing and analyzing the flow of traffic on highways.

Peak hour volume is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes. By counting the number of vehicles that pass a point on the roadway for duration of an hour (15-minute interval); it is possible to arrive at the 15-minute maximum volume. Then, 15 minute (quarter volume) is converted to peak hour volume.

Vertical curves: Vertical curves are also basic and influential parameter of road geometric alignment on the road safety which includes both crest and sag curves and it is considered as a candidate variable for regression analysis in this study.

Surface width: As depicted in the general descriptive crash analysis, different Pavement

Conditions have different magnitudes of traffic crashes and it is one of the contributing factors toit.

Median type: Median type also is a safety parameter, and in this study, it was considered as categorical variable and assigned as raised and painted median types.

Median width: median width is one among the road cross-sectional elements, and taken as a candidate variable in the analyzing models on the selected road sections.

Length of road segment: The study was conducted on different roadway sectionsand road length is one among the explanatory variable used in traffic safety analysis of study road.

Vertical gradient: Both upgrade and downgrade count per section of road segment were included in this study.

Median height: Median is central reservation that might be either raised or painted. Hence, median height data measurements were taken for twenty-nine (29) road sections for both raised and painted medians for the road crash prediction model.

Number of lanes: lane is a longitudinally marked part of road cross-section that is wide enough to accommodate one vehicle. In this study, number of lanes was considered for accident frequency modeling process.

Sidewalk or Shoulder width: It is also known as foot path or footway, is a path along the side of a roads. In this study, only one side of rural paved road data was considered as candidate variable for the models analyze in the traffic accident analysis.

From those proposed candidate explanatory variables for the models in the study, some of them were excluded from the model by statistical analysis, and only statistically significant variables were incorporated in the model development. Table 3.10 showed candidate variables considered in the models for effect analyzes of selected independent variables on dependent once of the study.

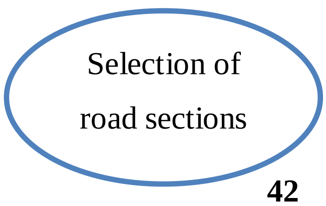
Table 3.10: Candidate Variables Considered in the checking Processfor the Effectsof geometric design parameters on traffic crashes occurrence

No.	Variable	Description
1.	NHC	Number of horizontal curves per road section
2.	NVC	Number of vertical curves per road section
3.	NVG	Number of vertical grades per road section
4.	NL	Number of lane on road section
5.	RSL	Road segment length in meter (m)
5.	SW	Width of the road surface in meter (m)
6.	SWoSHW	Width of the side walk or shoulder width in meter (m)
7.	NA	Number of access per road section
8.	NAC	Number of access control per road section
9.	ADT	Average daily Traffic on road section
10.	MW	Average width of the median in meter (m)
11.	MH	Average height of the median in meter (m)
12.	MT	= 1 if the median is a raised, = 0 other wise (painted)

3.3.11. Development of the Multivariate Models to analyze the effects of Geometric parameters on Traffic Crashes

A crash count statistical modeling technique is used to know the relationship between dependent variables and independent variables. This includes both Log-linear Poisson Regression Model and Negative Binomial Regression Model, which the study used to associate road geometric variables with road traffic crash occurrences. The estimated coefficients of the variables were tested to develop the final model. Statistically insignificant explanatory variables were systematically removed from the model and then, interpretations for those statistically significant variables were done.

Statistical significance was evaluated at a p-value of 10%. Figure 3.7 illustrated model development process in the study. In addition, the descriptive analysis of the general crash trends in the AletaWondo-Bona- Daye road sections was organized and analyzed using SPSS20 software package, Microsoft Excel and were presented in the forms of tables, charts, and graphs.



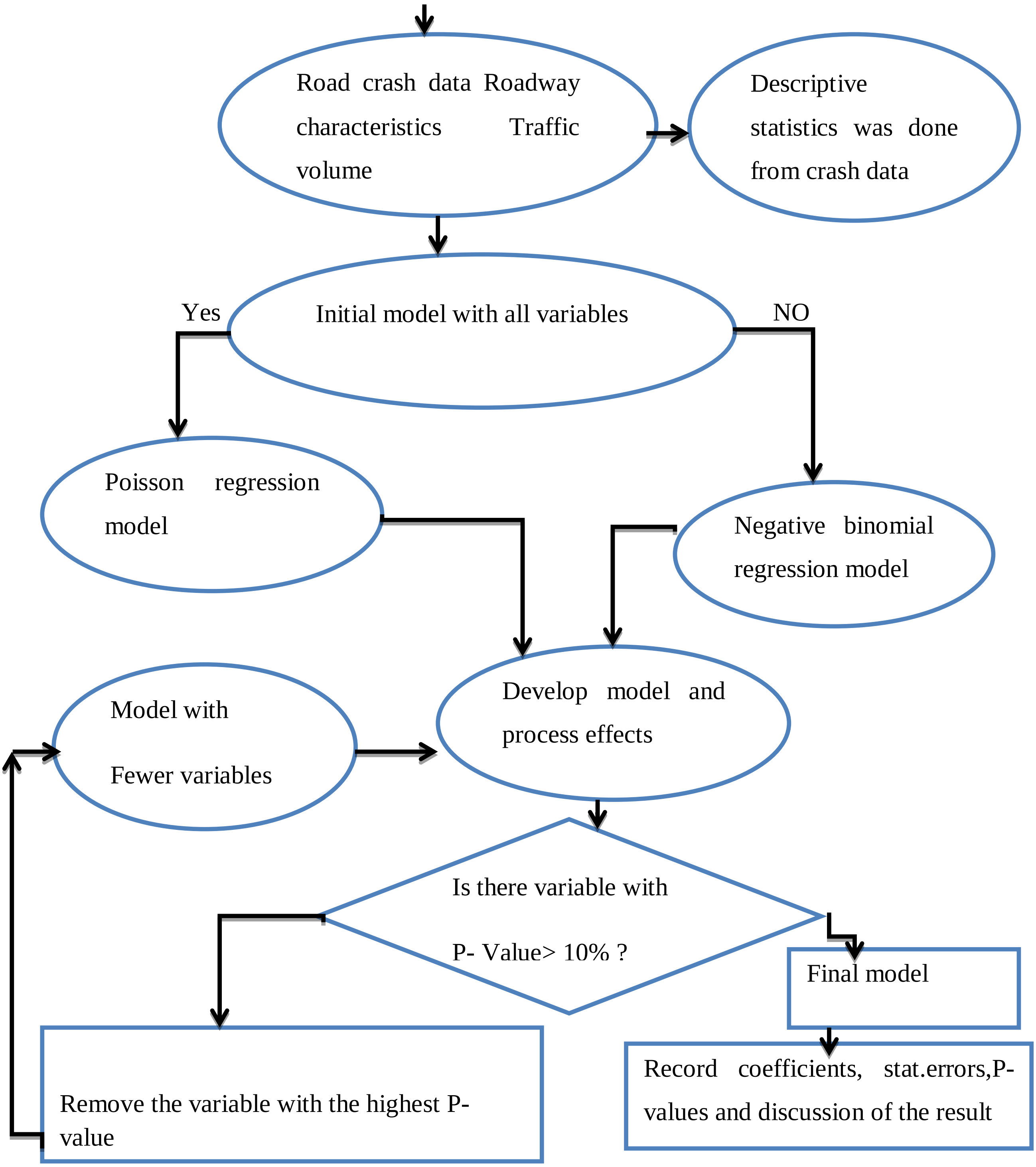


Figure 3.7 Model Development process to check the Effects of Geometric design parameters on Traffic crashes occurrence.

3.3.12. Empirical Bayesian (EB) Method for Additional Analysis

After collecting the necessary information, data processing and interpretations was done using statistical package for social sciences (SPSS 20) software as above shown.

Additional Empirical Bays (EB) method used to calculate expected number of crashes of road segments and horizontal and vertical curves effects on roads crashes since horizontal curves itself consists some other geometric parameters such as horizontal curves (HC) length, HC radius, spiral curves and super-elevation they also have their own effects on occurs of traffic crashes along existed road sections.

3.3.12.1. Base Model for Empirical Bayesian (EB) Method

Safety performance function is regression models for estimating the predicted average crash frequency of individual roadway segments. The base conditions for roadway segments on rural two-lane two-way roads that has been used to estimate according to AASHTO (2009) safety manual as table given below

Table 3.11: According to AASHTO (2009) safety manual base conditions for two-lane two-way rural road

No.	Road geometric design elements	Base conditions
1.	Shoulder width	1.83m
2.	Lane width	3.66m
3.	Shoulder type	Paved
4.	Roadside hazard rating (RHR)	3
5.	Driveway density (DD)	5 per mile
6.	Horizontal curvature	None
7.	Vertical curvature	None
8.	Centerline rumble strips	None
9.	Passing lanes	None
10.	Two-way left-turn lanes	None
11.	Lighting	None
12.	Automated speed enforcement	None

Evaluation of the fitting of SPF model to the specific sites should be assessed based on the following criterion. The model passes the goodness of fit criteria when the value of Pearson X^2 and Scaled Deviance G^2 statistics are greater than or equal to the value of χ^2statistics distribution with (n-p) degree of freedom at 95% confidence level according to Dissanayke, S. and Ratnayake, I. (2006) study. According to Miaou, S.P. (1994) study, the coefficient of determination (R^2) can also used to determine the amount of variability in the response variable explained by the variation in the selected set of explanatory variable.

The Pearson X^2 and Scaled Deviance G^2 statistics for NB distribution given according to Wood, G.R. (2002) study as below:

$$X^2 = \sum_{i=1}^{n} \frac{(yi - \mu i)2}{(\mu i + \alpha\mu 2i)} \quad (1)$$

$$G^2 = 2\sum_{i=1}^{n} \{(\ln \frac{yi}{\mu i})yi - (yi + \frac{1}{\alpha}) \ln \frac{(1 + \alpha yi)}{(1 + \alpha \mu i)}\} (2)$$

Where, y_i= observer number of accidents; μ_i= predicted number of accidents using SPF; α=dispersion parameter (in this study α=k).

The dispersion parameter can be estimated from observed data using the method of moments as function of the variance and the mean was determined according to Wood, G.R. (2002) study as:

VAR (Yi) $=\bar{y}_i+\alpha\ \bar{y}_i^2$ (3)

Where, VAR (Yi) = variance of accident count, and $\bar{y}$ = mean of accident count.

Steps to analysis of geometric parameters effects on traffic crashes occurrence as follow; All steps are from highway safety manual (Highway Safety Manual (HSM), 2008 and 16).

Step1: predicted average crash frequency for base condition

N_{spfrs}= AADT*L*365*10^{-6}*$e^{-0.312}$…………………………………………...Equation (3)

Where,

N_{spfrs}= Estimated total crash frequency for roadway sections;

ADT= Average daily traffic volume (vehicles per day);

L= length of roadway section (miles)

Step 2: Accident modification factors for each road parameter (AMFs).

Accident modification factor (AMFs) are used to adjust the safety performance function (SPF) estimate of predicted average crash frequency for the effect of individual geometric design and traffic control features as shown in the general.

The AMF for the SPF base condition of each geometric design or traffic control feature has value of 1.00. Any feature associated with higher crash frequency than the base condition has an AMF with a value greater than 1.00. Any feature associated with lower crash frequency than the base condition has an AMF with a value less than 1.00 (HSM, 2018).

AASHTO (HSM, 2009) provides twelve AMFs in the form of equations, tables and graphs of these factors, only three of them considered since other geometric design parameters effects on traffic crashes analyzed through Poisson and negative binomial regression models of SPSS version 20. For this analysis additional attention was given for horizontal curves since it comprises other parameters such as: length of HC, super elevation, spiral curves and transition curves on it. The AMFs for geometric design and traffic control features of rural two lane two-way segments presented below.

A. Horizontal Curves (HC)

$AMF_A=$ $\frac{1.55*Lc*+\frac{80.2}{R}-0.012*S'}{1.55*LC}$ $S' = 1$, for spiral curve present and $S' = 0$, for not or

AMF_A= 1.00 for Sv< 0.01

Where;

Lc= Horizontal curve (HC) length (miles);

S= spiral curve and

R= HC radius (ft)

B. Super elevations(% or m/m)

AMF_B= 1.00 for Sv< 0.01

AMF_B= 1.00+6*(Sv – 0.01) for $0.01 \leq Sv \leq 0.02$ or

AMF_B = 1.06 +3*(Sv – 0.02) for $Sv \geq 0.02$

Where;

Sv = super elevation variation (m/m)

C. Grades (g %)

$G \leq 3\%$, AMFc = 1.00; $3\% \leq G \leq 6\%$; AMFc = 1.10 and G>6%, AMFc =1.16

Where, G = Average grade of the road section

D. Lane width

AMF_D= (AMF_{ra} - 1)*P_{ra} +1

Where; AMF_{ra}= AMF related accidents, P_{ra}= proportion of related accidents

E. Shoulder width

$AMF_E = (AMF_{wra} + AMF_{tra} - 1) * P_{ra} + 1$

Where; w&t indicate with and types of shoulder respectively.

F. Driveway Density

$AMF_E = \frac{0.322 + DD*(0.05-0.005*\ln(AADT))}{0.322 + 5*(0.05-0.005*\ln(AADT))}$

Where; DD= Driveway density $e^{(-0.6869 + 0.0668*RHR)}$

G. Roadside Design

$AMF_G = \frac{Exp(-0.6869 + 0.0668*RHR)}{Exp(-0.4865)}$

Where; RHR = Road Hazard Rating

Step 3: Calibration factor

The general level of crash frequencies may vary substantially from one jurisdiction to another for a variety of reasons including climate, driver populations, and animal populations, crash reporting thresholds and crash reporting system procedures. $\Sigma_{\text{all site predicted crash}}$

$$Cr = \frac{\Sigma \text{ all site observed crash}}{\Sigma \text{ all site predicted crash(unadjusted)}}$$ ……………………………………Equation (4)

Where, Cr= calibration factor

Step 4: Predicted average crash frequency

$N_{predicted} = N_{spfrs} * Cr * (AMF_A * AMF_B * AMF_C * \ldots\ldots\ldots * AMF_n)$

Where;

Npredicted = predicted average crash frequency for an individual roadway segment for the selected years;

Nspfrs = predicted average crash frequency for base conditions for an individual roadway segment;

Cr= calibration factor for roadway segment for geographical areas;

$AMF_{A.........}$ AMF_C= Accident Modification Factors for rural two-way two-lane roadway two-lane roadway segments;

Step 5: weighed adjustment to be placed

$$W = \frac{1}{1 + k*(\Sigma \text{all study years Npredicted})} \text{..Equation (3)}$$

Where;

K = Over dispersion parameter from the associated SPF ($k = \frac{0.236}{L}$), L= segment length (miles)

Step 6: Expected crash frequency (EB regression method)

Nexpected = w*Npredicted+ (1-w)*Nobserved ....Equation (4)

Where;

Nexpected = Expected average crashes frequency for the study period,

Npredicted= predicted average crash frequency using a SPF for the study period using the given conditions,

w= weighed adjustment to be placed on the SPF condition,

Nobserved= observed crash frequency at the site over the study period of years,

Step 7: Potential improvement (identification of hazardous locations)

PSI_i=$Nexpected_i$ - $Npredicted_i$...Equation (5)

Where;

PSI_i= Potential Safety Improvement at site ‘’i”

$Nexpected_i$= Expected average crashes frequency for the study period at site ‘’i”

$Npredicted_i$= Predicted average crash frequency predicted using a SPF for the study period under the given conditions at site ‘’i”

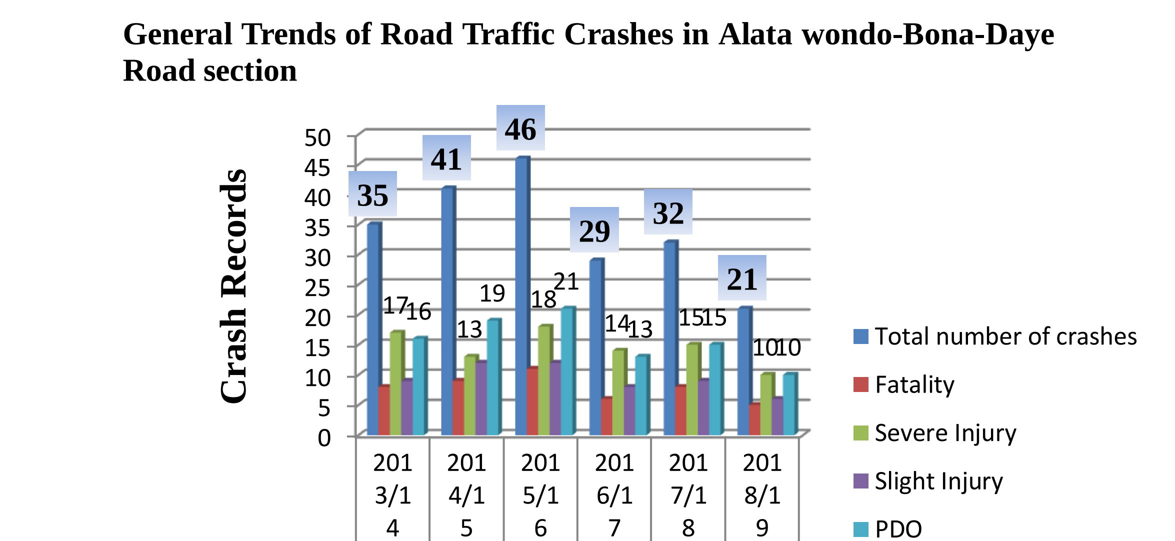
Step 8: Ranking of locations

The highest potential safety improvement is the the most hazardous section. Therefore the road sections rank in the descending order.

4.RESULTS AND DISCUSSIONS

4.1 Road Traffic Crash and Trends on the Study RoadSection

The crash records and general trends on the study road over the last five years (2013/14 to 2018/19) are shown in Figure 4.1. The average annual growth rate during the period was calculated at 14.7% which slightly decreased in 2018/19. The Figure also shows that the general trends of road traffic crashes have been slightly increasing for three serial years then at the middle decreased at some extent and final increased.



	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Total number of crashes	35	41	46	29	32	21
Fatality	8	9	11	6	8	5
Severe Injury	17	13	18	14	15	10
Slight Injury	9	12	12	8	9	6
PDO	16	19	21	13	15	10

Figure 4.1**:** General Trends of Road Traffic Crashes on the Study road

Source: Woredas and towns administrations of TC (2013/14-2018/19) Computed by the Author, 2019.

4.2 Analysis of Traffic Accidents on the Study Road Section

The study time frame was considered six years to show general trends of crash frequency. Accordingly, about 35 (17.2%), 41 (20.1%), 46 (22.5%), 29 (14.2%), 32 (15.7%) and 21 (10.3%) of the accidents occurred in years 2013/14, 2014/15, 2015/16, 2016/17, 2017/18 and 2018/19 respectively. These are illustrated in Figure 4.2. It can clearly be seen that the crashes significantly increased yearly in these time intervals.

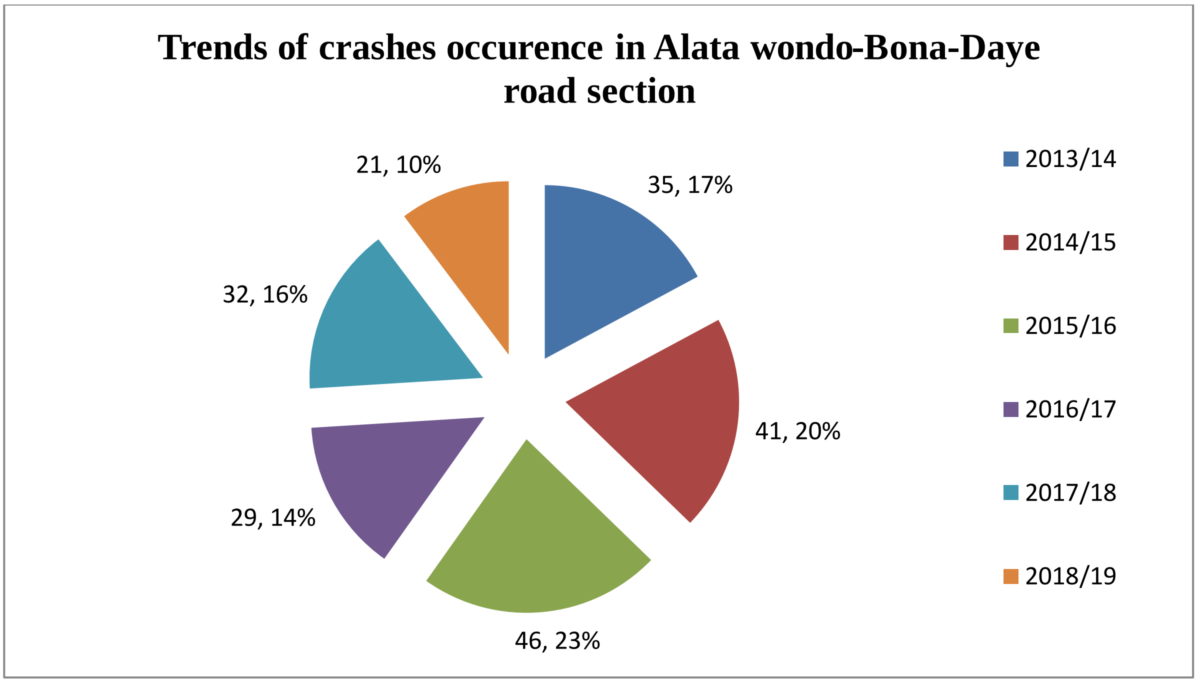


Figure 4.2: Road Traffic Crashes Trend on AlataWondo-Bona-Daye Road

Source: SZTPO, Woredas and Town Administrations TPO (2013/14-2018/19) computed by the Author, 2019.

Comparably, the total road crashes that occurred in Sidama Zone (36 Woredas and 7 town/city administrations) on different main road sections from2013/14 to 2018/19 were 667 and on the study road it was 203 which was 30.4% of the total occurred in the zone and which is highcompared to rest sections. Therefore, this is why studying the possible influencing factors for traffic crasheson the study road and recommending mitigation measuresfor policy makers is not an option but a must understanding the nature and characteristics of traffic accidentson the study road were used as the general guidance for the interdependence of road traffic crashes and the road characteristics for the later detail analysis and relationships/correlation between them.

4.2.1 Causes of Road Traffic Crashes

There are many causes of road traffic crashes according to the traffic police road crash investigation team reports. Accordingly; drunk driving, drug driving, driving without respecting the right hand rule, failure to give-way for the other vehicles, failure to give-way for pedestrians, tailgating, overtaking on crest vertical curve, overtaking on winding horizontal curve, improper turning after overtaking, driving above speed limit, improper overtaking, improper turning, not respecting traffic rules and others were the causes. Majorcauses of road traffic crashes for the consecutive of six years 2013/14 to 2018/19 were; over taking on winding horizontal curve (14.5%), over taking on crest vertical curves (10.5%), and tailgating (9.3%); whereas, other factors had almost negligible contribution to crashes (drink driving, drug driving and missing of right hand rule and not respecting traffic sign and others).

Traffic polices in developing countries have limited skill in road traffic engineering. Consequently, they underestimate the contribution of roadway to traffic crashes. As depicted in Table 4.1, the causes of road traffic crashes were generally classified into human factors; related to driver, passenger, and pedestrian who accounts about 84.5% of the total crashes (i.e. main causes of road crashes) and non-human factors; related to weather conditions, road characteristics and mechanical defects of vehicles, which account only 7.2% of total crashes. Furthermore, other causes of road crashes that are not mentioned were about 3.8% and unidentified causes of crashes estimated (4.2%) were included in the report.

Table 4.1: Causes of Road Traffic Crashes according to traffic data collected

No.	Causes of road traffic crashes	Fatal	Severe Injury	Slight Injury	PDO	(%)	
1.	Failure to give-way for vehicle	5	7	4	3	5.8	
2.	Failure give-way for Pedestrian	3	4	6	-	3.9	
3.	Driving W/t respecting right hand rule	1	2	-	2	1.5	
4.	Drunk driving	1	3	1	-	1.5	
5.	Improper turning after overtaking	2	6	4	9	6.3	
6.	Overtaking on winding horizontal curve	8	11	14	15	14.5	
7.	overtaking on crust vertical curve	6	15	3	11	10.5	
8.	Tailgating	7	9	5	10	9.3	
9.	Driving above speed limit	2	4	-	7	3.9	
10.	Improper overtaking	1	3	-	-	1.2	
11.	Improper turning	-	6	2	5	3.9	84.5%(due to Human Error)

12.	Not respecting traffic rules	3	7	1	8	5.7	
13.	Not respecting traffic Sign	-	3	-	9	3.6	
14.	Improper movement from stoppage		1	4	6	3.3	
15.	Improper stoppage	-	-	1	5	1.8	
16.	Driving without attention	1	5	3	7	4.8	
17.	Excess light	-	-	4	6	3.0	
18.	Excess loading	-	3	-	9	3.6	
19.	Pedestrian failure to respects traffic rule	1	4	2	8	4.5	
20.	Mechanical failure of vehicle	1	2	5	5	3.9	
21.	Due to road characteristics	1	3	3	4	3.3	7.2%
22.	Others	2	5	-	6	3.8	3.8%
23.	Unknown	2	-	5	8	4.5	4.2%
Total		47	87	56	141	100	

Source: Woredas and Town Administrations TPO (2013/14-2018/19), computed by the Author, 2019

4.2.2 Severity (Victims) of Road Traffic Crashes

In Table 4.2 showed victims of road traffic accidents for consecutive of five years were; pedestrians, passengers and drivers. Accordingly, out of the total road crashes, for these years, 45.2% were passengers that represented the highest proportion of the crashes. On the other hand, pedestrians, drivers and road side inhabitants shared 37.3%, 11.8% and 5.7% of the road crashes respectively. In addition, more than 80% of the victims were in the productive class of the society (18 and 50 years). Consequently, the road traffic crashes adversely affect the economy of the country. Generally, pedestrians and passengers shared about 87.9% of road traffic crashes (highest proportion of total crashes) while drivers account for a small share of crashes (12.1%).

Table 4.2: Crash Severity by Road User Distributions

Road users	Age	Crash Severity(2013/14-2018/19)					
		Fatal	Severe	Slight	Total	Percentage	
Driver	< 18	-	1	-	1	0.41	11.8%
	[18-30]	2	3	2	7	3.52	
	[31-50]	3	5	3	14	6.53	
	>50	1	-	2	3	1.51	
Pedestrian	< 7	-	1	-	1	0.41	37.3%
	[7-13]	1	2	-	3	1.51	
	[14-17]	3	1	4	8	4.11	
	[18-30]	12	7	2	21	11.0	
	[31-50]	9	15	11	35	18.4	
	>50	1	2	1	4	2.10	
Passenger	< 7	-	1	1	2	1.01	45.2%
	[7-13]	1	1	2	5	2.61	
	[14-17]	2	4	-	6	3.14	
	[18-30]	7	12	8	27	16.21	
	[31-50]	6	18	11	34	17.65	
	>50	1	2	2	5	2.61	
Road side inhabitants	< 7	1	1	1	3	1.51	5.7%
	[7-13]	-	-	-	1	0.41	
	[14-17]	1	-	-	1	0.41	
	[18-30]	-	1	2	3	1.51	
	[31-50]	-	1	1	2	1.01	
	>50	1	-	-	1	0.41	
Total		47	87	56	190	100	100

Source: Woredas and town administrations PC (2013/14-2018/19) Computed by the Author, 2019

4.2.3 Crashes by Days of Week

Average crashes that occurred during days of week were about: 29, 41, 23, 33, 18, 38, and 21 on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday respectively.

Table 4.3: Accident Ratios by Days of the weeks

Day	Average number of accidents	Ratio (of the lowest=18)
Monday	29	1.61
Tuesday	41	2.28
Wednesday	23	1.26
Thursday	33	1.83
Friday	18	1.0
Saturday	38	2.11
Sunday	21	1.16
Total	203	

Source: Woredas and town administrations PC (2013/14-2018/19) Computed by the Author, 2019

In Table 4.3 As shown, the lowest number of accidents occurred on Friday with 18 and the highest on Tuesday with 41. Regarding ratios, the Tuesday accidents were about 2.28 times that of the Friday accidents followed by Saturday which was 2.1 times that of Friday. Hence, the highest number of road traffic crashes occurred on Tuesday followed by Saturday. This might be due to Tuesday beinga market day and Saturday being the third highest is on Monday with a ratio of 1.61 times of Friday. This might be because Monday is the first working day of the week and most of the people did not want to stay at home on this day.

Similarly, the road sections are congested particularly during peak (rush) hours relating with other working days. As a result, high numbers of crashes occurred on Tuesday. Road traffic crashes are relatively low on Fridays and Sundays. Sunday is non-working day for most of government and private offices and on Friday there is no market in the study area. Hence, low movements of vehicles, passengers, and pedestrians occurred on these days compared to other days.

4.2.4 Crash Variations by Time of a Day

Times of days have different crash frequencies depending on activity of the people, the traffic situation, road users' conditions, work time rules and the others. Figurebelow depicts total daily crashes that happened at different hours of the days. The road sections were relatively safe from 9 p.m. to 5 a.m. Total number of crashes peaked between 7:00 to 18:00 (7am to 6pm) during daytimes in allthe five years and one additional study year. During these times, road users are active on the streets. Hence, high conflict amongst them is expected that might result in road crashes. The density of traffic on the streets also affects average vehicle speed and hence, prevalence and outcome of the crash. During daytime, density of traffic is high and therefore, higher number of road crashes would happen.

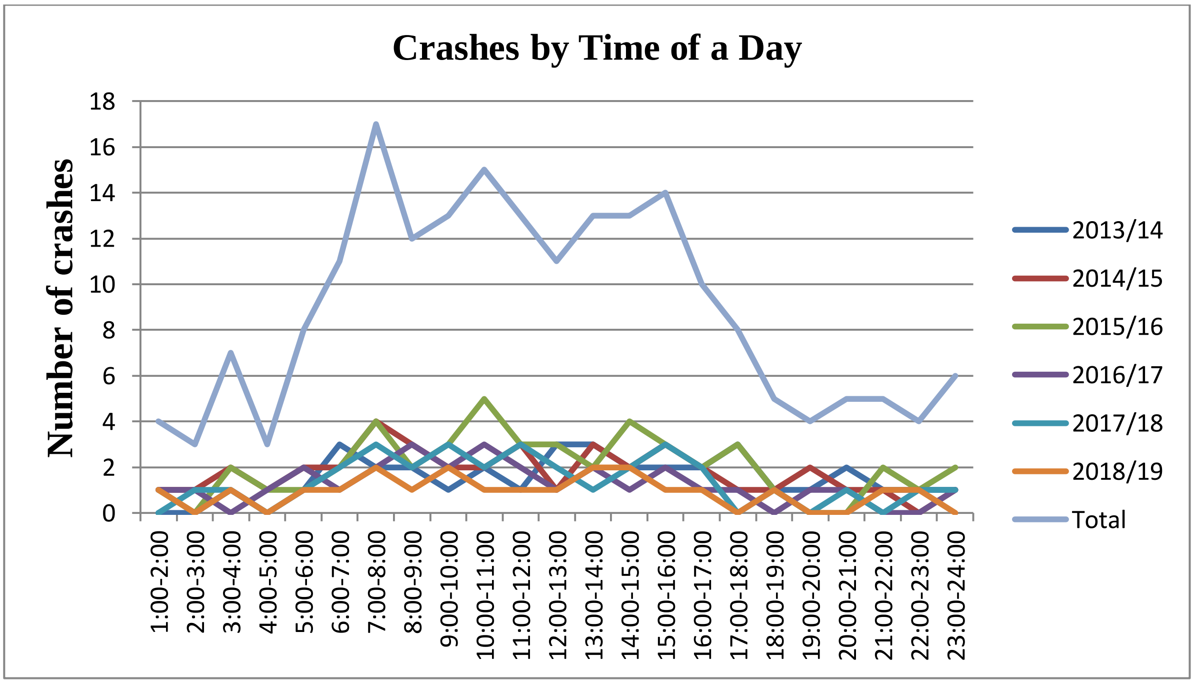
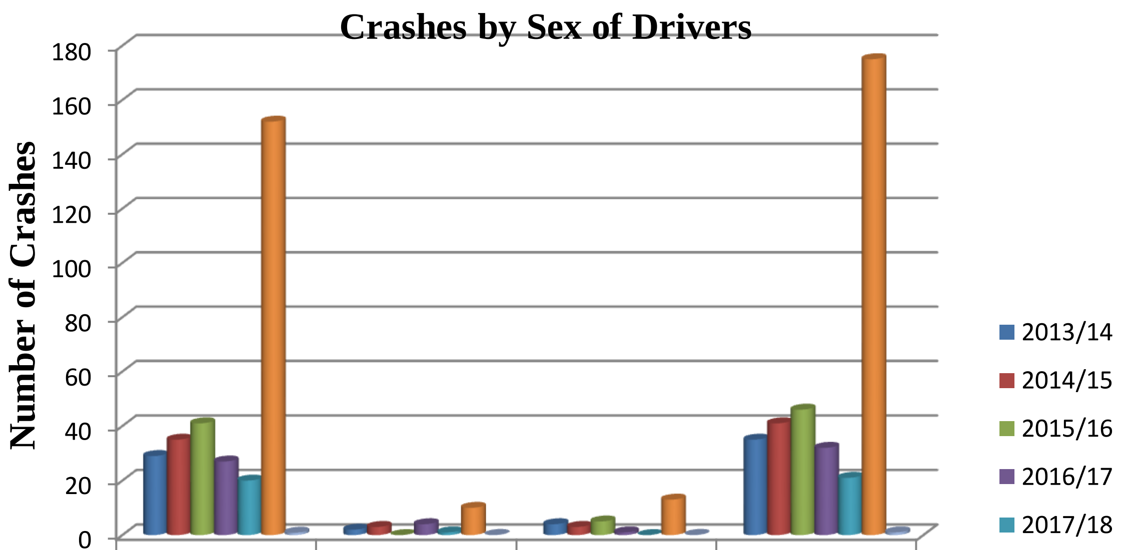


Figure 4.3: Crash Variations by Time of a Day in 24 hours

Source: Woradas and Town administrations TPC (2015/16-2017/18) computed by the Author, 2019

4.2.5 Distribution of Road Accidents by Gender

The occurrences of gender-related road crashes significantly varied on the study road road section. Accordingly, about 86.9% of road traffic crashes happened with male drivers, which left their lives and their families into jeopardy. However, only 5.7% of total crasheswere shared by female drivers. About 7.4% of the total crashes were not identified to either of the sexes. Figure 4.4 showed the general distribution of road crashes by gender recorded in the study road section in consecutive of five years.



	Male	Female	Unknown	Sum
2013/14	29	2	4	35
2014/15	35	3	3	41
2015/16	41	0	5	46
2016/17	27	4	1	32
2017/18	20	1	0	21
Sum	152	10	13	175
Percent	86.85%	5.71%	7.43%	100%

Figure 4.4: Distributions of Road Crashes by Gender

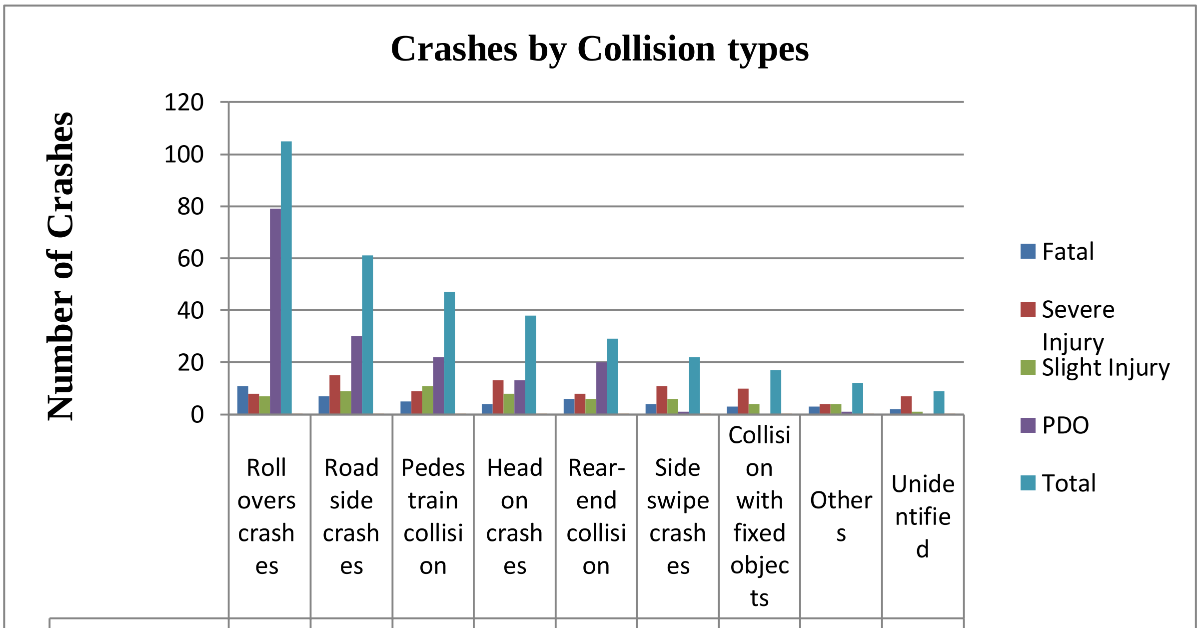
Source: Woradas and Town administrations TPC (2015/16-2017/18) computed by the Author, 2019

4.2.6 Road Traffic Crashes by Collision Type

Different typesof vehicle crashes by collision types and severity occurred on the study road as illustrated in Figure below. These accident types were; head-on crashes rear-end crashes, angle crashes, sideswipe crashes, rollover, and collision with pedestrians, collision with animals, fall from vehicles, collision with parked vehicles, and collision with a fixed object.

From the analyses, the percentages of these collision types constituted as; rear-end collisions (6.61%), sideswipe crashes (5.21%), head on crashes (12.1%), roadside crashes (18.3%), and collision with pedestrians (14.2%) were the most dominant types of collisions which frequently occurred on the study road. However, other accident types like; rollovers (32.5%), collision with fixed objects (4.6%), others (3.18%) and unidentified (2.3%) had relatively low number of accidents.

Moreover, collision types like collision with animals and fall from vehicles had insignificant effects on road crash occurrences on the study road section. Analyzing various types of collisions is important to identify the main causes and possible countermeasures with relation to quick traffic management related issues. Collision with pedestrians and rollover were the major causes of fatalities on the study road. Figure below illustrates crashes by collision types.



	Roll overs crashes	Road side crashes	Pedestrain collision	Head on crashes	Rear-end collision	Side swipe crashes	Collision with fixed objects	Others	Unidentified
Fatal	11	7	5	4	6	4	3	3	2
Severe Injury	8	15	9	13	8	11	10	4	7
Slight Injury	7	9	11	8	6	6	4	4	1
PDO	79	30	22	13	20	1	0	1	0
Total	105	61	47	38	29	22	17	12	9
Percent	32.50%	18.30%	14.20%	12.10%	6.61%	5.21%	4.60%	3.18%	2.30%

Figure 4.5: Total Road Traffic Crash by Collision Types on the Study Road

Source: Woradas and Town administrations TPC (2013/14-2018/19), computed by the Author, 2019

4.2.7. Crashes by Road Alignment

The road geometric alignments have significant impact on road traffic crashes. As illustrated in Table below, the major road geometric alignments categorized as straight and leveled, vertical curves, horizontal curves, upgrade and downgrade. The highest road traffic crashes were recorded on horizontal curves with percentage of 42.7%, downgrade 22.32%, road with straight terrain 15.1%, road with vertical curve 13.82% and followed by upgrade constitutes of 4.32%. Speed could be main reason for road traffic crashes happened on straight and leveled road alignments. From the analysis of police recorded traffic crash data it has clearly indicated that road geometric alignments like horizontal curve, vertical curves were the main road alignments where the frequent road traffic accidents occurred. However, crash frequency on road gradients (i.e. upgrade) and vertical curve consists of lower percentages.

Table 4.4: Road Traffic Crashes by Road Alignment

Road alignment	Total	Percentage (%)
Horizontal curve	87	42.7
Down grade	45	22.32
Road with flat terrain	31	15.1
Vertical curve	28	13.82
Upgrade	9	4.32
Un known	4	1.74
Total	203	100

Source: Woradas and Town administrations TPC (2013/14-2018/19) computed by the Author, 2019

4.2.8 Crashes by Vehicle Type

The Woreda's and Town administrations Traffic Police Officer divided vehicles in to different vehicle types; motor-bicycle, Taxi (Three wheel motor cycle and Damacus up to 8 seats), automobile, pick up < 10 quintal, truck 11-40 quintal, truck 41-100 quintal, truck with trailer, liquid cargo, minibus up to 12 seats, standard bus 13 to 45 seats, cart, and others involved in the crash frequency.

Accordingly, most frequent road traffic crashes were caused by Mini bus(up to 12 seats), Standard bus (13 up to 45 seats), Trucks 41-100 quintal (Sino truck), Motor bicycle, Truck 11-40 quintal (Isuzu), Pick up (<10 quintal) , Taxi (Three wheel motor cycle and Damacus up to 8 seats) and with percentage of crashes ; 23.7%, 19.8%, 18.3%, 16.1%, 4.7%, 3.6%, 3.1% respectively that constitute about 89.3% of the vehicles involved in road crashes. The remaining 10.7% of the crashes were due to Automobile (4.3 %%), Truck trailer (2.5%), Cart (1.05%), liquid cargo (0.15%) and unspecified or other types (2.7%) of vehicle. Liquid cargo and train are insignificantly contributes to crash occurrence. Road traffic crash occurrence due to vehicle types for duration of five years in Alatawondo- Bona-Daye road section as shown in Table below.

Table 4.5: Proportions of Road Traffic Crashes by Vehicles Type

No.	Type of vehicles	Fatal	Severe injury	Slight injury	PDO	Total	Percentage (%)
1.	Mini bus (up to 12 seats)	13	21	12	32	78	23.7
2.	Standard bus (13-45 seats)	10	15	11	30	66	19.8
3.	Truck (41-100 quintal)	5	10	8	38	61	18.3
4.	Motor bicycle	6	7	14	26	53	16.1
5.	Trucks	3	10	1	2	16	4.7
6.	Pick up	3	5	3	1	12	3.6
7.	Taxi (3-wheel and 8 seats taxi)	4	4	1	1	10	3.1
8.	Automobiles	2	4	3	5	14	4.3
9.	Truck trailers	-	3	1	4	8	2.5
10.	Cart	-	1	-	2	3	1.05
11.	Liquid cargo	-	-	1	-	1	0.15
12.	Unspecified or other type	2	5	1	2	10	2.7
	Total	47	87	56	141	331	100

Source: Woradas and Town administrations TPC (2013/14-2018/19) computed by the Author, 2019

4.2.9 Crashes by Pavement Surface Conditions

Table 4.6 summarized the surface condition where frequent traffic crash had occurred. Pavement condition isone of contributing factors to speeding of vehicles and hence, road traffic crashes. About 93.7% of road crashes happened on asphalt roads with good pavement conditions, while poor pavement conditions only contributed 6.3% to road crashes. However, gravel roads had either insignificant contributions to road crashes in the study road section were asphalts.

Table 4.6: Crash by Pavement Surface Conditions

No.	Types of Pavement	Fatal	Severe Injury	Slight Injury	PDO	Total	Percentage (%)
1.	Quality Asphalt	42	87	55	127	311	93.7
2.	Poor Asphalt	5	-	2	14	21	6.3
3.	Gravel	-	-	-	-	-	0
Total		47	87	57	141	331	100

Source: Woradas and Town administrations TPC (2013/14-2018/19) computed by the Author, 2019

4.2.10 Crashes by Defects of Vehicles

To analyze the level of road traffic crashes occurred by vehicle defect, some indicators presented as; brake pedal defects, steering wheel defect, tire defects, head and tail light defects, other mechanical problems, vehicles with no defect, and unspecified. From the mentioned vehicle defects, nearly all the accidents occurred by vehicles with no defects (88.18%). The remaining vehicle defects; brake pedal defects, steering wheel defect and tire defects insignificantly contributed to road traffic accidents in the study Road section, while head and tail light defects, other mechanical problem and unknown vehicle defects contributes to road crashes total about 11.82% as shown Table 4.7.

Table 4.7: Crashes by Defects of Vehicles

Vehicle defects	Total	Percentage (%)
Brake pedal defects	5	2.46
Steering wheel defect	2	0.99
Tire defects	-	0
Head and tail light defects	3	1.48
Other mechanical problem	3	1.48
With no defect	179	88.18
Unknown	11	5.41
Total	203	100

Source: Woradas and Town administrations TPC (2013/14-2018/19) computed by the Author, 2019

4.2.11 Crashes by Divider Types and around road structures provision area

As Table illustrated below the percentage of road crashes on different road divider types where the crashes frequently occurred. An estimated 88.2%, 5.4%, and 2.5% of the crash frequency occurred on undivided two way, Raised median separated and non-painted undivided two way respectively and 3.9% on and around structures provided along the road this cases of traffic crashes most of time occurred around and on Gellana river which 9.4 km far from Daye town and aroundErerte river which 7.9km far from Bona town. ForGellanaRiver Bridge provided on long and steep horizontal curve and for Ererte river site selected for bridges on steep down grade area. On two way undivided roads drivers' lane changing and insufficient sight distances might be the case. This implies, in the study road sections lack and insufficient provision of pavement markings that regulate traffic flow to be safer.

However, median separated roads appropriately regulate traffic flows and head-on collision crash type is controlled for this road divider types.

Table 4.8: Crashes by Divider Types and around road structures provision area

Lane type	Sum	Percentage (%)
Undivided two way	189	88.2
Raised median- separated	11	5.4
Non – painted undivided two way	5	2.5
One way	0	0
Around road structures area		
On Bridges or Culvert area	8	3.9
Total	203	100

Source: Data collected and arranged by author, 2019

4.2.12 Crash by Vehicle Maneuver

Contributions to percentage of crash frequency at a time of vehicles maneuver for five years as presented in Table below were; entering the intersections (1.4%), diverging movement (0.55%), turning to right (2.2%), turning to left (3.8%), U-turning (21.7%), overtaking (27.3%), straight movement (38.7%), moving backward (0.55%), while parking (0.55%), other (1.7%)and unspecified (2.4%). About total 87.7%% of crash frequencies happened when culprit vehicles were moving in straight movement, u-turning and overtaking of moving vehicles. This kind of maneuver takes place at road segments and the vehicles are expected to be at high speed.

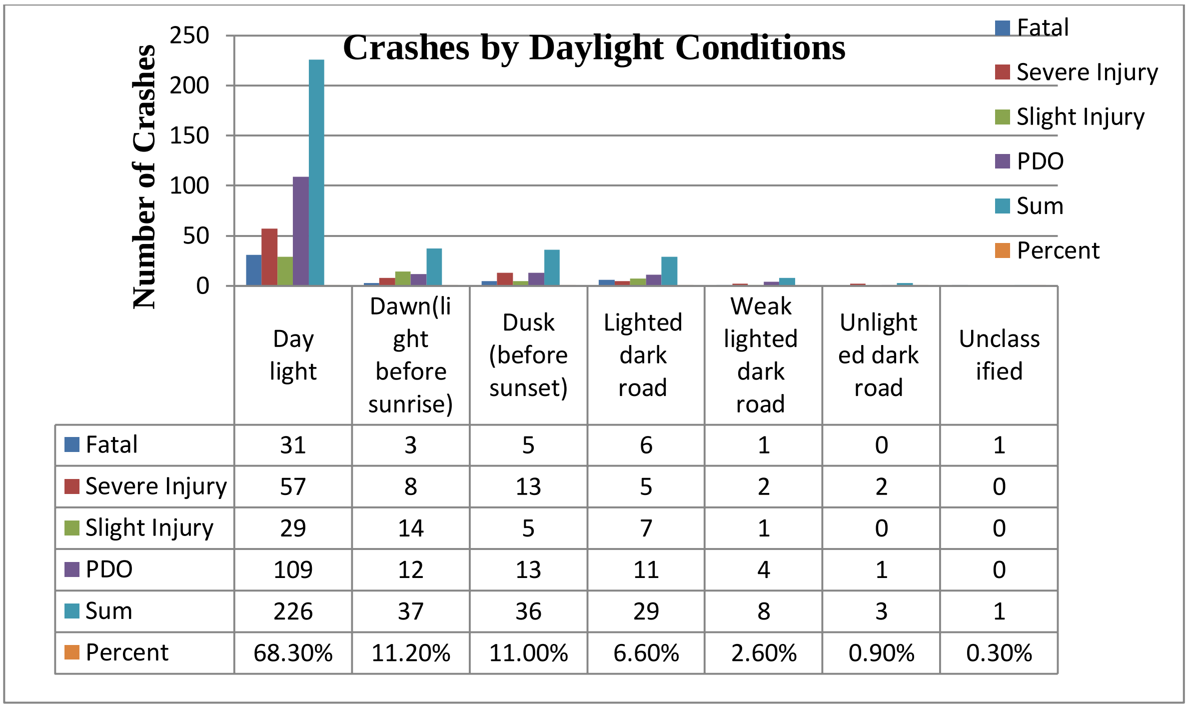
Table 4.9: Crashes by Movement of vehicles

No.	Movement of vehicles	2013/ 14	2014/ 15	2015/ 16	2016/ 17	2017 /18	Total	Percentage (%)
1.	Entering the intersections	1	-	1	1	-	3	1.4
2.	Diverging movement	-	-	-	-	1	1	0.55
3.	Turning to right	-	2	1	-	1	4	2.2
4.	Turning to left	3	2	1	1	-	7	3.8
5.	U-turning	10	13	8	10	3	40	21.7
6.	Overtaking	7	8	7	11	7	49	27.3
7.	Straight Movement	12	13	10	17	19	71	38.7
8.	Moving backward	-	-	-	-	1	1	0.55
9.	While parking(stopping)	-	-	-	-	1	1	0.55
10.	Other	1	-	1	1	-	3	1.7
11.	Unknown	1	1	-	2	-	4	2.4
	Total	35	41	29	46	32	183	100

Source: Woradas and Town administrations TPC (2013/14-2017/18) computed by the Author, 2019

4.2.13 Crashes by Light Conditions

Figure shows below crash happened by different light Conditions for durations of five years. Accordingly, light conditions shared different total crash frequency; day light (226), light before sunrise (37), before sunset (36), lighted dark road (29), weak lighted dark road (8), unlighted dark road (2), and unclassified (1). Even though the existence of light is very important for the reduction of road crashes, the analysis showed that most road traffic crashes occurred during the day light. Moreover, compared to day light, medium accidents were reported at dawn (light before sunrise), dusk (before sunset), lighted dark road in the study road section. Accidents those happened in weak lighted dark road and unlighted dark road were relatively low.



	Day light	Dawn(light before sunrise)	Dusk (before sunset)	Lighted dark road	Weak lighted dark road	Unlighted dark road	Unclassified
Fatal	31	3	5	6	1	0	1
Severe Injury	57	8	13	5	2	2	0
Slight Injury	29	14	5	7	1	0	0
PDO	109	12	13	11	4	1	0
Sum	226	37	36	29	8	3	1
Percent	68.30%	11.20%	11.00%	6.60%	2.60%	0.90%	0.30%

Figure 4.6: Road Traffic Crashes by light conditions

Source: Woredas and Town administrations TPC (2013/14-2017/18) computed by Author, 2019

4.2.14 Crashes by Weather Conditions

Total percentages of crash frequency occurred under different weather conditions and are shown in Table below. The analysis showed that about 81.3% of total crashes occurred at the time of good weather conditions whereas, only 18.7% of accident happened during moist-weather condition. Hence, the analysis confirms that the majority of traffic crashes happened under dry road surface conditions in the study road section.

Table 4.10: Crashes by Weather conditions

Weather conditions	Sum	Percentage (%)
Dry (Good weather)	165	81.3
Moist-weather	38	18.7
Total	203	100

Source: Woredas and Town administrations TPC (2013/14 – 2017/18G.c) computed by Author, 2019

4.2.15 Crashes by Land Uses

Land uses of the Study area are divided into urban area, school area, church area, market area, recreation area, hospital area, office area, residential area, and unspecified land uses in order to examine the accident extents in each area. Their associated percentage of crash occurrences during five years are shown in Table below. Accordingly, as the data collected: market area, residential area, and non-residential area road crash most frequently occurred.

Table 4.11: Crashes by Land Uses of study road section

Land uses	Sum	Percentage (%)
Urban area	30	15
School area	14	7
Church area	6	3
Recreational area	4	2
Market area	22	11
Hospital area	8	4
Office area	4	2
Residential area	34	17
Unspecified land uses	6	3
Nonresidential (forestry) area	73	36
Total	203	100

Source: Woredas and Town administrations TPC (2013/14 - 2017/18G.c) computed by Author, 2019

4.3. Road Traffic Crashes Prediction Models

To develop model and analyze data collected there are five basic assumptions that are required to be followed while applying Poisson and Negative Binomial Regression analysis technique to give a valid and meaningful result. However, it is essential that it is not uncommon for data to be violated (i.e., fail to meet) one or more of these assumptions. Nevertheless, even when data does fail some of these assumptions, there is often a solution to overcome this. These five assumptions are:

Assumption #1

The dependent variable consists of count data. Count data is different from data measured in other well-known types of regression (e.g. linear regression and multiple regressions require dependent variables that are measured on a "continuous" scale. Binomial logistic regression requires a dependent variable measured on a "dichotomous" scale, ordinal regression requires a dependent variable measured on an "ordinal" scale, and multinomial logistic regression requires a dependent variable measured on a "nominal" scale).

In contrast, count variables require integer data that must be zero or greater. Also, since count data must be "positive" (i.e., consist of "non-negative" integer values). Furthermore, it is sometimes suggested that Poisson regression is performed only when the mean count is a small value (e.g., less than 10). Where there are large numbers of counts, a different type of regression might be more appropriate (e.g., multiple regressions, gamma regression, Hence, road traffic crash (count variable without negative integers) are the modeling main dependent variable that perfectly fulfills the assumption requirement.

Assumption #2

The independent variables may be one or more, which can be measured on a continuous, ordinal or nominal/dichotomous scale. Ordinal and nominal/dichotomous variables can be broadly classified as categorical variables. Hence, in this the effects checking modeling process, the explanatory (independent) variables consist of categorical (median type); painted and raised median. Moreover, continuous variables of road geometric characteristics; road length, number of horizontal curves, number of vertical curves, gradient, number of lanes, surface width, median height, median width and sidewalk width, number of access, and the exposure variable average daily traffic (ADT) are used for the road crash occurrence prediction.

Assumption #3

The observations should be independent of one another. This means that each observation is independent of the other observation; that is, one observation cannot provide any information on another observation. This is a very important assumption. A lack of independent observation is mostly a study design issue. One method of testing for the possibility of independence of observations is to compare standard model-based errors to robust errors to determine if there are large differences.

Assumption #4

The distributions of counts (conditional on the model) follow a Poisson distribution. One consequence of this is that the observed and expected counts should be equal (in reality, just very similar). Essentially, this is saying that the model predicts the observed counts well. This can be tested in a number of ways, but one method is to calculate the expected counts and plot these with the observed counts to see if they are similar.

Assumption #5

The mean and variance of the model (dependent variable) are identical. This is a consequence of assumption number four; that there is a Poisson distribution. For a Poisson distribution, the variance has the same value as the mean. If it satisfies this assumption, it has equidispersion. However, often this is not the case and the data is either under-dispersed or over-dispersed with over-dispersion the more common problem. There are a variety of methods that could be used to assess over dispersion. Negative Binomial regression technique is chosen parallel to Poisson regression for the modeling purpose to analyze the effects of independent on dependent variables in the study (Lund Research Ltd, 2015).

4.3.1 Description of Data

To establish the relationship between road geometric characteristics and occurrence of traffic crashes, data were collected from 29 road sections in Alatawondo-Bona-Daye. Fatal crash data were collected from Sidama zone Police Commission and records of injury crashes and property damage only (PDO) were collected from six (6) woredas and two (2) town administrations Police Station. After excluding records with missing variables, the data for this study included a total of 331 road crashes (47 fatal, 143 injuries and 141 PDO) which occurred on selected road sections over a period of five years. Total percentage of road traffic crashes by crash severity types, descriptive statistics of categorical variables and continues variables are shown in Figure 4.7 and Tables 4.12.

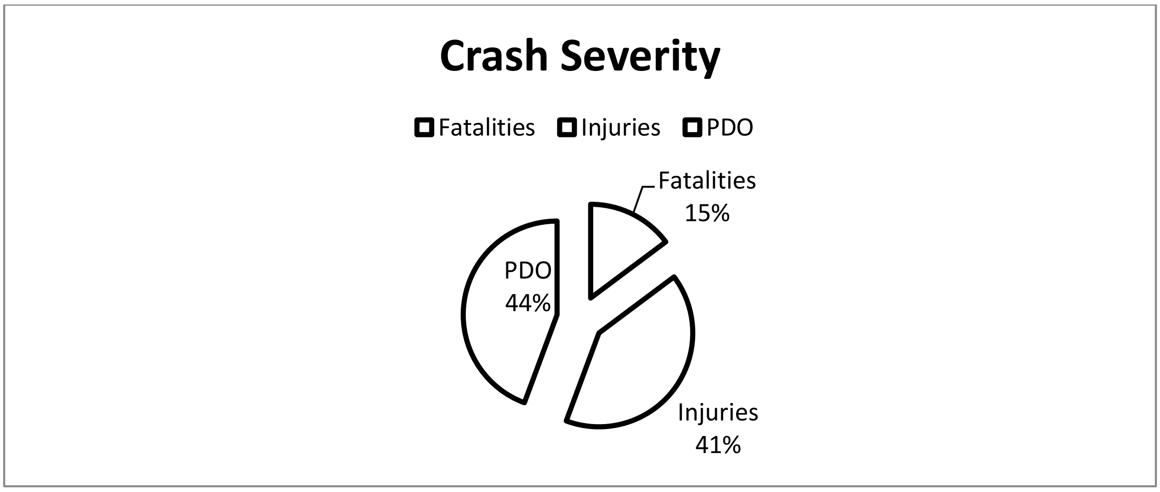


Figure 4.7: Percentage of Road Crash Severity in the Model as traffic policy recorded

The explanatory variables included in the model are road geometric characteristics and exposure variables.

The major road geometric design elements included in the study were:

- Road segment lengths;
- Number of lanes;
- Surface width;
- Median width;
- Median height;
- Median type;
- Number of horizontal curves;
- Number of vertical curves;
- Number of vertical gradients;
- Sidewalk or shoulder width;
- Number of access points;
- Access controls; and
- Average daily traffic (ADT)

Table 4.12: Descriptive Statistics of Categorical Variables

Crash Severity		Fatal	Injury	PDO	Total	Percentage
Drivers characteristics						
Gender	Female	2	1	3	6	1.72
	Male	45	134	143	325	98.28
	Total	47	135	146	331	100
Driver education	College and above	8	16	20	44	13.5
	High school	22	68	71	161	48.7
	Primary and below	17	51	55	126	37.8
	Total	47	135	146	331	100
Driver experience	0-5 years	23	69	73	165	49.52
	6- 10 years	15	43	45	103	31.25
	>10 years	9	26	28	63	19.23
	Total	47	135	146	331	100
Drivers' relation to vehicle	Employee	40	114	125	279	84.28
	Owner and Family	7	21	24	52	15.72
	Total	47	135	146	331	100
Vehicle characteristics						
	Minibus & Bus	19	56	61	136	41.2

Vehicle type	Trucks	12	36	40	88	26.7
	Auto & Taxis (including passengers cars)	9	22	24	55	16.6
	Motor cycle (2&3 wheels)	6	17	20	43	12.9
	Non – motorized	1	4	5	9	2.6
	Total	47	135	146	331	100
Roadway characteristics						
Type of median	Painted median	42	113	133	291	87.92
	Raised median	5	22	13	40	12.08
	Total	47	135	146	331	100
Road Condition						
Road condition	Dry	38	109	122	269	81.3
	Wet	9	26	27	62	18.7
	Total	47	135	146	331	100
Time						
Time of Day	Day light	40	125	132	299	90.3
	Night time	7	13	14	32	9.7
	Total	47	135	146	331	100
Days						
Day of the week	Monday – Friday	36	96	103	235	70.87
	Weekend	11	39	43	96	29.13
	Total	47	135	146	331	100

Descriptive statistics of continues variables are different from the categorical variables in a way that they can be shown in numbers. Road characteristics and crash occurrences are categorized under this type of statistics as shownin Table below.

Table 4.13: Descriptive Statistics of Continues Variables

Variables	Minimum	Maximum	Mean	Std. Deviation
Total crash occurrence	3	17	7	3.81
Road segment length (m)	1,580	4,720	2,913.8	855.2
Number of horizontal curves	2	7	3.34	1.51
Number of vertical curves	3	10	4.21	2.05
Vertical grades count	1	6.5	3.12	1.81
Number of lanes	2	4	2.07	0.36
Surface width (m)	7	15.8	8.33	2.36
Median height (m)	0	0.24	0.013	0.044
Median width (m)	0.1	0.4	0.12	0.04
Side walk or shoulder width (m)	0.75	2.5	1.14	0.43
Number of Access	5	16	8.13	2.59
Number of Access control	0	2	0.55	0.73
Exposure Variables				
ADT	722	1,570	1,074.4	516.3
Number of Observation	29			

4.3.2 Model Selection

4.3.2.1 Crash Count Modeling Techniques to Analyze Effects

Authors have developed a number of statistical analytical tools for analyzing crash data in the past. For instance, crash count modeling techniques are used in the highway safety analysis. Lao et al. (2011) stated that different types of explanatory variables can affect road crash frequency such as road geometric, driver behaviors, vehicle, and environment. The researches indicated that both behavioral factors related to the driver's errors, and non-behavioral factors related to road geometry, vehicle, and environment can significantly affect road traffic crashes.

Lord and Mannering (2010) stated that crash frequency can be estimated in two different ways. The first crash frequency estimation techniques are conventional univariate regression models, which encompass the Poisson Regression model, Negative Binomial model, Poisson lognormal model, zero-inflated model, and Conway Maxwell Poisson model. The other models are generalized additive models, random, parameters models, finite mixture, Markov switching models, and hierarchical models.

Road traffic accident prediction models were at the beginning based on the simple multiple linear regression models that accepts normally distributed errors (Caliendo et al., 2007). Researchers concluded that crash occurrence is more fitted with the Poisson distribution, which was developed by an advanced modeling technique (i.e. generalized linear models) (GLM). The generalized Poisson regression models are statistical modeling techniques used to model the relationships between road geometry, site characteristics, traffic variables and the expected number of resulting crashes on roadway sections or intersections. Crash data are nonlinear, random, and non-negative (count data) which approximately follow the Poisson distribution.

Poisson regression models are generalized linear modelswith the logarithm as the link function, and the Poisson distribution function as the assumed probability distribution of the response. Negative binomial regression is a popular generalization of Poisson regression because it loosens the highly restrictive assumption that the variance is equal to the mean made by the Poisson model (Nelder, 1972).

$$E(\mu i) = \beta_o Q^{\beta} e^{\Sigma \beta i x i} \qquad \text{Equation (4)}$$

$E(\mu i)$ = expected number of accidents

β_o= Intercept (Estimate)

Q= Traffic Volume (ADT)

β=effect of traffic volume on the expected number of accidents and is modeled as elasticity

βi=parameters to be estimated and represent the effect of risk factors, i, on the expected number of accidents other than traffic volume

xi= vector of values of risk factors, i, other than number of vehicles

The effects of risk factors that influence the probability of accidents given exposure are modeled as an exponential function that is as e (the base of natural logarithms) raised to the sum of the product of coefficients, βi, and values of the explanatory variables, xi, denoting risk factors.

Researchers empirically demonstrated the Poisson regression and negative binomial regression to model accident frequencies. (Miaou, 1994) for example, evaluated crashes and road features using Poisson and negative binomial model.

In recent times, investigators have proposed the possibility of using Poisson-lognormal model instead of the negative binomial to model road crash data. Moreover, the Poisson-lognormal provides more flexibility than the negative binomial.

Consul and Famoye (1992) and Famoye (1993) the probability function for the generalized Poisson regression model; f (yi; μi, ϕ) is given by

$$f(y_i;\mu_i,\varphi) = \left(\frac{\mu_i}{1+\varphi\mu_i}\right)^{yi} \frac{(1+\varphi yi)^{yi-1}}{yi} \ exp\left[\frac{\mu i(1+\varphi yi)}{1+\varphi\mu i}\right], y_i = 0, 1, 2, 3, \dots \tag{4.2}$$

Where,

$$\mu_i = \mu_i(x_i) = \exp(\textstyle\sum_{i=0}^{k} xi\beta j)\ , xi = (xi1 = 1, xi2, \dots, xik) \tag{4.3}$$

Is the i-the row of covariance matrix X and $\beta = \beta_1, \beta_2 \dots, \beta_k$ are unknown k - dimensional column vector of parameters. The model in equation 4.1 is based upon the generalized Poisson distribution and the mean of yi is given by μiand the variance of yi is given by $\mu i\ (1+\phi\mu i)^2$. Moreover, it is an extension of the Poisson regression model. When $\phi = 0$, the generalized Poisson distribution model reduces to the Poisson regression model. When $\phi > 0$, the GPR model is used to model count data that exhibits over dispersion and when $\phi < 0$, the model is used to describe count data that shows under dispersion.

Lawless (1987) and Cameron and Trivedi (1998) the probability function for the negative binomial regression (NBR) model, is given as g (yi; μi, τ_i)as follow:

$$g(y_i;\ \mu_i,\tau) = \binom{y_i + \tau^{-1} - 1}{y_i} \left(\frac{1}{1+\tau\mu i}\right)^{1/\tau} \left(\frac{\tau\mu i}{1+\tau\mu i}\right)^{yi}, yi = 0, 1, 2, 3, \dots \tag{4.4}$$

Where $\mu_i$is defined in equation 4.2 that the mean of yiis given by$\mu_i$and the variance of yiis given by $\mu_i\ (1+\tau\mu i)^2$. The model in equation 4.3 reduces to the Poisson regression model when $\tau \to 0$. It can be used to model count data with over dispersion when $\tau > 0$.

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	Total crash occurrence	3	3.0000	17.0000	9.000	7.2111026
Covariate	Average daily traffic	3	722.0000	1570.0000	1122.133	426.0103911

In order to select the best model which fits the data well, two different models were considered namely; Poisson and Negative binomial models. In this study different model election criteria were considered like the variance to mean relation and omnibus test.

Table 4.14: Omnibus test for Poisson regression model

Source	Type		
	Likelihood ratio chi-square	df	Sig.
Value	149.635	8	.000

Dependent Variable: Total crash occurrences

Model: Poisson regression

Table 4.15: Omnibus test for Negative binomial regression model

Source	Type		
	Likelihood ratio chi-square	Df	Sig.
Value	112.0	8	.000

The omnibus test for both models is significant. Even if negative binomial regression model best fit for this analysis since the previous assumption for the Poisson regression is the mean and variance should be approximately the same but it is not equal ,unfortunately both models parallel used for analysis of the study.

4.3.3 Discussion of the Result

4.3.3.1 Discussion of the Result by using Negative Binomial and Poisson Regression models

In the study through using SPSS software those variables their p -value >10% some of the predictor variables were found statistically insignificant in the analysis of the model. Explanatory variables such as; road segment length, median height and median width were systematically removed from the model and then, interpretation for those statisticallySignificant variables were done.

The final model for analysis is done based on the statistical significance of each explanatory variable had with the dependent variable. Log-linear Poisson regression and Negative binomial regression model was used to investigate the effect of road geometric design elements on the road crash occurrences.

As clearly shown in the Table below the explanatory variables such as median type, number of horizontal curves, number of vertical curves, sidewalk width, vertical grade counts, and number of lanes, average daily traffic, number of access points and number of access control had significant effects on the occurrence of road traffic crashes. Those explanatory variables have played significant influence for the happening of daily life taking road traffic crashes in the study area.

Table 4.16: Modeling Resultsto check Effects of statistical significant Geometric design parameters on Traffic Crashes

Geometric parameters description	Poisson Regression Model					Negative Binomial Regression Model				
	Estimated Coefficient	Standard error	95% confidence interval		P-value	Estimated Coefficient	Standard error	95% confidence interval		P- value
Constant	2.561	0.5002	2.307	3.486	0	4.17	10.022	-11.518	20.915	0.047
Road characteristics										
Painted medians	0.0935	0.0210	0.017	0.143	0.003	0.717	0.3842	-1.031	1.116	0.01
Number of horizontal curves	0.072	0.0112	0.037	0.105	0	0.083	0.2587	-0.410	0.503	0.05
Number of vertical curves	0.034	0.0132	0.017	0.032	0	0.035	0.1042	-0.243	0.332	0.054
Number of grades count	0.014	0.0113	0.016	0.0511	0.003	0.042	0.1471	-0.258	0.0379	0.081
Number of lanes	0.029	0.0137	0.002	0.056	0.037	0.036	0.2242	-0.404	0.475	0.087
Side or shoulder walk width	-0.047	0.0106	-0.054	-0.023	0	-0.034	0.2097	-0.372	0.302	0.065
Number of access	0.024	0.0019	0.021	0.027	0	0.028	0.0345	-0.028	0.107	0.024
Number of access controls	-0.043	0.0119	-0.039	-0.015	0.001	-0.031	0.108	-0.357	0.267	0.052

Exposure Variable										
LOG ADT	0.214	0.1052	0.043	0.527	0.010	0.141	2.5676	-3.862	4.203	0.081
Dispersion parameter						0.69				
Log-likelihood value at Convergence	-107					-74				
Log-likelihood value at Zero	-149.63					-112				
AIC =	12.02					11.15				
Number of sample	29									

From the above result, when road segment with raised median is compared with painted median, painted median positively affects crash occurrences. The result shows higher road crashes occurred at road segments with painted median since the raised medians partially controls the vehicle's movement from one direction to others, while painted medians allow vehicles maneuvers at any locations of the road segments. In addition, the painted median types of the study location were two directional lanes with poor channelization of opposite direction vehicles movements that is exposed to road crashes. The study conducted in Las Vegas Valley inferred the road segments with raised median had lower rear-end, sideswipe and injury crash rates by 18.7%, 21.7%, and 23.7%, respectively (Timur, 2010) this confirmed with study.

The number of horizontal curve variable has a positive coefficient. This explains that when the number of horizontal curves in a given road segment increases, road traffic crash frequency also increases which affect road safety. The study finding is consistent with study conducted in road segments extend from Wolayitasodo to Allaba town , which found that the more number of horizontal curves in a road segment increase traffic crash and cause a safety problem for lack of concentration by drivers and high-speed vehicles. Limiting the number of horizontal curves during design of new road and controlling already built road is an important safety criteria (Mulugeta Daniel, 2017).

Vertical curve variable has a positive coefficient, which indicates that an occurrence of road crashes in a specified road section is positively associated with the number of vertical curve in the road segments. This indicates more number of vertical curves on road sections results in road crash frequency. A study was conducted on effect of vertical alignment on driver perception of horizontal curves and found that perception of the driver of the road features ahead is an important human factor and should be addressed during road design.

The number of grades count has a positive coefficient. This explains that when the grades get increases in a given road segment increases, road traffic crash frequency also increases which affect road safety. This study get consistent with ChrisroJ.Bener&Joster Maki (1999) study review steeper grades increase the accident rates, and the accident rate in mountainous terrain is higher than in flat terrain.
An erroneous perception of the road can lead to actions that may compromise traffic safety. Poor coordination of horizontal and vertical alignments is believed to cause such wrong perceptions (Mohita, 2014). The overtaking maneuver, movements to driveways or access on the vertical curves, there is increased potential for crash risk, particularly when sight distance is short and drivers are not concerned.

The number of lanes has a positive correlation in the coefficient of estimated model, which implies that the more the number of lanes, the higher road traffic crashes at road segments. A study conducted in Florida also concluded that wide pavement surface and multiple lanes had significant weaving maneuvers on major approaches, tends to increase the risk of crash frequency (Zhenyu et al., 2011).

The coefficient for a number of access control variable is negative, which implies that less crashes occur on a road segment with more access control in it. This result makes sense because more access control creates less opportunity for conflicts, and thus tend to cause less crashes. Access control techniques are used to improve traffic performance and safety on highways. One important benefit of access control is improved safety (Henry and Andrzej, 1999).
Sidewalk or shoulder width is another significant explanatory variable to crash occurrence with a negative estimated coefficient. The finding implies road crash frequency decreases as the width of the sidewalk increases. The lack of separation between vulnerable road users and motorized traffic leads to a considerably larger set of potential crash risk opportunities for pedestrians compared to separated facilities encountered in developed

countries. Consequently, as the width of sidewalk decreases, the pedestrians are forced to use roadways with motorized traffics (Tulu et al., 2013).

The coefficient for number of access variable has positive relationship with road traffic crash occurrence on the road segments in the model. This is due to insufficient sight distance provision for minor intersections. Consequently, it causes road traffic collision between vehicles coming from access road and the road segment. Moreover, road segments associated with high number of access exposed to unexpected traffics that collide with high-speed vehicle on the road segment. Provision of access controls and different traffic control devices, it is possible to reduce road traffic crashes (Tefera, 2015).

Exposure variables, a logarithm of the average daily traffic (ADT) has positive coefficient, which indicates that when there is more traffic volume in a road segment, more traffic crashes occur. Alemu (2016) stated that due to more interactions between vehicles, many potential conflicts in road segment can cause more crashes. The vehicles entering the road from the driveway had no gap to join the road and so, the driver was forced to enter the road illegally.

4.3.3.2 Discussion of the Result by using Empirical Bayesian (EB) Method

Additional Empirical Bays (EB) method used to calculate expected number of traffic crashes on road segments of horizontal and vertical curves effects on roads crashes since horizontal curves itself consists some other geometric parameters such as horizontal curves (HC) length, HC radius, spiral curves and super-elevation they also have their own effects on occurs of traffic crashes along existed road section.

This approach takes into account of effects due to site specific factors by developing their relation with crash frequency. All steps are from highway safety manual (Highway Safety Manual (HSM), 2008).

Table4.17: Estimated total crash frequency (N_{spfrs}) for study roadway sections in different period of study years

S.no	Sections	L (km)	L (miles)	AADT					N_{spfrs} $N_{spfrs}=AADT*L*365*10^{-6}*e^{-0.312}$				
				2014 /15	2015 /16	2016 /17	2017 /18	2018 /19	2014 /15 (N_1)	2015 /16 (N_2)	2016 /17 (N_3)	2017 /18 (N_4)	2018 /19 (N_5)
1.	Sc-1	2.150	1.3359	763	1013	622	983	1126	0.272	0.362	0.222	0.351	0.402
2.	Sc-2	1.730	1.0749	763	1013	622	983	1126	0.219	0.291	0.179	0.282	0.323
3.	Sc-3	1.870	1.1619	763	1013	622	983	1126	0.237	0.314	0.193	0.305	0.349
4.	Sc-4	2.420	1.5037	763	1013	622	983	1126	0.307	0.407	0.250	0.395	0.452
5.	Sc-5	1.920	1.1930	763	1013	622	983	1126	0.243	0.323	0.198	0.313	0.359
6.	Sc-6	2.510	1.5596	763	1013	622	983	1126	0.318	0.422	0.259	0.410	0.469
7.	Sc-7	1.580	0.9817	763	1013	622	983	1126	0.200	0.265	0.163	0.258	0.295
8.	Sc-8	1.820	1.1309	763	1013	622	983	1126	0.231	0.306	0.188	0.297	0.340
9.	Sc-9	3.470	2.1562	763	1013	622	983	1126	0.439	0.583	0.358	0.566	0.649
10.	Sc-10	4.130	2.5663	763	1013	622	983	1126	0.523	0.694	0.426	0.674	0.772
11.	Sc-11	4.720	2.9328	763	1013	622	983	1126	0.598	0.794	0.487	0.770	0.882
12.	Sc-12	3.460	2.1499	763	1013	622	983	1126	0.438	0.582	0.357	0.565	0.647
13.	Sc-13	2.520	1.5658	763	1013	622	983	1126	0.319	0.424	0.260	0.411	0.471
14.	Sc-14	3.570	2.2183	481	752	541	469	953	0.285	0.446	0.321	0.278	0.565
15.	Sc-15	3.210	1.9946	481	752	541	469	953	0.256	0.400	0.288	0.249	0.508

16.	Sc-1 6	4.200	2.6096	481	752	541	469	953	0.335	0.524	0.377	0.327	0.664
17.	Sc-17	3.720	2.3115	481	752	541	469	953	0.297	0.464	0.334	0.289	0.588
18.	Sc-18	2.810	1.7460	481	752	541	469	953	0.224	0.351	0.252	0.219	0.444
19.	Sc-19	3.830	2.3798	481	752	541	469	953	0.306	0.478	0.344	0.298	0.606
20.	Sc-20	3.670	2.2804	481	752	541	469	953	0.293	0.458	0.329	0.286	0.581
21.	Sc-21	3.910	2.4295	481	752	541	469	953	0.312	0.488	0.351	0.304	0.619
22.	Sc-22	3.780	2.3487	481	752	541	469	953	0.302	0.472	0.339	0.294	0.598
23.	Sc-23	3.170	1.9697	481	752	541	469	953	0.253	0.396	0.285	0.247	0.501
24.	Sc-24	2.560	1.5907	481	752	541	469	953	0.204	0.320	0.230	0.199	0.404
25.	Sc-25	2.930	1.8206	481	752	541	469	953	0.234	0.366	0.263	0.228	0.464
26.	Sc-26	2.410	1.4975	481	752	541	469	953	0.192	0.301	0.216	0.188	0.381
27.	Sc-27	2.040	1.2675	481	752	541	469	953	0.163	0.255	0.183	0.159	0.323
28.	Sc-28	2.070	1.2862	481	752	541	469	953	0.166	0.259	0.187	0.162	0.329
29.	Sc-29	2.320	1.4416	481	752	541	469	953	0.185	0.289	0.208	0.181	0.367
	Total	84.50	52.51						8.351	12.034	8.047	9.505	14.382

N.B: AMF_1= Accident Modification Factor for Horizontal curves (HC) of study road sections

Table 4.18: Accident Modification Factors (AMFs) for Horizontal Curves at road sections

Sections	AMF_1	AMF_2	AMF_3	AMF_4	AMF_5	AMF_6	AMF_7	AMF_8	AMF_9	Avg AMF
Sc-1	1.01262	1.01991	1.00592	1.01991	1.0441	-	-	-	-	1.02049
Sc-2	1.15340	1.14323	1.00680	1.01263	-	-	-	-	-	1.07901
Sc-3	1.03586	1.01256	1.08277	-	-	-	-	-	-	1.04373
Sc-4	1.01265	1.15371	1.01996	1.01265	-	-	-	-	-	1.04974
Sc-5	1.01076	1.01992	1.03584	1.04483	-	-	-	-	-	1.02784
Sc-6	1.00827	1.01956	1.01956	1.01956	1.0000	-	-	-	-	1.01339
Sc-7	1.00349	1.00645	1.01261	1.04483	1.0358	-	-	-	-	1.02064
Sc-8	1.15337	1.01199	1.01263	1.03587	-	-	-	-	-	1.05347
Sc-9	1.00413	1.01992	1.02298	1.02003	1.1543	1.0139	-	-	-	1.03921
Sc-10	1.04879	1.03452	1.00895	1.12004	1.0069	1	1.0051	-	-	1.03204
Sc-11	1.05067	1	1.03545	1.02241	1.0687	1.0597	1.0443	1.0042	1.0113	1.03297
Sc-12	1.0115	1.02241	1.10751	1.05756	1.0032	1.0362	1.000	1.0031	-	1.03019
Sc-13	0.97671	1.01784	1.00352	1.05632	-	-	-	-	-	1.01359
Sc-14	1.16484	1.00753	1.02241	1.04304	1.0041	-	-	-	-	1.04838
Sc-15	1.08343	1.01675	1.01267	1.09983	1.0432	-	-	-	-	1.05118
Sc-1 6	1.00452	1.01287	1.12008	1.01549	1.0453	1.0164	1.0197	-	-	1.03348
Sc-17	1.00324	1.00000	1.02135	1.02237	1.0052	1.0163	-	-	-	1.01141

Sc-18	1.01773	1.03376	1.03587	1.00543	-	-	-	-	-	1.02319
Sc-19	1.02241	1.01195	1.01383	1.01195	-	-	-	-	-	1.01504
Sc-20	1.04304	1.00415	1.01176	1.01411	1.0157	-	-	-	-	1.01775
Sc-21	1.00532	1.01223	0.98371	1.01374	-	-	-	-	-	1.00375
Sc-22	1.01774	1.00000	1.04772	1.15321	1.02243	-	-	-	-	1.04822
Sc-23	1.04483	1.00831	1.00514	1.04114	1.01885	1.0023	-	-	-	1.02009
Sc-24	1.01442	1.04892	1.00023	1.15371	-	-	-	-	-	1.05432
Sc-25	1.04377	1.01675	1.08358	1.01542	0.98529	-	-	-	-	1.02896
Sc-26	1.03573	1.00374	1.01675	-	-	-	-	-	-	1.01874
Sc-27	1.03225	1.01187	1.01276	1.0001	-	-	-	-	-	1.01424
Sc-28	1.01273	1.01569	1.00370	-	-	-	-	-	-	1.01071
Sc-29	1.01152	1.00362	1.00231	-	-	-	-	-	-	1.00872

N.B: where, AMF = Accident Modification factors

Table 4.19: Accident Modification Factors (AMFs) for super elevation (%), lane width (m), shoulder width (m), grades (%), driveway density (per mile), and roadside density (RHR).

Sections	AMF2 (G.%)	AMF3 (Supe. %)	AMF4 (lane)	AMF5 (shoulder)	AMF6 (DD)-yr-1	AMF6 (DD)-yr-2	AMF6 (DD)-yr-3	AMF6 (DD)-yr-4	AMF6 (DD)-yr-5	AMF7 (RHR)
Sc-1	1	1	1.01134	1.01	1	1	1	1	1	1
Sc-2	1.1	1	1	1	1	1	1	1	1	1
Sc-3	1	1	1	1	1	1	1	1	1	1

Sc-4	1.1	1	1	1	1	1	1	1	1	1
Sc-5	1.1	1	1	1	1	1	1	1	1	1
Sc-6	1.1	1.013	1	1	1	1	1	1	1	1
Sc-7	1.1	1	1.0021	1.01	1	1	1	1	1	1
Sc-8	1	1	1.02257	1.01	1.2073	1.1927	1.2168	1.1945	1.1876	1
Sc-9	1.1	1.041	1.01134	1.01	1	1	1	1	1	1
Sc-10	1.1	1.041	1	1	1	1	1	1	1	1
Sc-11	1.16	1.041	1	1	1	1	1	1	1	1
Sc-12	1.1	1.041	1.0021	1.01	1	1	1	1	1	1
Sc-13	1.1	1.012	1.01134	1.01	1	1	1	1	1	1
Sc-14	1.1	1	1.0021	1.01	1	1	1	1	1	1
Sc-15	1.1	1	1	1	1	1	1	1	1	1
Sc-1 6	1.16	1.012	1	1	1	1	1	1	1	1
Sc-17	1.1	1	1	1	1	1	1	1	1	1
Sc-18	1.1	1	1	1	1	1	1	1	1	1
Sc-19	1.1	1.012	1	1	1	1	1	1	1	1
Sc-20	1.1	1.041	1	1	1	1	1	1	1	1
Sc-21	1.1	1.041	1	1	1	1	1	1	1	1
Sc-22	1.1	1	1.01134	1.01	1	1	1	1	1	1
Sc-23	1.1	1	1.0124	1.01	1.2289	1.2078	1.2234	1.2301	1.196	1
Sc-24	1.16	1.012	1	1	1	1	1	1	1	1

Sc-25	1.1	1.041	1	1	1	1	1	1	1	1
Sc-26	1.1	1	1	1	1	1	1	1	1	1
Sc-27	1.1	1	1.01694	1.01	1	1	1	1	1	1
Sc-28	1.1	1	1	1	1	1	1	1	1	1
Sc-29	1.1	1	1.0124	1.01	1.2289	1.2078	1.2234	1.2301	1.196	1

N.B: where, AMF = Accident Modification factors

Table 4.20:Total accident modification factors (AMFs) among different road sections of study road in study periods

Sections	AMF1 (HC)	AMF2 (G.%)	AMF3 (Supe. %)	AMF4 (lane)	AMF5 (shoulder)	AMF6 (DD)-yr-1	AMF6 (DD)-yr-2	AMF6 (DD)-yr-3	AMF6 (DD)-yr-4	AMF6 (DD)-yr-5	AMF7 (RHR)	(AMF1*. AMFn)
Sc-1	1.02049	1	1	1.01134	1.01	1	1	1	1	1	1	1.04238
Sc-2	1.07901	1.1	1	1	1	1	1	1	1	1	1	1.18691
Sc-3	1.04373	1	1	1	1	1	1	1	1	1	1	1.04373
Sc-4	1.04974	1.1	1	1	1	1	1	1	1	1	1	1.15471
Sc-5	1.02784	1.1	1	1	1	1	1	1	1	1	1	1.13062
Sc-6	1.01339	1.1	1.013	1	1	1	1	1	1	1	1	1.12922
Sc-7	1.02064	1.1	1	1.0021	1.01	1	1	1	1	1	1	1.13631
Sc-8	1.05347	1	1	1.02257	1.01	1.2073	1.1927	1.2168	1.1945	1.1876	1	2.70432
Sc-9	1.03921	1.1	1.041	1.01134	1.01	1	1	1	1	1	1	1.21552
Sc-10	1.03204	1.1	1.041	1	1	1	1	1	1	1	1	1.18178

Sc-11	1.03297	1.16	1.041	1	1	1	1	1	1	1	1	1.24737
Sc-12	1.03019	1.1	1.041	1.0021	1.01	1	1	1	1	1	1	1.19397
Sc-13	1.01359	1.1	1.012	1.01134	1.01	1	1	1	1	1	1	1.15253
Sc-14	1.04838	1.1	1	1.0021	1.01	1	1	1	1	1	1	1.16719
Sc-15	1.05118	1.1	1	1	1	1	1	1	1	1	1	1.15629
Sc-1 6	1.03348	1.16	1.012	1	1	1	1	1	1	1	1	1.21322
Sc-17	1.01141	1.1	1	1	1	1	1	1	1	1	1	1.11255
Sc-18	1.02319	1.1	1	1	1	1	1	1	1	1	1	1.12551
Sc-19	1.01504	1.1	1.012	1	1	1	1	1	1	1	1	1.12994
Sc-20	1.01775	1.1	1.041	1	1	1	1	1	1	1	1	1.16542
Sc-21	1.00375	1.1	1.041	1	1	1	1	1	1	1	1	1.14939
Sc-22	1.04822	1.1	1	1.01134	1.01	1	1	1	1	1	1	1.17778
Sc-23	1.02009	1.1	1	1.0124	1.01	1.2289	1.2078	1.2234	1.2301	1.196	1	3.06518
Sc-24	1.05432	1.16	1.012	1	1	1	1	1	1	1	1	1.23768
Sc-25	1.02896	1.1	1.041	1	1	1	1	1	1	1	1	1.17826
Sc-26	1.01874	1.1	1	1	1	1	1	1	1	1	1	1.12061
Sc-27	1.01424	1.1	1	1.01694	1.01	1	1	1	1	1	1	1.14591
Sc-28	1.01071	1.1	1	1	1	1	1	1	1	1	1	1.11178
Sc-29	1.00872	1.1	1	1.0124	1.01	1.2289	1.2078	1.2234	1.2301	1.196	1	3.03111

N.B: where, AMF = Accident Modification factors

Table 4.21:Number of predicted Accidents of the study road sections

Sections	Site observed Crash	N_{spfrs}					(AMF1*. *AMF7)	Npredicted(unadjusted)				
		2014 /15 (N_1)	2015 /16 (N_2)	2016 /17 (N_3)	2017 /18 (N_4)	2018 /19 (N_5)		Np1	Np2	Np3	Np4	Np5
Sc -1	3	0.272	0.362	0.222	0.351	0.402	1.04238	0.2835	0.3773	0.2314	0.3659	0.4190
Sc -2	3	0.219	0.291	0.179	0.282	0.323	1.18691	0.2599	0.3454	0.2125	0.3347	0.3834
Sc -3	5	0.237	0.314	0.193	0.305	0.349	1.04373	0.2474	0.3277	0.2014	0.3183	0.3643
Sc -4	6	0.307	0.407	0.250	0.395	0.452	1.15471	0.3545	0.4699	0.2887	0.4561	0.5219
Sc -5	6	0.243	0.323	0.198	0.313	0.359	1.13062	0.2747	0.3652	0.2239	0.3539	0.4050
Sc -6	5	0.318	0.422	0.259	0.410	0.469	1.12922	0.3591	0.4765	0.2925	0.4629	0.5296
Sc -7	10	0.200	0.265	0.163	0.258	0.295	1.13631	0.2273	0.3011	0.1852	0.2932	0.3352
Sc -8	9	0.231	0.306	0.188	0.297	0.340	2.70432	0.6247	0.8275	0.5084	0.8032	0.9195
Sc -9	17	0.439	0.583	0.358	0.566	0.649	1.21552	0.5336	0.7086	0.4352	0.6879	0.7888
Sc -10	13	0.523	0.694	0.426	0.674	0.772	1.18178	0.6181	0.8202	0.5034	0.7965	0.9123
Sc -11	14	0.598	0.794	0.487	0.770	0.882	1.24737	0.7459	0.9904	0.6075	0.9605	1.1002
Sc -12	15	0.438	0.582	0.357	0.565	0.647	1.19397	0.5229	0.6449	0.4262	0.6746	0.7725
Sc -13	8	0.319	0.424	0.260	0.411	0.471	1.15253	0.3677	0.4887	0.2997	0.4736	0.5428
Sc -14	4	0.285	0.446	0.321	0.278	0.565	1.16719	0.3326	0.5206	0.3747	0.3245	0.6595

Sc -15	3	0.256	0.400	0.288	0.249	0.508	1.15629	0.2960	0.4625	0.3330	0.2879	0.5874
Sc -16	7	0.335	0.524	0.377	0.327	0.664	1.21322	0.4064	0.6357	0.4574	0.3967	0.8056
Sc -17	5	0.297	0.464	0.334	0.289	0.588	1.11255	0.3304	0.5162	0.3716	0.3215	0.6542
Sc -18	4	0.224	0.351	0.252	0.219	0.444	1.12551	0.2521	0.3951	0.2836	0.2465	0.4997
Sc -19	9	0.306	0.478	0.344	0.298	0.606	1.12994	0.3458	0.5401	0.3887	0.3367	0.6847
Sc -20	11	0.293	0.458	0.329	0.286	0.581	1.16542	0.3415	0.5337	0.3834	0.3333	0.6771
Sc -21	7	0.312	0.488	0.351	0.304	0.619	1.14939	0.3586	0.5609	0.4034	0.3494	0.7115
Sc -22	4	0.302	0.472	0.339	0.294	0.598	1.17778	0.3557	0.5559	0.3993	0.3463	0.7043
Sc -23	5	0.253	0.396	0.285	0.247	0.501	3.06518	0.7755	1.2138	0.8734	0.7571	1.5356
Sc -24	6	0.204	0.320	0.230	0.199	0.404	1.23768	0.2525	0.3961	0.2647	0.2463	0.5000
Sc -25	4	0.234	0.366	0.263	0.228	0.464	1.17826	0.2757	0.4312	0.3098	0.2686	0.5467
Sc -26	7	0.192	0.301	0.216	0.188	0.381	1.12061	0.2152	0.3373	0.2421	0.2107	0.4269
Sc -27	4	0.163	0.255	0.183	0.159	0.323	1.14591	0.1869	0.2922	0.2097	0.1822	0.3701
Sc -28	3	0.166	0.259	0.187	0.162	0.329	1.11178	0.1846	0.2879	0.2101	0.1801	0.3658
Sc -29	6	0.185	0.289	0.208	0.181	0.367	3.03111	0.5608	0.8759	0.6305	0.5486	1.1124
Total	203	8.351	12.034	8.047	9.505	14.382		10.8896	15.6985	10.5514	12.3177	18.836

$$Cr=\frac{\Sigma \text{ all site observed crash}}{\Sigma \text{ all site predicted crash(unadjusted)}}=\frac{203}{10.8896+15.6985+10.5514+12.3177+18.836}=2.834$$

Table 4.22: Predicted average crash frequency and potential safety improvement

Section	Observed Crashes in study years	ΣNpredicted (unadjusted) in study years	Predicted crashes (in study period)	K	W	Nexpected N(E)	PSI	D/ ND
Sc -1	3	1.6771	4.7529	0.1765	0.5438	3.9532	- 0.8197	ND
Sc -2	3	1.5359	4.3527	0.2196	0.5113	3.6916	-0.6611	ND
Sc -3	5	1.4591	4.1351	0.2031	0.5435	4.5299	0.3948	D
Sc -4	6	2.0911	5.9262	0.1569	0.5182	5.9609	0.0347	D
Sc -5	6	1.6227	4.5987	0.1978	0.5237	5.2661	0.6674	D
Sc -6	5	2.1206	6.0013	0.1513	0.5241	4.5248	-1.4765	ND
Sc -7	10	1.342	3.8032	0.2404	0.5224	6.7628	2.9596	D
Sc -8	9	3.6833	10.4385	0.2087	0.3146	9.4525	-0.986	ND
Sc -9	17	3.1541	8.0202	0.1095	0.5324	12.2191	4.1989	D
Sc -10	13	3.6505	10.3455	0.0919	0.5126	9.6393	-0.7062	ND
Sc -11	14	4.4045	12.4823	0.0805	0.4988	13.243	0.7607	D
Sc -12	15	3.0411	8.6184	0.1098	0.5138	11.7211	3.1027	D
Sc -13	8	2.1725	6.1568	0.1507	0.5187	6.0439	-0.1129	ND
Sc -14	4	2.2119	5.2685	0.1064	0.5998	3.3606	-1.9079	ND
Sc -15	3	1.9668	5.5739	0.1183	0.6026	4.551	-1.0229	ND
Sc -16	7	2.7018	7.6569	0.0904	0.5909	7.3882	-0.2687	ND
Sc -17	5	2.1939	6.2175	0.1021	0.6117	5.7447	-0.4728	ND
Sc -18	4	1.677	4.7459	0.1352	0.6091	4.4543	-0.2916	ND
Sc -19	9	2.296	6.5068	0.0992	0.6077	7.4849	0.9781	D
Sc -20	11	2.269	6.4303	0.1035	0.6004	8.2564	1.8261	D
Sc -21	7	2.3838	6.7559	0.0971	0.6039	6.8516	0.0957	D
Sc -22	4	2.3615	6.6925	0.1005	0.5979	5.6099	-1.0826	ND
Sc -23	5	4.1554	8.7764	0.1198	0.4148	4.8109	-3.9655	ND
Sc -24	6	1.6596	3.1031	0.1484	0.5889	5.2364	2.1333	D
Sc -25	4	1.832	5.1919	0.1296	0.5978	4.7125	-0.4794	ND
Sc -26	7	1.4322	4.0588	0.1576	0.6098	5.2065	1.1477	D
Sc -27	4	1.2411	3.5173	0.1862	0.6043	3.7083	0.191	D
Sc -28	3	1.2285	3.4815	0.1835	0.6102	3.2938	-0.1877	ND
Sc -29	6	3.7282	10.5657	0.1637	0.3664	7.6729	-2.8928	ND

N.B: D= Dangerous, ND= Not Dangerous

4.3.3.2.1 Loss categories of study road sections

In Empirical Bayesian (EB) method after analysis safety of the road it categories in to four (4) types based on potential of road sections to reduction road crashes.

Table 4.23: Loss categories according to Erata changes to the highway safety manual, 1st Edition

Loss	Condition	Description
I	$\sigma < N_{observed} < (N_{predicted} - 1.5^{*} (\sigma))$	Indicates a low potential for crash Reduction
II	$(N_{predicted} - 1.5^{*} (\sigma)) \leq N_{observed} < N_{predicted}$	Indicates low to moderate potential for crash reduction
III	$N_{predicted} \leq N_{observed} < (N_{predicted} + 1.5^{*} (\sigma))$	Indicates moderate to high potential for crash reduction
IV	$N_{observed} \geq (N_{predicted} + 1.5^{*} (\sigma))$	Indicates a high potential for crash reduction

Where: $\sigma = \sqrt{k * N\ 2predicted}$, σ = standard deviation, k = over dispersion parameter

$N_{observed}$= Number of observed crashes

$N_{predicted}$= Number of predicted crashes occurrences

Source: 2016 Erata changes to the highway safety manual, 1st Edition

Table 4.24: Loss categories of study road sections

Section	$N_{observed}$ crashes	$N_{predicted}$ crashes	K	(N^2) Predicted	σ	($N_{predicted}$ - 1.5*(σ))	($N_{predicted}$ + 1.5*(σ))	Loss Categories
Sc -1	3	4.7529	0.1765	22.5900	1.9968	1.7577	7.7481	II
Sc -2	3	4.3527	0.2196	18.9459	2.0397	1.2931	7.4123	II
Sc -3	5	4.1351	0.2031	17.0991	1.8636	1.3397	6.9305	III
Sc -4	6	5.9262	0.1569	35.1198	2.3474	2.4051	9.4473	III

Sc -5	6	4.5987	0.1978	21.1480	2.0452	1.5309	7.6665	III
Sc -6	5	6.0013	0.1513	36.0156	2.3343	2.4999	9.5027	III
Sc -7	10	3.8032	0.2404	14.4643	1.8647	1.0061	6.6003	IV
Sc -8	9	10.4385	0.2087	108.962	4.7687	3.2854	17.5916	II
Sc -9	17	8.0202	0.1095	64.3236	2.6539	4.0394	12.001	IV
Sc -10	13	10.3455	0.0919	107.029	3.1362	5.6412	15.0498	III
Sc -11	14	12.4823	0.0805	155.807	3.5415	7.1701	17.7945	III
Sc -12	15	8.6184	0.1098	74.2768	2.8558	4.3347	12.9021	IV
Sc -13	8	6.1568	0.1507	37.9062	2.3900	2.5718	9.7418	III
Sc -14	4	5.2685	0.1064	27.7571	1.7185	2.6907	7.8463	II
Sc -15	3	5.5739	0.1183	31.0684	1.9171	2.6983	8.4495	II
Sc -16	7	7.6569	0.0904	58.6281	2.3022	4.2036	11.1102	II
Sc -17	5	6.2175	0.1021	38.6573	1.9867	3.2375	9.1975	II
Sc -18	4	4.7459	0.1352	22.5236	1.7450	2.1284	7.3634	II
Sc -19	9	6.5068	0.0992	42.3384	2.0494	3.4327	9.5809	III
Sc -20	11	6.4303	0.1035	41.3487	2.0687	3.3272	9.5334	IV
Sc -21	7	6.7559	0.097	45.6422	2.105	3.5981	9.9137	III

			1		2			
Sc -22	4	6.6925	0.1005	44.7895	2.1216	3.5101	9.8749	II
Sc -23	5	8.7764	0.1198	77.0252	3.0377	4.2199	13.3329	II
Sc -24	6	3.1031	0.1484	9.6292	1.1954	1.31	4.8962	IV
Sc -25	4	5.1919	0.1296	26.9558	1.8691	2.3883	7.9955	II
Sc -26	7	4.0588	0.1576	16.4738	1.6113	1.6419	6.4757	IV
Sc -27	4	3.5173	0.1862	12.3714	1.5177	1.2408	5.7938	III
Sc -28	3	3.4815	0.1835	12.1208	1.4914	1.2444	5.7186	II
Sc -29	6	10.5657	0.1637	111.634	4.2749	4.1534	16.978	II

From the above result out of 29 study road sections , 0 section (0%), 13 sections (44.83%), 10 sections (34.48%), 6 sections (20.69%) are belongs to II, III and IV loss categories respectively.

4.3.3.2.2 **Effects of Horizontal Curves on road safety**

The joint effect of horizontal curves (HC) elements such as radius of the curve, total length of curves (include both circular and transition) and super-elevation on road safety are discussed below from above results of Empirical bay (EB) method in the following. The study road section comprises radius of curves(R) minimum 110m at segment 9 and maximum 1905m at segment 2 in [110m , 1905m]. For effect analysis purpose different radius divided in to three intervals such as A. [110m, 380m], B. [380m, 550m] and C.[550m, 1905m].

A. Horizontal curves effect on road safety of the curves radius [110m, 380m]

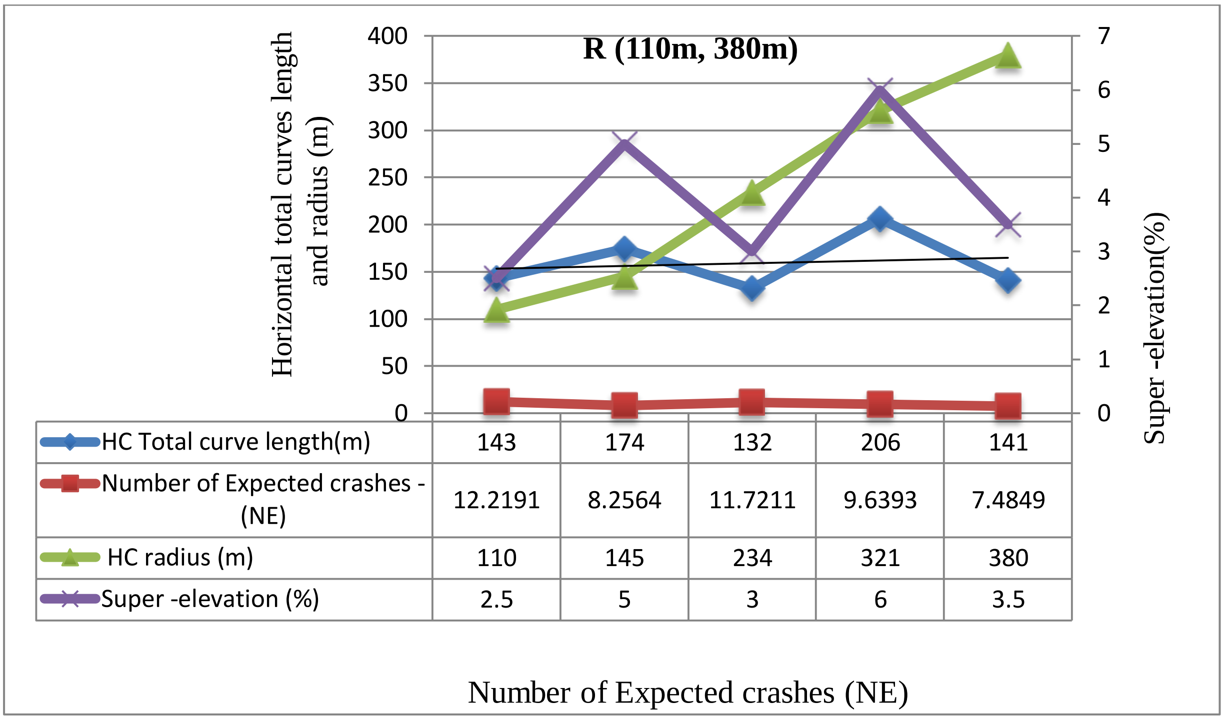


Figure 4.8: Horizontal curves effect on road safety of the curves radius [110m, 380m]

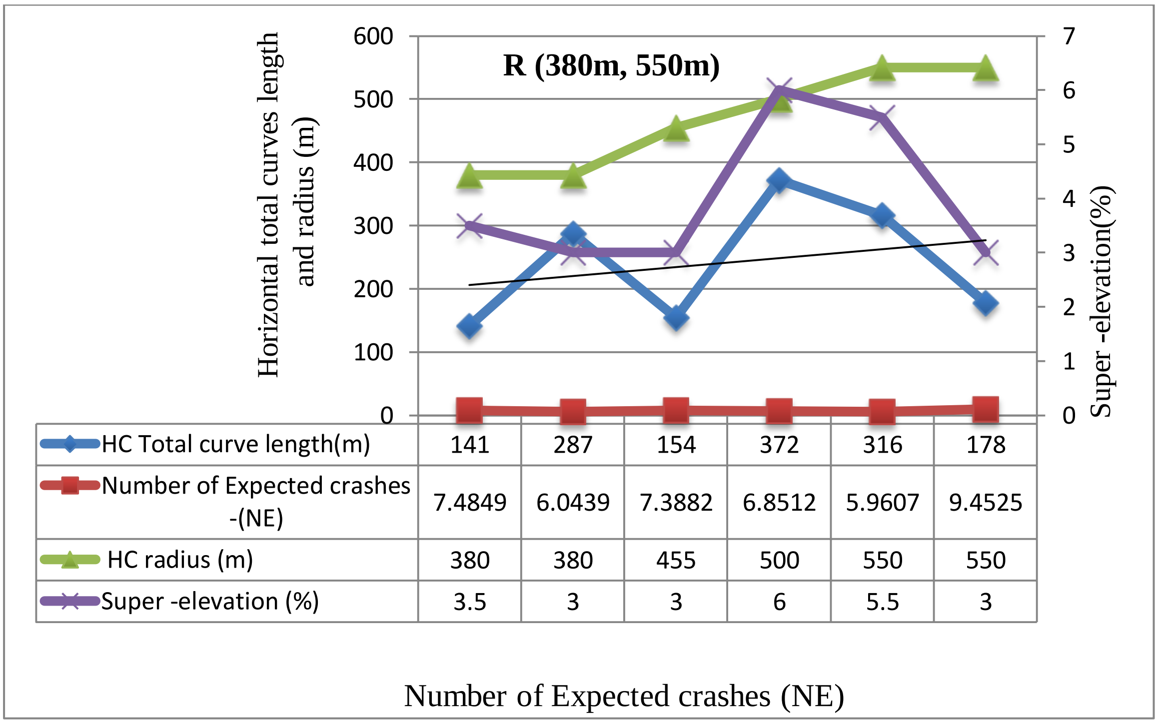
I. From the above figure (A), while horizontal curves parameters such as total curves length (m), radius (m) and super-elevation (%) increased by 31 m (143 to 174), 35 m (110 t0 145) and 2.5% (2.5 % to 5 %) respectively ,then number of expected traffic crashes decreased by32.43% (12.2191 t0 8.2564). This indicated that when the sharpness of horizontal curves improved by increasing the size dimensions of its parameters safety of the road well improved. This finding is confirmed with findings of previous studies of Hauer, E. (1997) and Abebe. M.T. (2018) as shown in literature review. But in this study number of expected traffic crashes decreases compare with previous studies, this due to the amount of crashes may depend on other factors such access control, surface conditions and sight distance respectively.

II. When radius of curve increased by 89 m (145 to 234) while curve length and super-elevation decreased by 42 m (174 to 132) and by 2% (5 to 3) the number of expected crashes increased by 41.97% (8.2564 to 11.7211). This can states that when curve radius increased in shorter length of curve and small super-elevation increased percentage of number of expected crashes were unexpected result. Further study of the characteristics of this road section is required.

III. When increasing all horizontal curve (HC) elements such as radius of curve by 87m (234 to 321 m), length of curve by 74 m (132 to 206 m) and super-elevation by 3% (3 to 6 %) improved road safety only 17.76% which is small compare with the above road section. In this stage, even if all parameters of horizontal curves improved at larger rate road safety increased at slower rate and this also required further investigation.

IV. While decreasing length of curve by 65 m (206 to 141 m), super-elevation by 2.5 % (6 to 3.5 %) and increasing radius of curve by 59 m (321 to 380 m) and also improves road safety by 22.35% .This indicates that the safety of road too much sensitive to the radius of the sharp curves. additionally total length of curve and road safety seem negatively correlated. This probably may be due to that when the length of transition curve increased the curve become more flatter and flattening is expected to reduce number of traffic crashes.

B. Horizontal curves effect on road safety of the curves radius [380m, 550m]



HC Total curve length(m)	141	287	154	372	316	178
Number of Expected crashes -(NE)	7.4849	6.0439	7.3882	6.8512	5.9607	9.4525
HC radius (m)	380	380	455	500	550	550
Super -elevation (%)	3.5	3	3	6	5.5	3

Figure 4.9: Horizontal curves effect on road safety of the curves radius [380m, 550m]

I. From the above figure (B), shows that at constant radius (R= 380m), increasing length of the curve by 146 m (141m to 287 m) and super- elevation decreasing by 0.5 percentage (3.5% to 3%) and decreases certain amount of expected number of accidents and accounted for 21.25%. This shows that at a given radius, total curve length reversely and super-elevation directly associated with expected number of accidents in a given range of radius.

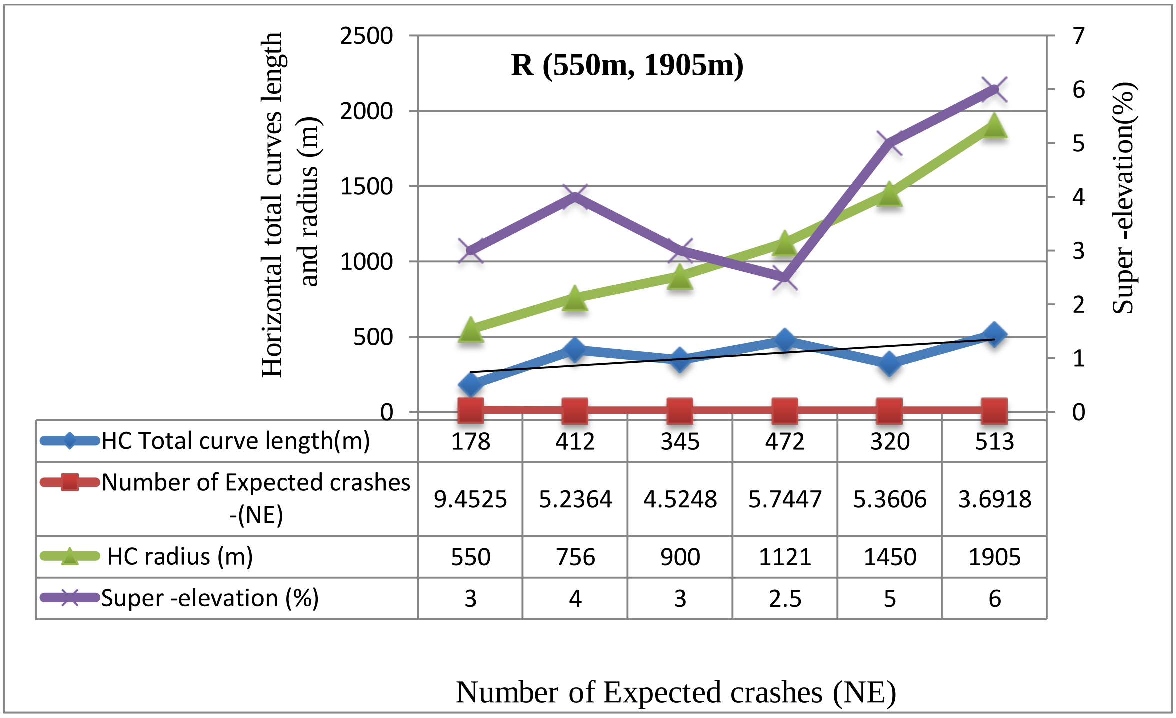
II. When at constant super-elevation (3%), the length of the curve reduced by 133 m (287 to 154 m) and radius of curve improved by 75 m (389 to 455 m) the amount of expected number of accident increased by 23.24 % (6.0439 to 7.3882). Though the result confirmed with previous results indicated in literature part, in addition to HC parameters the result obtained in this step was may be due to the effect of other road parameters like access controls, lane and shoulder width and number of vertical curve along road section and it needs future further investigations.

III. A figure (A) has already discussed in stage (I);

IV. Decreasing length of curve by 56 m (372 to 316 m) and super-elevation by 0.5 % (6% to 5.5%) and radius of curve improved by 50 m (500 to 550m) respectively and the expected number of accident decreased by 13.65%. This confirmed that the road safety more depend on radius of curves in the road section.

V. At constant radius (R= 550 m), radius of curves decreased by 138 m (316 to 178 m) and by 2.5 % (5.5 to 3%), increases substantial amount of expected number of accidents in the road section and accounted for 58.46%. This clearly stated that safety of road section at constant radius depend on other parameters such as curve length and super-elevation.

C. Horizontal curves effect on road safety of the curves radius [550m, 1905m]



HC Total curve length(m)	178	412	345	472	320	513
Number of Expected crashes -(NE)	9.4525	5.2364	4.5248	5.7447	5.3606	3.6918
HC radius (m)	550	756	900	1121	1450	1905
Super -elevation (%)	3	4	3	2.5	5	6

Figure 4.10: Horizontal curves effect on road safety of the curves radius [550m, 1905m]

I. As radius of curve, length of curves and super-elevation respectively improved the safety of road or number of expected accidents decreased by 44.61% (9.4525 to 5.4525%). This is the same as with the result get in previous figure (A) stage (I) previously discussed and explained.

II. When super-elevation slightly decreased in 1% (4 to 3%) and also length of curves decreased by 67 m (412 to 345m) while radius of curve improved by 144m (756 to 900m) and number of expected accidents decreased by 13.59% (5.2364 to 4.5248). This states that the road safety more depend on radius of curves and the combined improvements of radius of curve, length of curve and super-elevation can improve road safety and slightly or small improvement of length of curve and super-elevation will bring slight improvement on roads safety.

III. When increasing both radius and length of the curve by 221m (900 to 1221m) and by 127m (345 to 472m) respectively, but reducing super-elevation by 0.5% percentage points (3 to 2.5%) increase the number of expected accidents by 26.96% (4.5248 to 5.7447). previous as explained in the literature, due to a few increasing of radius of curve from 100o m onward a slight increase of accident may be expected. This also indicates that the effect of other road parameters that may have an effect on increasing the number of expected accidents.

IV. Large improvement of radius of curve and super-elevation by 329 m (1121 to 1450m) and 2.5% (2.5 to 5%) respectively even though the length of curve decreased by 152 m (472 to 320m) decreases expected number of accidents by 6.68% (5.7447 to 5.3606). This slight improvement on number of expected accidents clearly stated that, the road safety may depend on other parameters such as road access, access control, number of vertical curves rather than length of curve and further investigations needed in this road section.

V. This is the same as with figure (A) in stage (I) and it has already discussed.

4.3.3.2.3 The Effects of Grades on Road Crashes

The effect of grades on road safety already discussed previous through Negative Binomial and Poison regressions. Now for study purpose on the exist road sections grade divided into three accordingly their categories such as

A. Flat road section [$G \leq 3\%$]
B. Mild road section [$3\% \leq G \geq 6\%$]
C. Steep road section [$G \geq 6\%$]

From the above grades of the study road section and expected number of accidents on the section relation explained that i.e. [sec-1], [sec-2], [sec-3], [sec-23] [sec-27] and [sec-28] with grades [2%], [3%], [2%], [3%], [3%] and [2.5%] respectively which categorized under flat road section with [3.9532], [3.6916], [4.5299], [4.8109], [3.7083] and [3.2938] expected number of accidents respectively except [sec-7] with grade [3%] and expected number of accidents [6.7628] which is some high when compare with rest once this may due to fact that drivers tend to travel at higher speeds on flat sections and it require further investigations for the future and this confirmed with study of Hedman (1990) quoting Swedish's research stated that grades of 2.5% and 4% increase crashes by 10 and 20%, respectively and author stated that steep gradients are generally associated with high crash rates.

For the second(mild grade road sections) i.e. [sec-4], [sec-5], [sec-6], [sec-8], [sec-9], [sec-10], [sec-13], [sec-14], [sec-15], [sec-17], [sec-18], [sec-19], [sec-20], [sec-21], [sec-22], [sec-24],[sec-25],[sec-26],[sec-29] with grades [5%],[4%],[5%],[3.5%],[5%],[6%],[5%],[5.5%],[4%],[5%],[5%],[4%],[5%],[5.5%],[4%],[5.5%],[5.5%],[5.5%],[4%] and [3.5%]respectively which categorized under mild road section with [5.9609],[5.2661],[4.5248],[9.4525],[12.2191],[9.6393],[6.0439],[3.3606],[4.5510],[5.7447],[4.4543],[7.4849],[8.2564],[6.8516],[5.6099],[5.2364],[4.7125],[5.2065] and[7.6729] expected number of accidents. From the result of expected number of accidents this mild road sections about 85% (17 out of 20 road sections categorized under mild grades) was medium value of road safety except [sec-8],[sec-9] and[sec-20] results got are some higher compare with the rest once. This due to [sec-9] has no access controls with 12 accesses to road section and more number of vertical curves when compare with two road sections and this research get is confirmed with literature review explained early but in expected number of expected accidents depends on other parameters such as number access controls and vertical curves more explained here . Even though [sec-8] and [sec-20] are categorized under mild grades, number of access with access controls and it have small number of vertical curves it expected higher number of accidents this due to may it affected by other geometric design parameters rather than grades and others mentioned here, so it needs further investigations in the future.

For the third case (steep grade sections) i.e. [sec-10], [sec-11], [sec-12] and [sec-16] with grades [6%], [6.5%], [7%] and [6.5%] respectively with [9.6393],[13.243], [11.7211] and [7.3882] expected number of accidents respectively. This confirmed that steep road sections have more road safety problems and expected number of accidents than flat and mild grades geometrically.

On the sections with high gradient, safety problems may occur from inadequate passing sight distance (PSD), speed differences between passenger cars and heavy vehicles (when it taking long time on upgrade sections), sliding asphalt surface when rain seasons and increases in braking distances on downhill sections.

4.3.3.2.4 The Effects of Vertical and Horizontal Curves Alignments on Road Crashes

When horizontal and vertical alignments have inefficient combination may result to be road safety problems, even when the vertical and horizontal alignments are separately correct and according to the standards correct and according to the standards.

According to Hassan,Y. Sayed, T. and Bidulka,S.(2002,) Poor coordination of horizontal and vertical alignments can create locations where the available sight distance drops below the required sight distances special passing sight distance (PSD) with other geometric parameters such as number of access with regarding access controls.

In the previously explained literature review, the coincidence of horizontal curve and a crest curve may, under certain conditions, lead to significant limitation of the variable sight distances special stopping sight distance (SSD), passing sight distance(PSD) and prevent the prompt perception of the curves. For instance, [Sec-7], [Sec-9], [Sec-11], [Sec-12], [Sec- 26] and [Sec-27] are good examples, those study gets from the previous categorized as dangerous road section (marked as “D”) consists the specified combination of vertical and horizontal alignments. For the time being and due to scarce resource the author of this study didn’t take detail investigations on the effects of inefficient combination of horizontal and vertical alignments on traffic crashes and it require further future investigation on it relating with sight distances.

The same is true; the coincidence of a left horizontal curve and sag vertical curve may create a false impression of the degree of curvature i.e. the horizontal curve may seem to have a higher radius than the actual and may contribute to increased traffic crashes. For instance, [Sec-3], [Sec-4], [Sec-5], [Sec-19], [Sec-20], [Sec-21], [Sec-24], [Sec-26] and [Sec-27] are study get from the previous as dangerous road section (marked as “D”) consists the specified combination of sag vertical and horizontal alignments. This is the same result as from previous explained literature review Abebe. M.T (2018) and similarly, For the time being and due to scarce resource the author of this study didn’t take detail investigations on the effects of inefficient combination of horizontal and vertical alignments on traffic crashes and it require further future investigation on it relating with sight distances.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and Conclusions

The study analyzed the effects of road geometric design parameters on road traffic crash occurrences using crash counting model (Poisson log-linear regression and Negative Binomial regression) models and Empirical Bayesian (EB) method based on five years crash records from 2014/15 to 2018/19 and additional one year (2013/14) back for more precision purpose. Moreover, descriptive general analysis of crash trends in Aletawondo- Bona-Daye two way rural trunk road sections is incorporated in the study.

Selected road geometric parameters in the study were: number of horizontal curves, number of vertical curves, vertical gradient counts, length of road segments, number of lanes, surface width, sidewalk width, median type, median height, median width, number of road access and number of road access controls. In addition, average daily traffic (ADT) was also included in the model as an exposure variable and average annual daily traffic (AADT) forEmpirical Bayesian (EB) method analysis for horizontal curves (HC) and grades effects on traffic crashes occurrence. The study used twenty-nine representative road sections to achieve the stated objectives using convenience sampling method from woredas, Alatawondo and Daye town traffic police offices based on the requirements to obtain a sample of road sections incorporating a different road geometric design elements. To estimate ADT, peak hour count method was used and the other road geometric parameters were measured from the study sites and five years data from 2014/15 to 2018/19 of average annual daily traffic (AADT) from shashemene district of Ethiopian Roads Authority (ERA).

The model shows that road traffic crash frequency in selected road segments in the study road sections is influenced by average daily traffic as an exposure variable, number of horizontal curves, number of vertical curves, number of lanes, gradient, surface width, sidewalk or shoulder width, median type, number of road access and number of access control. The design parameters of study 29 road sections directly and indirectly have influences on traffic crashes and each parameter listed and characterized through descriptive statistics in the study. However, length of road segments, median width and median height were found statistically insignificant in the output of the model.

The traffic crashes characterized based on different physical and design parameters of study section. Accordingly traffic crashes have direct relation with painted medians, number of horizontal curves, number of vertical curves, grades count, number of lanes and average daily traffic (ADT) and inverse or indirect relationship with width of shoulder or side walk and number of access.

Similarly, painted medians had positive correlation with road crashes. Further, road segments with painted medians had higher road traffic crashes compared with raised median. Moreover, number of horizontal curves, number of vertical curves, and number of lanes, number of access, gradient and average daily traffic positively affected road traffic crashes that occurred on the selected segments. The result implies that as the numbers of these explanatory variables increases in the road segments, the corresponding crash occurrences also increases. On the other hand, sidewalk or shoulder width and number of road access controls had negative coefficient. This indicates that as width of sidewalks or shoulders increase and also the number of access controls on the road sections, the probability for potential crash risk is reduced.

In addition, it revealed that road crash frequently occurs on a horizontal curve road with flat terrain road geometry, quality asphalt, and rear-end collision types.

The study additionally used Emprical Bayesian (EB) method for analysis of horizontal curves elements and grades on traffic crashes occurrence the following conclusions are drawn. Horizontal curves have higher crash rates than straight sections of similar length and traffic composition; this difference becomes apparent at radii less than 1000 m this is confirmed with this study as literature review explained.

To analyze and identification of the most hazardous road was addressed by using Empirical Bayesian (EB) method and Safety Performance Function (SPF) approach in case of horizontal curve components in addition after analyzed the whole geometric design parameters effects on traffic crashes. This approach takes into account of effects due to site-specific factors developing their relation with crash frequency. From the total 29 section selected as sample 13 section was selected as hazardous road section as Potential for Safety Improvement (PSI) values.

From the analysis of effects of horizontal curves parameters by using EB method on traffic crashes showed that small curve radius (i.e., $110 \leq R \leq 380$ m) that is short and sharp associated with higher number of expected accidents. For the middle radius of curves (i.e., $380 \leq R \leq 550$ m) associated with moderate number of accident and partial it affected by some other parameters such as number of access with number of control access and gradients of road section. For wider curves on study road (i.e., $550 \leq R \leq 1905$ m),the effect of horizontal curve parameters on number of crashes occurrence is found to be not consistent and hence it may be highly affected by the availability of other risk indicating road parameters rather than horizontal curves (i.e., number of access, access control, gradient, sight distances). Totally, this study found that the number of expected accidents decreased as the radius of the curve, transition curve length and super-elevation of horizontal curves jointly or partial increased in the study road sections.

Additionally, number of expected accidents increase identified in this study when road section transformed from flat to mild grade and mild to steep grades respectively with perspective other parameters of study road sections.

Finally, the study concluded that the Ethiopian government conjugated with national Road and Transport Ministry should include basic training of geometric design parameters basic concept for Traffic policies those who ignored and not concerned about its effects on traffic crashes during reporting and recording traffic crashes as policy to minimize traffic accidents infliction on human deaths and property damages on as whole country. Study also conclude that number of expected accidents have been quantified when the road section parameters improved.

5.2 Recommendations and Future Study

5.2.1 Recommendations

The based on collected data and the analysis, as well as from the perspectives of the main causes of road crashes, the following recommendations were given to facilitate road safety at the road segments.

- The SNNPR regional state conjugate with Sidama Zone and Woredas Traffic Management Agency should expend considerable resources and effective monitoring in an effort to improve safety by implementing countermeasures that include improving highway geometrics, highway signing, and other road safety considerations on the AlataWondo –Bona –Daye road two way rural trunk road sections.
- Widening painted medians width or changing to raised medians in dangerous sections and the section with congested traffic since they were more effective on road safety than the painted median.
- Minimizing road access, placing warning signs at the roads access, and also removing obstacles from road layouts.

- Providing traffic signs , warning signs and post speed limit or upgrade it at steep grades and highly horizontal curves area specially from Alatawondo town up to Adola (Kibremengist) to Hulla (Hagereselam) trunk road intersections.
- The vehicles had involved other types of accidents like roll over, collision with fixed objects, head on collision with fixed objects, rear end collision and turnover along study area. In order to improve such accidents, segregating fast moving and show moving traffics by constructing separate lanes for non-motorized traffic and widening pedestrians walking lanes around sub-urban area (i.e., Sec-8 of study area). Equally, attention should give and equipped with reflective materials, column handrails and effective traffic signs at the front and rear approach of Gellana river bridge which at 13.5 km far from Daye town and others road sections selected as dangerous point of study area to improve visibility through service time.
- Generally, function ably and cost effective countermeasures such as provision of warning signs with recommended speed, road surface marking, construction of painted guard rail (i.e., only provided two study road sections, [Sec-10] and [Sec-12] which also not sufficient and convenient) outside the curve, provision of rumble strips widening of walking shoulder lanes and others are proposed in order to reduce the excess number of expected accidents. Therefore, implementation of the identified countermeasures for the road sections identified as dangerous in analysis and abbreviated as ''D'' will be vital to reduce the number of expected accidents.

- Providing well-constructed sidewalk or shoulder on the both sides of road segments for pedestrians.
- Provide access control to guide both vehicles and the pedestrians and should upgrade seasonal.
- Banning street shops (or not to sell) some goods on the shoulder of road sections in rural areas.
- Trimming trees from the road medians that limits the visibility of the driver during the turning maneuvers.
- The national as well as regional transport authority should consider proportionate a number of lanes with average daily traffics as safety criteria, and as well as number of horizontal and vertical curves, sidewalks and driveways while designing the new street and the rehabilitations of the existing road geometric design elements andProviding appropriate crash location information.

- Road traffic accident and safety education campaign should be given for all society including for pedestrian, drivers and traffic police too; planners and designers should also consider the effects of geometric design parameters on road safety. Implementing the existing road traffic safety rule and regulations to satisfy the present road traffic safety condition through including Ethiopian Roads Authority (ERA) road safety manual properly and accordingly and some of international standard recognized traffic rule and regulations during the design and construction of geometry of road projects.

5.2.2 Future Study

- The study tried to address the influence of road geometric design elements on road traffic crash frequency in AlataWondo-Bona-Daye two way rural trunk road sections. As the result shows, road geometric parameters had a significant role on the crash occurrences at road segments resulting in both loss of human lives and properties. On the other hand, the incorporation of other important road geometric parameters and its environments like; posted speeds, sight distances, land uses, and road traffic management related issues with more sample sizes and data are recommended to be from different road sections. Accordingly, further research is required in this area.
- Moreover, pedestrian volume from exposure variables is recommended to be included in the model for more realistic findings in the future studies. Furthermore, it's shown in the general causes of accidents analysis that human error contributes about 84.5% to road traffic crashes. Therefore, human factor (or drivers' attitudes and behaviors) need to be considered as explanatory variables on the road crashes to further research.
- The combinations of horizontal and vertical curves effects (was not detail analyzed), vehicle factors, human factors and pavement surface moisture conditions were not correlated with expected number of accidents. Therefore, recommended that further study should be conducted to get solution. Also road and its environment variable such as land use, posted speed, percentages of heavy vehicles and others were not incorporated. For realistic and more precision findings for the future further research is required in this study area.
- For the further study researchers on this section of road will may use and refer loss categories of each section of the study road.

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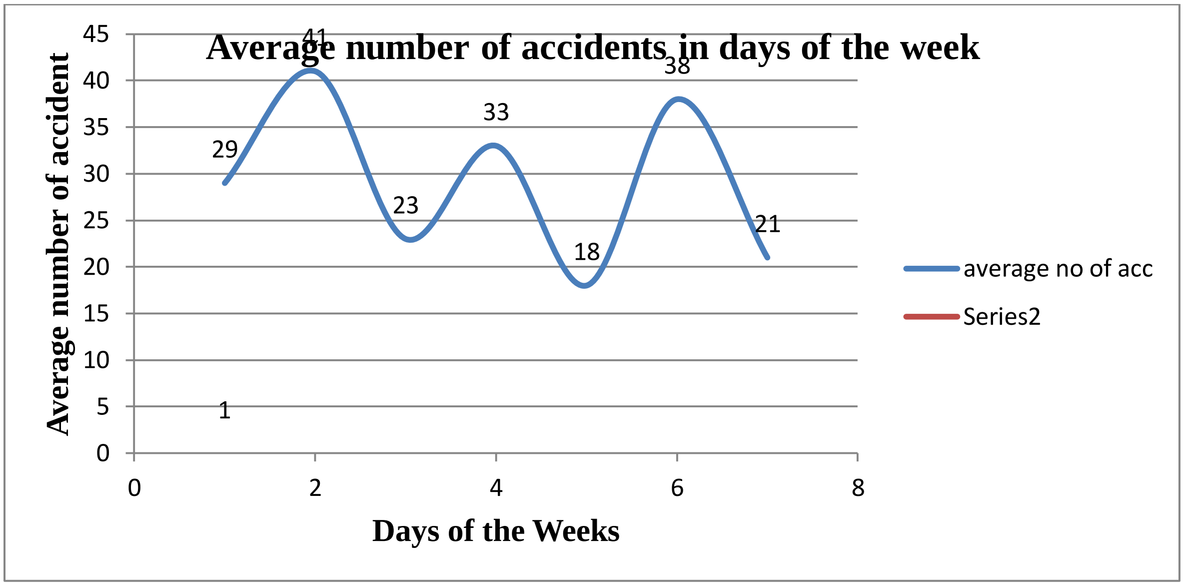
Appendices

Appendix A: Traffic data collection formats

Name of road section: ___________________________

No.	Severity Type	Crash hour	Day/ Night	Day of the week	Date	Year	Gender	Age	Education	Relation with Vehicle	Experience	Type	Code	Plate co de	Ownership	Service yea r

Appendix B: Average number of accidents in day of the week



Appendix C: Peak hour Traffic volume Counted Data for Motorized Vehicles

Road Section Name: ________________ Starting Point: ____________ End point: ________

Time	Vehicle Classifications					
	Passenger cars	Standard buses	Min buses	Trucks	Articulated trucks	Motor cycle (2&3 wheels)
Starting time End time						
6:30 6:45						
6:45 7:00						
7:00 7:15						
7:15 7:30						
Total						

Appendix D: Road Geometry Data Format

No.	Road section		Road Geometry				Other control points		
	Start	End							
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
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19.									
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21.									
22.									
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25.									
26.									
27.									
28.									
29.									

Appendix E: Models information

Dependent Variable	Total crash occurrence
Probability Distribution	Poisson ,NB
Link Function	Log

Categorical Variable Information

			N	Percent
Factor	Road segment length in meter	1580.0000	1	33.3%
		2913.8000	1	33.3%
		4720.0000	1	33.3%
		Total	3	100.0%
	Number of horizontal curves in number	Mean	1	33.3%
		3.3400	1	33.3%
		7.0000	1	33.3%
		Total	3	100.0%
	Number of vertical curves in number	Std.Deviation	1	33.3%
		4.2100	1	33.3%
		10.0000	1	33.3%
		Total	3	100.0%
	Vertical grades count by percent	Maximum	1	33.3%
		3.1200	1	33.3%
		6.5000	1	33.3%
		Total	3	100.0%
	Number of lanes	Mean	1	33.3%
		2.0700	1	33.3%
		4.0000	1	33.3%
		Total	3	100.0%
	Surface Width in meter	7.0000	1	33.3%
		8.3300	1	33.3%
		15.8000	1	33.3%
		Total	3	100.0%
	Median height in meter	Minimum	1	33.3%
		.0130	1	33.3%
		.2400	1	33.3%
		Total	3	100.0%

	Median width in meter	.1000	1	33.3%
		.1200	1	33.3%
		.4000	1	33.3%
		Total	3	100.0%
	Side Walk or shoulder Width in meter	.7500	1	33.3%
		1.1400	1	33.3%
		2.5000	1	33.3%
		Total	3	100.0%
	Number of access	5.0000	1	33.3%
		8.1300	1	33.3%
		16.0000	1	33.3%
		Total	3	100.0%
	Number of access control	Minimum	1	33.3%
		.5500	1	33.3%
		Mean	1	33.3%
		Total	3	100.0%

Continuous Variable Information

Variables		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	Total crash occurrence	3	3.0000	17.0000	9.00000	7.2111026
Covariate	Average daily traffic	3	722.0000	1570.0000	1122.133	426.01039

Appendix E: Loss Categories of Study Road Sections

Section	$N_{observed}$ crashes	$N_{predicted}$ crashes	k	(N^2) Predicted	Σ	$(N_{predicted}-1.5*(\sigma))$	$(N_{predicted}+1.5*(\sigma))$	Loss categories
Sc -1	3	4.7529	0.1765	22.5900	1.9968	1.7577	7.7481	II
Sc -2	3	4.3527	0.2196	18.9459	2.0397	1.2931	7.4123	II
Sc -3	5	4.1351	0.2031	17.0991	1.8636	1.3397	6.9305	III
Sc -4	6	5.9262	0.1569	35.1198	2.3474	2.4051	9.4473	III
Sc -5	6	4.5987	0.1978	21.1480	2.0452	1.5309	7.6665	III
Sc -6	5	6.0013	0.1513	36.0156	2.3343	2.4999	9.5027	III
Sc -7	10	3.8032	0.2404	14.4643	1.8647	1.0061	6.6003	IV
Sc -8	9	10.4385	0.2087	108.962	4.7687	3.2854	17.5916	II

Sc -9	17	8.0202	0.1095	64.3236	2.6539	4.0394	12.001	IV
Sc -10	13	10.3455	0.0919	107.029	3.1362	5.6412	15.0498	III
Sc -11	14	12.4823	0.0805	155.807	3.5415	7.1701	17.7945	III
Sc -12	15	8.6184	0.1098	74.2768	2.8558	4.3347	12.9021	IV
Sc -13	8	6.1568	0.1507	37.9062	2.3900	2.5718	9.7418	III
Sc -14	4	5.2685	0.1064	27.7571	1.7185	2.6907	7.8463	II
Sc -15	3	5.5739	0.1183	31.0684	1.9171	2.6983	8.4495	II
Sc -16	7	7.6569	0.0904	58.6281	2.3022	4.2036	11.1102	II
Sc -17	5	6.2175	0.1021	38.6573	1.9867	3.2375	9.1975	II
Sc -18	4	4.7459	0.1352	22.5236	1.7450	2.1284	7.3634	II
Sc -19	9	6.5068	0.0992	42.3384	2.0494	3.4327	9.5809	III
Sc -20	11	6.4303	0.1035	41.3487	2.0687	3.3272	9.5334	IV
Sc -21	7	6.7559	0.0971	45.6422	2.1052	3.5981	9.9137	III
Sc -22	4	6.6925	0.1005	44.7895	2.1216	3.5101	9.8749	II
Sc -23	5	8.7764	0.1198	77.0252	3.0377	4.2199	13.3329	II
Sc -24	6	3.1031	0.1484	9.6292	1.1954	1.31	4.8962	IV
Sc -25	4	5.1919	0.1296	26.9558	1.8691	2.3883	7.9955	II
Sc -26	7	4.0588	0.1576	16.4738	1.6113	1.6419	6.4757	IV
Sc -27	4	3.5173	0.1862	12.3714	1.5177	1.2408	5.7938	III
Sc -28	3	3.4815	0.1835	12.1208	1.4914	1.2444	5.7186	II
Sc -29	6	10.5657	0.1637	111.634	4.2749	4.1534	16.978	II