EVALUTION OF THE CONTRIBUTION OF GEOMETRIC DESIGN OF THE ROAD INTERSECTION IN ALLEVIATING TRAFFIC ACCIDENT

IN SHASHEMENE TOWN

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

October, 2020

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A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING

HAWASSA INSTITUTE OF TECHNOLOGY,

FACULTY OF CIVIL AND BUILT ENVIRONMENT

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN CIVIL ENGINEERING

(SPECIALIZATION: ROAD AND TRANSPORT ENGINEERING)

October, 2020

ADVISORS' APPROVAL SHEET

This is to certify that the Thesis entitled **"Evaluation of the contribution of Geometric Design of the Road Intersection in alleviating Traffic Accident in Shashemene Town"** submitted in partial fulfillment of the requirements for the degree of **Master's** with specialization in **Road and Transport Engineering,** the Graduate Program of the Department of Civil Engineering, and has been carried out by **Yasin Assefa (ID. No. PGRO/022/10),** under us supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by Yasin Assefa have read and evaluated his thesis entitled **"Evaluation of the contribution of Geometric Design of the Road Intersection in alleviating Traffic Accident in Shashemene Town"**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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DECLARATION

I hereby declare that this MSc thesis entitled "**Evaluation of the contribution of Geometric Design of the Road Intersection in alleviating Traffic Accident in Shashemene Town"** is my original work and has not been presented for a degree in any other university.

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ACKNOWLEDGMENTS

First and foremost, I am grateful to the support, guidance and encouragement from my major advisor, Dr. Alemayhu Ambo. Secondly my deepest gratitude goes to my Co-advisor Ins. Thomas Bezabih (MSc.) who have been assisting and guiding me throughout the whole process of my thesis. The research would not have been completed without their professional invaluable support and encouragements during consultancy of the research.

Moreover, I am thankful for the sponsorship of Ethiopian Roads Authority (ERA) in providing the full funding of the program I have involved in.

Next there are numerous people, without whom, completing this thesis work would not have been successful. I am appreciating the support and assistance of my family and the understanding of all of my friends. I would like to sincerely thank officials of the Shashemene town Transport Bureau, Shashemene Traffic policy commission and Shashemene town municipality for providing me the necessary data as input this thesis. Finally, I thank all the people who had participated in the preparation of this thesis work, as their involvement has contributed to the successful completion of my thesis.

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ABBREVIATIONS

AACRA: Addis Ababa City Road Authority

AADT: Average Annual Daily Traffic

AAPC: Addis Ababa Police Commission

AASHTO: American Association of State Highway and Transportation Officials

CBD: Central Business District

EB: Empirical Bayesian

ECE: Economic Commission for Europe

ERA: Ethiopian Road Authority

FHWA: Federal Highway Administration

ISD: Intersection Sight Distance

HCM: Highway Capacity Manual

ORA: Oromiya Road Authority

PDO: Property damage only

STPC: Shashemene Town Police Comission

STTB: Shashemene Town Transport Bureau

STP: Shashemene Traffic Policy

STTPO: Shashemene Town Traffic Police Office

SULGA: Shashemene Urban Local Government Administration

UIDG: Urban Intersection design Guide

USDG: Urban Street Design Guide

WHO: World Health Organization

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ABSTRACT

Efficiency of intersections contributes significantly towards the efficiency of urban road networks. Whereas intersections constitute a very small part of the entire transportation network, more than 50% of all motor vehicle accidents occur at intersections. Because of the overrepresentation of intersection-accidents, intersections require special attention in the planning and designing of road networks. Thus, the main aim of this research study is the evaluation of the contribution of geometric design of the road intersections in alleviating traffic accident in the Shashemene town. Abosto and Kudus Mikael signalized intersections while Tekliye, Semaniyaand (81), arada Sefer, Gibrna, Zero Amst (05) and Mobile non signalized intersections were chosen for this thesis. These intersections were selected for the study from different locations within the town. They have more traffic accident than any other similar junctions do in Shashemene town. The geometric, traffic and accident data were collected during the morning and afternoon peak time periods using site observation, field measurement and video camera in each of the selected junctions. The study use four distinct scientific principles namely: accident frequency, accident rate, empirical Bayesian and critical accident method to identify black spot locations at selected intersections. Out of the methods, empirical Bayesian proved superiority so that much of the conclusion was based on this method. Log-linear Poisson regression and Negative binomial regression model was used to investigate the effect of road geometric design elements on the road crash occurrence in the selected junctions.The results of paper proved that road junction Semaniyand, Tekliye, Kudus Mikael and Abosto were highly prone to accidents than other road junctions in Shashemene town with adjusted accident frequency values of 27.85, 26.54, 25.25 and 22.65 respectively. And also the result of this study shows, there is a strong correlation between road geometric design elements and road crash occurrence. The modeling result indicated that the explanatory variables such as lane width, super elevation, gradient, and intersection sight distance, shoulder width, median type, and median width, angle of intersection, side walk width and curves radius had significant effects on the occurrence of road traffic crashes.

Key words: *accident, alleviate, Black spot, geometric design, intersection, Negative binomial regression model, Poisson regression model*

1. INTRODUCTION

1.1. General

Transportation is essential for any nation's development and growth. Transportation plays a significant role by facilitating trade, commerce, and social interaction, while consuming a considerable portion of time and resources. Many organizations and agencies exist to plan, design, build, operate, and maintain transportation systems. The movements of people and goods, which is the basis of transportation, has always been undertaken to accomplish those basic objectives or tasks that require transfer from one location to another. Every day, millions of people leave their homes and travel to a workplace, office, classroom, or distant city (Garber, 2010; Abojaradeh, 2013; Abojaradeh, 2014).

Intersections are an important part of a highway facility because, to a great extent, the efficiency, safety, speed, cost of operation, and capacities of the facility depend on their design. Each intersection involves through- or cross-traffic movements on one or more of the highways and may involve turning movements between these highways. Such movements may be facilitated by various geometric design and traffic control, depending on the type of intersection (AASHTO, 2001).

According to Shirley (2000), geometric planning is planning the road where the geometry or the real dimensions of the road along with parts adapted to the demands and characteristics of traffic. Geometric planning generally involves planning aspects such as road width, bend, ramps, visibility, and also combinations of these parts. This geometric design is closely related to traffic flow, while the road construction design has more to do with the traffic load. Planning geometric intersection aims to reduce the possibility of collisions between motor vehicles, bicycles, pedestrians and other facilities that provide convenience, comfort and serenity to the users' way through the intersection.

1.2. Background of the study

Shashemene town is one of the growing town in Ethiopia. While the economic opportunities, created through expansion of trade and service sector in the town, have attracted many migrants at the time; the high rates of population growth led to traffic problem in the city. On the other hand, the daily movement of passengers and freight within the city is becoming more difficult and complex. It has been evident that there are traffic accidents and increase in mobility in the town (STTB, 2017).

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 occur in low and middle income countries, which have only 54% of the world’s registered vehicles.

Road traffic crashes are the major economic, social and health problems, especially in developing countries. For example, in Ethiopia, it’s found with one of the world's worst accident records when estimated by fatality rate of 25.3 per 100,000 population, as well as road traffic crashes cost about 0.8 to 0.9 % of its gross domestic product (WHO, 2015). 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).

Junctions are usually considered as the critical points within the urban road network and the evaluation of their performance will provides valuable understanding and useful indication about the performance of the network and their design is a complex process where factors related to operational efficiency such as capacity, delay and emissions are an important consideration along with safety features and geometrical constraints. A poorly designed intersection may contribute to traffic congestion, increase in vehicular emissions and road accidents (ERA, 2013).

Shashemene town has non-signalized, signalized and roundabout intersections. During peak hours, it is becoming common to see accident, congestion, long queues and delay at some of these intersections. Their capacity and level of service was not well studied and at the intersections, the geometric design is simply design without any scientific study (STTPO, 2015).

The trend of crash occurrences increased at Shashemene town road intersection from time to time that costs human life and economy of the country. Hence, the research evaluates the contribution of major geometric design characteristics that influence road junction traffic crashes in this town and finally, recommendations are forwarded to facilitate road safety. The result of this research will be useful for concerned body (the city administration) to do future innovations and improvements on the junctions those designing poorly.

1.3. Statement of Problem

In Ethiopia, road traffic crash is a cause of significant losses of human life and economic resources. According to the Addis Ababa Police Commission report on road traffic crashes in the city, the trend of crashes is not in a state of declining rather has continued to rise at an alarming rate over consecutive of five years from 2010/11 to 2014/15. The reported total crashes during these years were, 13,598 without property damages only (AAPC, 2015).

In addition, related to other town Shashmene had the highest number of road crashes. Data from the Shashemene town Police Commission (STPC) indicate, during the year 2013/14, 15 deaths, 38 heavy injuries and 59 light injuries were caused by crashes on the road. In the year 2012/13, 9 deaths, 29 heavy injuries and 54 light injuries occurred. In the year 2011/12, there were 12 deaths, 19 heavy injuries and 47 light injuries occurred. In the year 2010/11, 13 deaths, 18 heavy injuries and 31 simple injuries occurred. The number of crashes in the town is increasing from 62 in 2010/11 to 78 in 2011/12 then to 92 in 2012/13 and in the year 2013/14 is 112 without including property damage only (STPC, 2014).

While the economic opportunities, created through expansion of trade and service sector in the town, have attracted many migrants at the time; the high rates of population growth led to traffic problem in the city. On the other hand, the daily movement of passengers and freight within the city is becoming more difficult and complex. It has been evident that there are traffic accidents and increase in mobility in the town. It is common to observe traffic accident at some intersections and roundabouts occurring during peak hours. Efficiency of intersections contributes significantly towards the efficiency of urban road networks. Intersections constitute a very small part of the entire transportation network in the Shashemene town. But more than 50% of all motor vehicle accidents occur at intersections according to Shashemene Transport Authority.

Shashemene road intersection sections had a considerable share of fatal and non-fatal crashes in the 2011/12 -2013/14 year during peak hours, probably because much pedestrian crossing takes place in these sections. Overall, 18 % of fatalities and 24 % of non-fatal injury crashes occurred on intersection road sections. Their capacity and geometric design was not well studied and also in some intersections, there were no privilege for pedestrian crossing (STTPO, 2015).

Therefore, in order to manage these problems, it was essential to evaluate the contribution geometric design of road intersection in case of Shashemene town.

1.4. Research Objectives

1.4.1. General objective

The main objective this research is to evaluate the contribution of geometric design of the road intersections in alleviating traffic accident in Shashemene Town.

1.4.2. Specific objectives

The specific objectives of this research are to:

- To identify junctions with abnormally high number of road traffic accidents (black spots).
- To investigate the effects of road intersection geometric design elements on traffic accidents in the selected junctions.

1.5. Research Questions

This research answers the following questions;

1. Which junctions have abnormally high number of road traffic accidents (black spots)?

2. What is the effects of road intersection geometric design elements on traffic accidents in the selected junctions?

1.6. Significance of the Study

The investigation has revealed the contribution of geometric design of the road intersections in alleviating traffic accident. Thus, the significances of the research findings are envisaged to be:

- Road safety authorities, road designers and planners;
- Developing countries like Ethiopia and others with similar road condition and traffic characteristics; and
- Other researchers who are interested to study on related areas.

1.7. Scope and Limitation of the Study

1.7.1 Limitation of the Study

The objective of this thesis is to evaluate the contribution of geometric design of the road intersections in alleviating traffic accident in Shashemene Town. To do such kind of research problem like resources faced the researcher during the whole period. This is due to the university allotted very small money which was not sufficient to do the thesis as result the researcher used small sample size. The study used information of five years from 2013 to 2018 and also the study only focused on the road intersection .Another limitation of this study is that crashes data from different sources have lack of significant level of consistency and accuracy.

1.7.2. Scope of the Study

This particular research focuses on evaluation of the contribution of geometric design of the road intersections in alleviating traffic accident in Shashemene Town. The results, discussions and generalizations of the study will therefore be preliminarily for the study area. The availability and reliability of data employed in any study is very important which have instrumental impact on the precision of the results and conclusions. This study mainly used Shashemene town road traffic crash data and information of 5 years which is collected from the road traffic crash database of Shashemene Town Traffic Police Office.

2. LITERATURE REVIEW

2.1. General Overview

These days, the dramatic growth of motorization, population expansion and urbanization become the most critical hindrances of the safety aspects of road networks of the whole globe. Hence, this situation distracts the attention of transportation agencies, transport planners, engineers and the relevant stakeholders on doing their part for improving the safety issue in appropriate manner. Consequently, many researchers have been performed their research concerning the provision of safety improvements on the problematic road networks by preparing various models which integrates different accident causative explanatory independent variables or factors (WHO,2004).

A junction, or intersection, is the general area where two or more roads join. A disproportionate amount of traffic accident occurs at junctions, and thus, from a traffic safety aspect, junctions require attention and careful design. Good junction design should allow transition from one route to another or through movement on the main route and intersecting route with minimum delay and maximum safety (ERA Manual, 2013).

2.2. Definition of Road Traffic Crashes

Widely accepted definition of road traffic accidents is given by the Economic Commission for Europe (ECE) that is "road traffic accidents (RTAs) are those accidents that occur on a way or street open to public traffic; resulted in one or more persons being killed or injured, and at least one moving vehicle was involved." It implies that RTA is collisions between vehicles, vehicles and pedestrians, vehicles and animals and between vehicles and fixed obstacles (ECE, 2005).

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". Alternatively, road crash classified on the basis of the following conditions; the death of a person within 30 days of the crash; or 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.

A traffic accident is defined as a random event or an occurrence involving one or more motor vehicles in a traffic accident that results in property damage, injury, or death (Garber, 2010). Each year millions of humans are killed or seriously injured in motor vehicle accidents as reported by the Federal Highway Research Institute (FHWA, 2010). In addition, the causes of traffic accidents are usually complex and involve several factors. And a safer highway system is likely to result with the reduction or elimination of traffic accidents causing factors (WHO, 2007).

2.2.1. National Road traffic accident and safety

Ethiopia is one of those rising countries with low level of income accompanied by high rate of population growth and high number of traffic accident. As part of the developing world, Ethiopia is mostly an important country with low level of urbanization. The economic performance of different sectors of the national economy is not pleased. This low performance is due to a number of limitations such as low level of investment in different sectors of the national economy. On other hand there are less than 600,000 vehicles in Ethiopia but the traffic accident rate too much as compared to the volume of traffic (National Road Safety Coordination Office, 2006).

Overview of the Road Safety Activities in Ethiopia).According to the Ethiopian federal police commission report the estimated five year traffic accident shown below on figure 2.1.

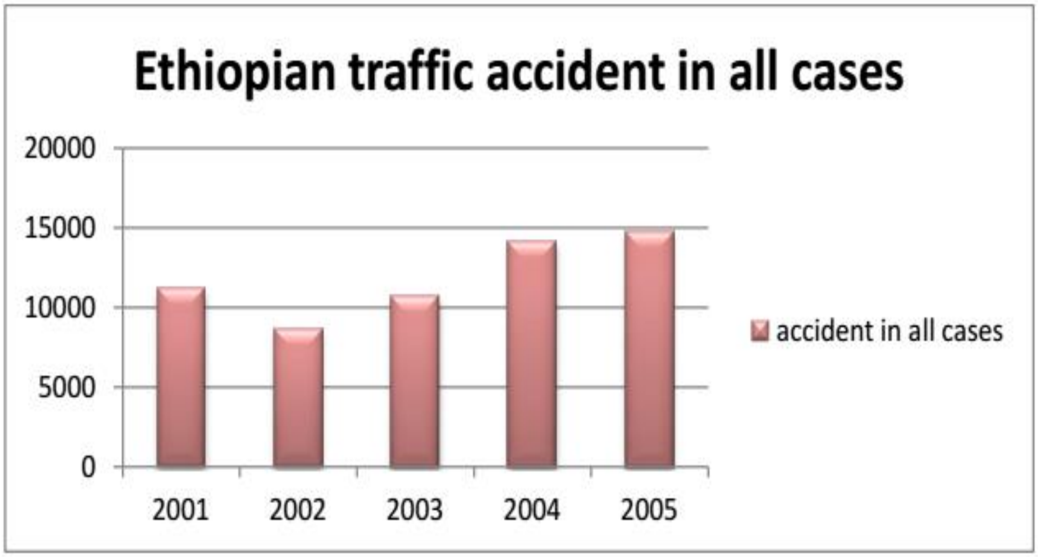

Figure 2.1: Ethiopian traffic accidents in all cases. (Source: Federal police commission annual report from (2001-2005))

This report shows that the traffic accident increased from time to time. As figure 2.2 indicated, accident number increased by more than 1000 within the past five years according to federal police report.

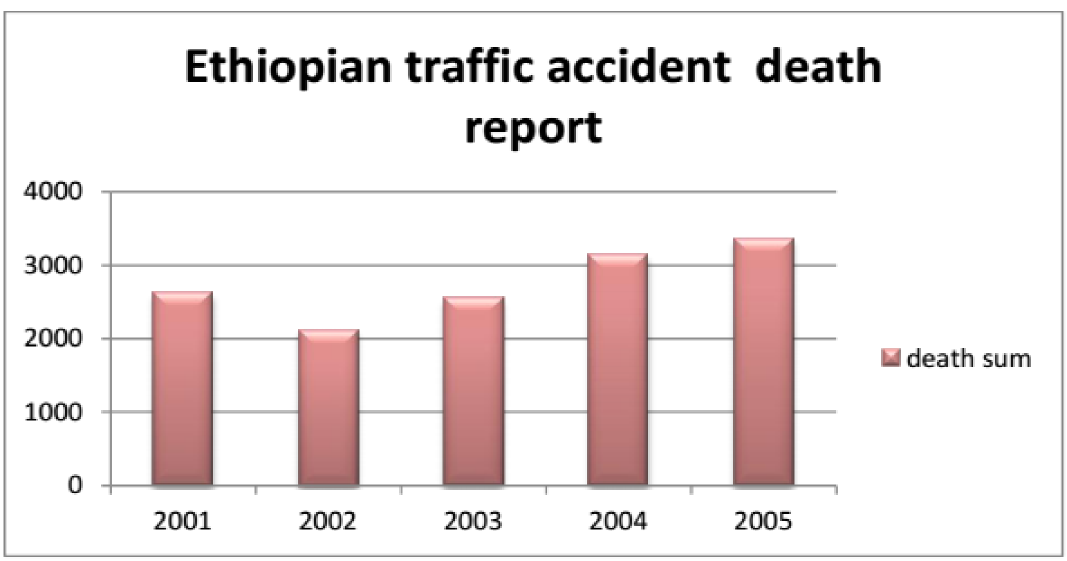

Figure 2.2: Ethiopian traffic accident death reports (Source: Federal police commission annual report from (2001-2005))

2.2.2. Black spot criteria identification, analysis and treatment

The term black spot is said to derive from the method that was originally used to identify hazardous sites. “Accident is pinpointed on a map using colored to represent the severed of each of this site and black is also represented for accident having caused of fatal and property damage. On other hand black spot is universally defined hazardous location and high accident location the location which identified by black spot is highly profitable action of accident reduction and cost effectiveness. In most developed countries, by taking simple countermeasures, accidents are reduced to 40 to 50% and in some areas to 80%. Human error is the major causal factor in road accidents. However, engineering measures and planning improvements, such as, traffic signals, pedestrians' crossings, junction layouts, and speed control humps can affect road user behavior in such a way that errors are less likely to happen, or when they do happen, the environment can make them less serious (TRL) (Oliver Michaud, 2004).

Evaluation of the Iowa DOT’s Safety Improvement Candidate List Process stated that the most frequently used methods to identify and prioritize candidate high crash locations include the Crash Frequency Method, Crash Rate Method, Rate-Quality-Control Method, and Bayesian Approach. Each of these methods is explained in the following sections.

Accident frequency method

This Method uses the number of accidents at a location to identify its safety performance. Locations with more than a predetermined number of accidents are classified as high-accident locations. But, the shortcoming is, the difference of road and traffic conditions were not taken into account (Layton, 1996; Mc Millen, 1999).

Accident rate method

This method uses accident numbers divided by vehicle number to provide rates such as accidents per million entering vehicles per spot location and accidents per million vehicle-Km for sections of highways. Locations with higher than a predetermined rate are classified as high accident locations. But, the shortcoming is that accident rate value is high in the section where traffic number value and accident number value are low. Another shortcoming is that accident rate value is low in the section where traffic number value and accident number value are high (Layton, 1996; Mc Millen, 1999).

Quality control methods

This is the method that is used for section of black spot segments and junction. The logic of this method is that a location is considered to be a black spot if its safety parameter shows higher values than the critical value. They assured control of the quality of the analysis by applying a statistical test. This is based on the assumption that occurrences of traffic accident follow the Poisson distribution. Several parameters can be used such as accident rate, accident frequency, and accident severity. For example, when using accident rate as a parameter, the locations with an accident rate that is greater or significantly greater than the average accident rate for the similar region are pointed out. In other words, the locations with accident rate greater than the critical rate are classified as a black spot location (Homburger, 1996; Layton, 1996; Traffic Institute, 2000).

Empirical Bayesian Method

The use of the Empirical Bayesian (EB) method for crash prediction seems to have become widely accepted as one that yields 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. The EB model assumes that the number of observed crashes on a road section or intersection is distributed according to the Negative Binomial distribution. Using a weight factor, the historical crash record and the expected crash frequency are combined to obtain a more accurate estimate of the safety performance at a location. The weight factor depends on the magnitude of the crash record and on the reliability of the crash prediction model (Hauer et al., 2002).

2.3. Contributing Factors of Road Accident

The causes of traffic accidents are usually complex and involve several factors. Previous works of many researchers proved that the main factors can be divided into four separate categories such as human factors, the vehicle, the roadway, and the environment. According to Austroads road accidents occurred as a result of one, or more than one of the following factors: -

A) Human factors;

B) Vehicle factors; and

C) Road and environmental factors.

Some factors may not appear to be directly related to road traffic injuries. Some causes are immediate, but they may be underpinned by medium-term and long-term structural causes. Identifying the risk factors that contribute to road traffic crashes is important in identifying interventions that can reduce the risks associated with those factors (Lisa, David et al. 2005).

2.4. Junction Safety

Junctions are important area types of road network, where a significant number of traffic crashes occur. This is because junctions are locations where two or more roads cross each other with high number of conflict points. The number of crashes occurring at junctions is relatively high considering that they are a small portion of the highway system (Haleem et al., 2010)

Many studies have been done to examine the effect of junctions. The purpose is to develop means to evaluate those effects and provide safety countermeasures or improvements. According to results of relative studies, the number of intersection legs affects the intersection's risk. More specifically, four-leg intersections experience more accidents than comparable three-leg intersections. This result has been quantified by Bauer and Harwood (1996).

In addition, the crash rate at intersections increases as the volume of traffic entering at intersections increases (Hall et al., 1992). This can be justified as more traffic conflicts will occur between vehicles or between vehicles and vulnerable users (bicyclists, pedestrians, etc.). Moreover, numerous studies have proved that the implementation of left-turn lanes, regardless if the intersections are signalized or not, leads to intersection-related crash reduction (Haleem and Abdel-Aty, (2010). Finally, it can be noted that the traffic control type at an intersection impacts on the intersection crash risk.

Specifically have observed that total crashes for signal-controlled intersections were fewer than other traffic control type intersections. This conclusion could be reversed only if the traffic volume is much lower in the unsignalized intersection compared to the signalized one concluded that conversion from no control to yield-controlled intersections leads to less traffic crashes (Haque et al., 2012; Bhat et al., 2013).

Intersection fatalities declined from 8,922 in 2001 to 8,657 in 2007. However, during this time period, intersection fatalities decreased mostly from 2005 until 2007 as shown in the figure 2.3.

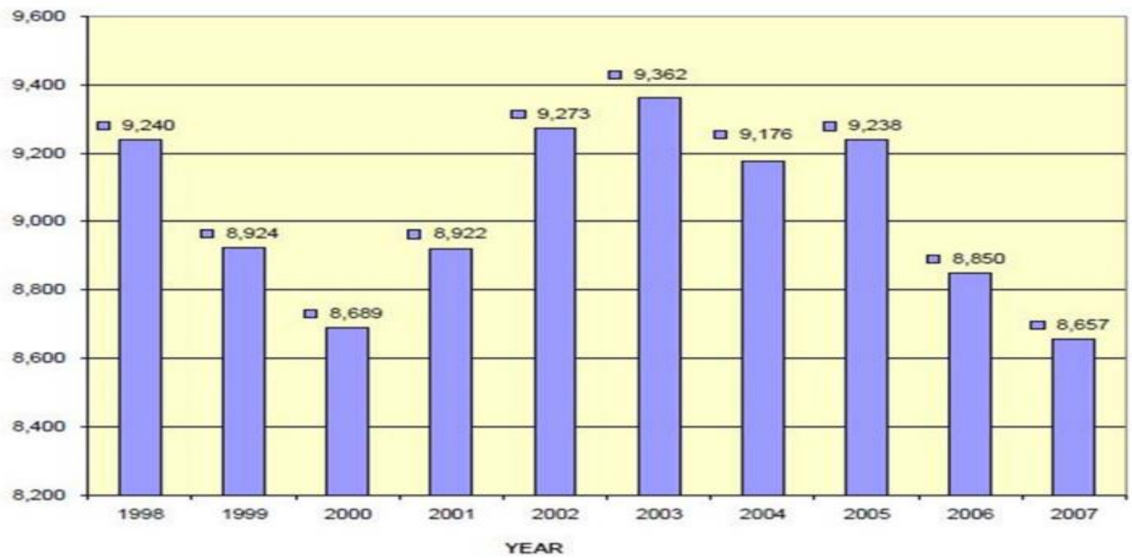

Figure 2.3: Intersection fatalities evolution from 1998 since 2007 (Source: Coakley and Stollof, 2009)

In 2007, approximately 2.4 million intersection-related crashes occurred, representing approximately 40 percent of total reported crashes. This caused an annual cost to society for intersection crashes of approximately $83 billion (Coakley and Stollof, 2009).

As for intersections' control type, intersections are controlled by traffic signals, stop signs or yield signs but some have neither. Figure 2.4 shows the distribution of intersection-related crashes over traffic control devices. In an estimated 787,236 intersection-related crashes, about 52.5 percent of the vehicles were controlled by at least one traffic signal and 31.3 percent by at least one stop sign. About 15.9 percent of vehicles were controlled with no traffic control device (National Highway Traffic Safety Administration, 2008).

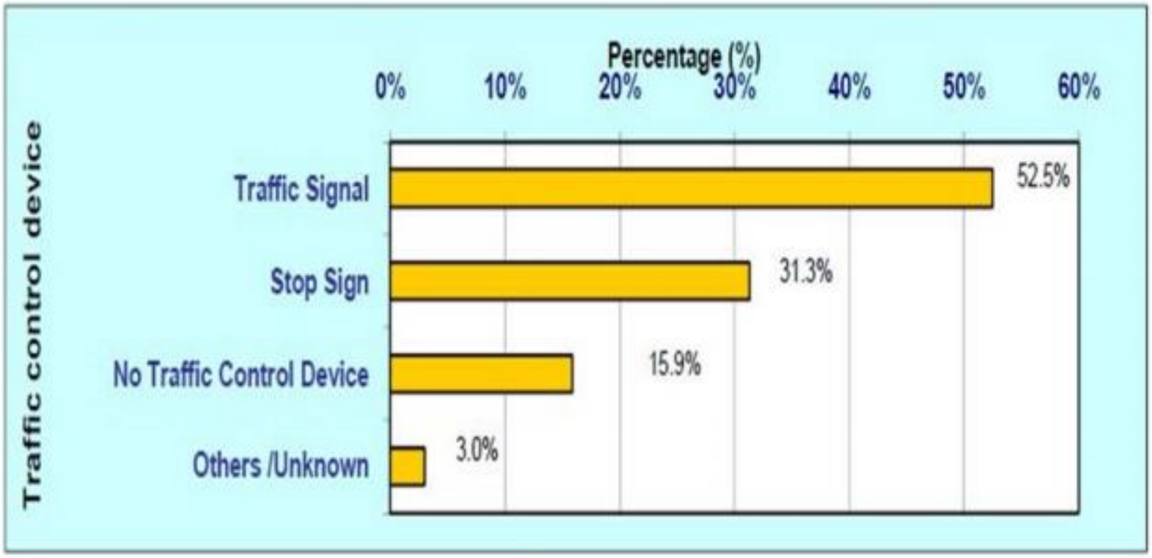

Figure 2.4: Distribution of intersection-related crashes in different traffic control types

(Source: National Highway Traffic Safety Administration, 2008)

As far as the atmospheric conditions are concerned, most of the intersection-related crashes (78.6%) occurred in clear weather, followed by cloudy weather (16%) and rain (6.2%) as presented in figure 2.5.

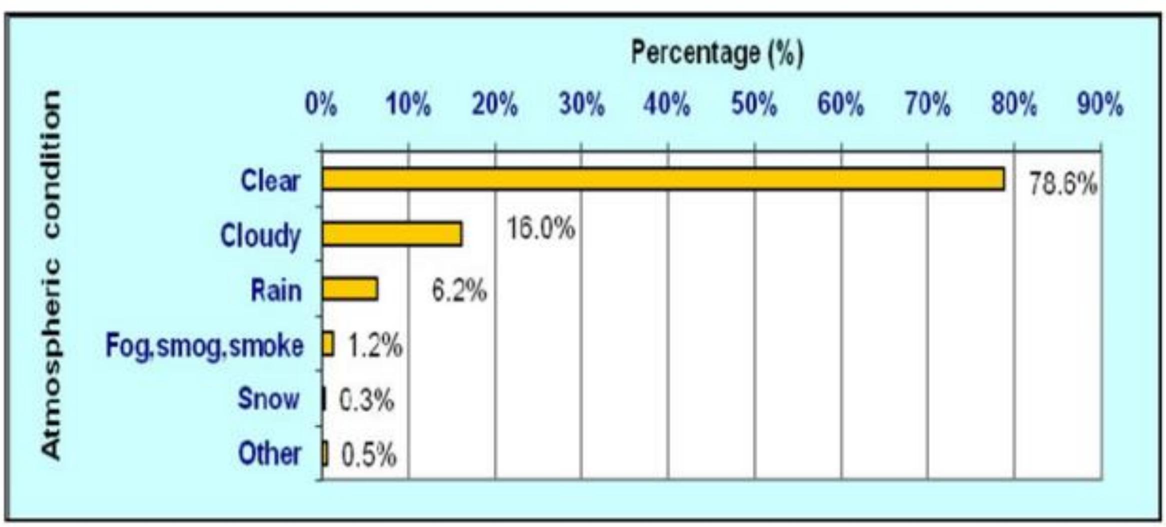

Figure 2.5: Distribution of intersection-related crashes in different atmospheric conditions (Source: National Highway Traffic Safety Administration, 2008)

According to Federal Highway Administration and Fatality Analysis Reporting System, intersection-related crashes are declining. Though, vehicle registrations have increased by 250% since 1960 and are still increasing. Thus, as long as vehicles continue to increase, the number of traffic conflicts will increase too. Consequently, the proper countermeasures have to be implemented in order to reduce significantly the intersection-related crashes as they decreased only by 6.3% in 9 years. The factors that influence the number of intersection crashes deal with the geometric intersection design and generally the traffic management in the intersection area.

2.4.1. Traffic Crashes at Junctions

This section was decided to be included in the literature review because the study area in those research papers contains mixed road environment (urban & rural areas). In addition, junction crashes include not only intersection crashes, but also intersection related crashes and interchange crashes (railroad crossings, ramps, etc.) as well.

In the research center of Finland, Kulmala in 1994 explored the effects of road measures implemented at 623 main junctions for the years 1984-1986. The number and type of accidents were studied at each junction both before and after the implementation of the measure. The effects of the measure were determined by comparing the observed number of accidents after the measure with the number that would have been expected to occur at the junction if the measure had not been implemented. The expected number of accidents was calculated based on accident prediction model. Outcomes show that road lighting, STOP signs, signal control, and lower speed limits were found to decrease the number of accidents. Additionally, road widening and additional lanes for turning vehicles did not seem to affect junction safety.

Moreover, Mountain et al., (1996) developed a method for predicting expected accidents on main roads with minor junctions where traffic counts on the minor approaches are unknown. Data used include 3800 km of highway in the U.K. with more than 5000 minor junctions. Generalized linear modelling was used to develop regression estimates and an empirical Bayes procedure was used to improve these estimates.

Accident prediction models have been developed for six types of highway. The results lead to the conclusion that accidents on highway links are not proportional to exposure (traffic flow and link length) as is commonly assumed. In addition, the presence of minor junctions has an important influence on link accident frequencies.

Furthermore, Mountain et al., (1998) developed junction accident models in order to predict both aggregate accident totals and accidents disaggregated by severity, lighting and road surface condition. Of particular concern is the effect of accident trends on model predictions over time. Generalized linear modelling was used, which allowed for estimation of accident risk probability over time. Data included 501 major junctions in U.K. for time periods between 1980 and 1994. Findings support that accident risk was shown to be declining annually by 6%, with no significant difference in the value of trend between accident types. Also, the factors which affected the proportions of accidents of various types included the method of junction control, speed limit and traffic flow.

2.4.2. Intersection – Related Crashes at Signalized Intersections

As most of the signalized intersections are located in the urban environment which includes all multimodal movements, the distinction between signalized and unsignalized is necessary. One of the first studies in this area was executed by Chin et al., (2003). The authors developed a random effect negative binomial model (RENB) to identify factors that affect intersection safety. The model examined the relationship between accident frequencies and the geometric, traffic and regulatory control characteristics of 52 four-legged signalized intersections from 1992-1999. Results depicted that the total approach volumes, the number of phases per cycle, the uncontrolled left-turn lane and the presence of a surveillance camera are among the variables that significantly affected traffic crashes.

Then, Abdel-Aty et al., (2005) examined the various parameters that affect crash severity levels. Data from the Florida Department of Transportation (FDOT), the Department of Highway Safety and Motor Vehicles (DHSMV) and counties' databases were combined for the analysis, from 832 signalized intersections during 2000-2001. Ordered probit modeling and tree-based regression methodology have been adopted in this study. Results showed that having a divided minor roadway or a higher speed limit on the minor roadway decreased injury levels while crashes involving a vulnerable road user (pedestrian/bicyclist) and left turn crashes had the highest probability of more severe crashes.

Moreover, a study was conducted in the University of Singapore by Helai et al., (2008) in order to investigate the key parameters that affect the severity of driver injury and vehicle damage in traffic crashes at signalized intersections for the time period 2003- 2005. A Bayesian hierarchical binomial logistic model was used in order to account for severity correlations between driver-vehicle units involved in the same crashes that are usually ignored. The results indicate that crashes occurring in peak time, in good street lighting condition and those involving pedestrian injuries tend to be less severe. However, crashes that occur during night, at T/Y type intersections, on right-most lane, and in intersections where red light cameras are installed tend to be more severe. Additionally, heavy vehicles are more likely to be involved in less severe injuries, while two-wheel vehicles, young or aged drivers and involvement of offending party are more likely to result in severe injuries.

Finally, Guo et al., (2010) performed a study in order to evaluate safety risk factors from 170 signalized intersections in the state of Florida in close proximity to corridors. Poisson and Negative Binomial Bayesian models were developed to model the crash data. The results indicated that Poisson models provide the best fitting. From the risk factors, the traffic conditions by turning movement on the major and minor roads, the intersection size and the traffic signal coordination were found to have the most significant impact on intersection safety.

2.4.3. Intersection – Related Crashes at Unsignalized Intersections

One of the first studies in this area was executed by Thompson in 1978. The author used an uncertainty model as a measure of safety value in order to obtain quantifiable results. The method was used to compare differences in the priority rules in New Zealand, before and after the Traffic Regulations alteration in 1977. Thus, it can be predicted if a change of the regulations will enhance traffic safety. The analysis made showed that the new priority system is inferior to the previous one. Suggestions for the reduction of uncertainty include simplification of priority rules at intersections, recoding the Road Code and implementation of control signing in uncontrolled intersections.

In addition, research was conducted by Polus (1985) about the effect of traffic signage on accident rates and if an increase in the level of traffic control is beneficial in terms of safety. The study is based on a ’’before’’ and ’’after’’ evaluation of accident rates at 160 unsignalized intersections in Israel's 3 major cities, where the level of control was changed. The results illustrate that any increase in the level of control tended to cause more vehicle accidents and fewer pedestrian accidents. Thus, increasing the control level at unsignalized intersections is not a sure remedy to hazardous urban intersections.

In addition, Frith et al., (1987) conducted a research at unsignalized intersections where give way signs have been replaced with stop signs. Data were collected for New Zealand during 1972-1981. The method of analysis used a binomial model and the variable of interest is the fractional change in accident rate before and after the abovementioned changes. The results estimate a favorable effect on accident rates where give way signs have been replaced with stop signs. However, the sample size is small and the results not statistically significant. Thus, it can be concluded that any important advantage from give way signs is unlikely.

Moreover, Golias in 1992 explored the effect of traffic flows on crashes at unsignalized four-arm junctions. 43 junctions with other than flow parameters that are similar with each other were examined for 5 years in the city of Athens, Greece. In this study a new exposure index is proposed consisting of an expression of the flows of the junction's interacting traffic streams. The regression of this exposure index on the expected number of accidents per year at junctions, yields a satisfactory correlation coefficient. To conclude, the most important factor affecting crash potential in an urban junction is a function of the interacting traffic stream flows.

Haleem et al., in 2010, examined the effect of updating the parameters of the covariates in the fitted Negative Binomial (NB) and Bayesian models in order to more accurately predict crash frequencies at 433 unsignalized intersections in Orange County, Florida. Both models yielded favorable results. However, in terms of standard errors as a measure of uncertainty, Bayesian models performed better. Finally, as for the model structure, the log-gamma likelihood function for updating parameter estimates resulted in the least standard error values.

Additionally, Haleem et al., in 2010, explored a multiple approach analysis of crash injury severity at 2,043 unsignalized intersections in six counties in the state of Florida from 2003 until 2006. The multiple approaches dealt with an ordered probit model, a binary probit model and a nested logit model. Several important factors affecting crash severity were identified: traffic volume on the major approach, the number of through lanes on the minor approach, geometric factors (upstream/downstream distance to the nearest signalized intersection, left/right shoulder width, number of left turn movements on the minor approach, number of right/left turn lanes on the major approach), driver factors (young/very young drivers were related with the least fatal probability compared to other age groups). Finally, countermeasures that may reduce injury severity include: safety campaigns for speeding enforcement, 90-degree intersection design and marking stop lines at unsignalized intersections.

2.5. Intersection Design Principles

According to Urban Street Design Guide 2010 Intersection design is an important task. They need to be designed carefully after considering a number of factors. Some of the main design principles are mentioned below-

1. Uniformity and Simplicity– Intersections must be designed and operated for simplicity and uniformity. The design must keep the capabilities and limitation of drivers, pedestrians and vehicles using intersection. It should be based on a knowledge of what a driver will do rather than what he should do. All the intersection movements should be obvious to the drivers, even if he is a stranger to the area thus maintaining uniformity.

2. Minimize Conflict Points- any location having merging, diverging or crossing maneuvers of two vehicles is a potential conflict point. The main objective of the intersection design is to minimize the number and severity of potential conflicts between cars, buses, trucks, bicycles and pedestrians and whenever possible, these should be separated. This can be done by:

- Space separation- by access control islands through channelizing
- Time separation- by traffic signals on waiting lanes

3. Safety- The safety of a particular design can best be assessed by studying the frequency with which types of accidents occur at a particular type of intersection and its correlation with volume and type of traffic.

- Provision for vulnerable road users: Pedestrians (including especially abled) often need to cross a road in two separate maneuvers. Properly sighted traffic islands have the added advantage that they can be used as refuges by these vulnerable road users especially at intersections on wide roads.

- Provision of good safe locations for the installation of traffic control devices: The possible use of traffic control devices should always be considered; for instance, the design of an intersection to be eventually controlled by signals may differ from one requiring channelization and signs.

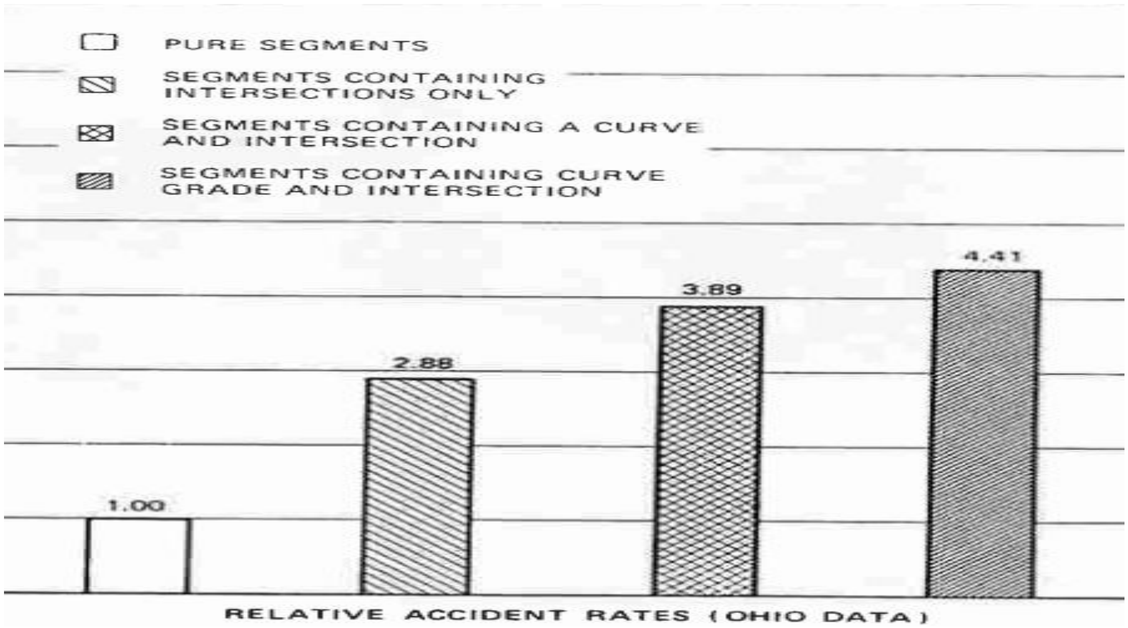

Figure 2.6: Effects of Geometry on intersection accident rate (Sources: NCHRPR, 1985)

4. Alignment and Profile- The intersecting roads shall meet at or nearly at right angle. However, angles above 60° do not warrant realignment. Intersection on sharp curves should be avoided because the super elevation and widening of pavement complicates the design. Grades in excess of 3 percent should, therefore, be avoided on intersections while those in excess of 6 percent should not be allowed.

5. Encourage low vehicle speeds on the approaches to right-angle intersections- Minor road vehicles intending to cut across major road traffic should approach the intersection slowly so that they can easily stop and give way to through traffic. This can achieved by funneling by traffic islands, chicanes etc.

6. Favor high priority traffic movements– The operating characteristics and layout of an intersection should deliberately favor the intended high-priority movements. This principle, principle generally improves intersection capacity as well as safety.

7. Discourage undesirable traffic movements-Traffic islands and corner radii can be used to discourage motorists from taking undesirable travel paths, and encourage them to take defined ones.

8. Provide reference markers for road users– Drivers should be provided with appropriate references at intersections, e.g. Stop/Give Way lines which indicate where, say, the lead vehicle in a minor road traffic stream should stop until a suitable entry gap appears in the main road stream.

9. Provide advance warning for change– Drivers should never be suddenly faced with unexpected. Advance signing that warns of intersection ahead should be provided on minor roads leading to controlled intersections, on all roads where visibility is restricted prior to an intersection, and on high speed roads where it is desirable to cause vehicles to slow.

10.Illuminate intersections wherever possible– Priority for lighting a night should be given to intersections with heavy pedestrian flows and/or with heavy vehicular flows, at roundabouts and where raised channelization islands intrude on what might be considered the 'natural' vehicle pathways , and where an interesting road already has lighting.

2.6. Intersection Design Elements

In general, there are different design elements for road junction. These design elements are described as follows based on UIDG 2004:

2.6.1. Intersection Sight Distance

The provision of appropriate intersection sight distance (ISD) reduces the potential for conflicts at intersections. As a motorist approaches an intersection, the right of way is established by the traffic control devices or by state traffic laws.

The operator of a vehicle approaching an intersection should have an unobstructed view of the entire intersection and an adequate view of the intersecting highway to permit control of the vehicle to avoid a collision. When designing an intersection, the following factors should be considered:

- Adequate sight distance should be provided along both highway approaches to allow drivers and other road users to anticipate and avoid potential collisions.

- Gradients of intersecting roadways should be as flat as practical on sections that are to be used for storage of stopped vehicles.
- Combination of vertical and horizontal curvature should allow adequate sight distance of the intersection.
- Traffic lanes should be clearly visible at all times.
- Lane and crosswalk markings and signs should be clearly visible and understandable from a desired distance.
- Intersections should be evaluated for the effects of barriers, rails, retaining walls, land scaping, curbside parking, and other vertical elements on sight distance.

Identification of Sight Obstructions within Sight Triangles

The profiles of the intersecting roadways should be designed to provide the recommended sight distances for drivers on the intersection approaches. Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered, if practical. Such objects may include: buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmoved grass, tall crops, walls, fences, and the terrain itself. Particular attention should be given to the evaluation of clear sight triangles at interchange ramp/crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 1,080 mm [3.5 ft] above the roadway surface and that the object to be seen is 1,080 mm [3.5 ft] above the surface of the intersecting road.

This object height is based on a vehicle height of 1,330 mm [4.35 ft], which represents the 15th percentile of vehicle heights in the current passenger car population less an allowance of 250 mm [10 in]. This allowance represents a near-maximum value for the portion of a passenger car height that needs to be visible for another driver to recognize it as the object. The use of an object height equal to the driver eye height makes intersection sight distances reciprocal (i.e., if one driver can see another vehicle, then the driver of that vehicle can also see the first vehicle).

Where the sight-distance value used in design is based on a single-unit or combination truck as the design vehicle, it is also appropriate to use the eye height of a truck driver in checking sight obstructions. The recommended value of a truck driver's eye height is 2,330 mm [7.6 ft] above the roadway surface.

Table 2.1: Minimum Distances for sight triangle: No control (Source: Garber and Hoel, 2002)

Minimum Distances for sight triangle :No control	
Speed(mph)	**Distance (ft)**
10	45
15	70
20	90
25	110
30	130
35	155
40	180
50	220
60	260
70	310

Adjustment for Skewed Intersections

HCM 2010 states that when two roadways intersect at an angle less than 60 deg and realignment to increase the angle of intersection is not justified, some of the factors for determination of intersection sight distance may need adjustment. Realignment may not be justified in cases involving intersections with low crossroad traffic volumes and no apparent safety concerns. However, if traffic volumes are expected to increase in the near term, or if the intersection may be signalized, realignment should be considered.

At an oblique-angle intersection, the length of the travel paths for some turning and crossing maneuvers will be increased. The actual path length for a turning or crossing maneuver can be computed by dividing the total widths of the lanes (plus the median width, where appropriate) to be crossed by the sine of the intersection angle. If the actual path length exceeds the total widths of the lanes to be crossed by 12 ft [3.7 m] or more, then an appropriate number of additional lanes should be used in applying the adjustment for the number of lanes to be crossed.

In the obtuse-angle quadrant of an oblique-angle intersection, the angle between the approach leg and the sight line is often so small that drivers can look across the full sight triangle with only a small head movement (see Figure 3-3). However, in the acute-angle quadrant, drivers are required to turn their heads considerably to see across the entire clear sight triangle. For this reason, it is recommended that the sight distance criteria for Case A not be applied to oblique-angle intersections and that sight distances at least equal to those for Case B be provided, whenever practical.

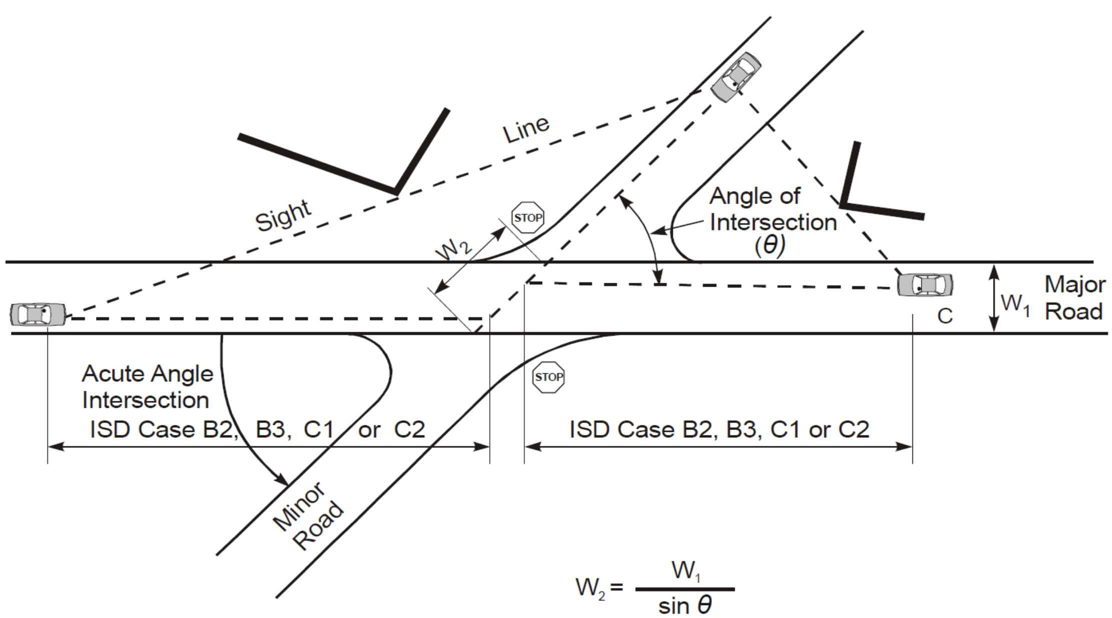

Figure 2.7: Sight triangle at skewed intersection (Sources: UIDG, 2004)

2.6.2. Horizontal Alignment

There are a number of general considerations that are important in attaining safe, smooth flowing, and aesthetically pleasing facilities. These are describe below based on FWHA 2009

Horizontal Curvature at Intersections

Intersections on sharp horizontal curves should be avoided. Super elevation and the widening of pavement on those curves complicate the design of the intersection and may affect sight distance. In addition, the curves should be evaluated with respect to the requirements imposed by the design speed on the respective roadways. The greatest benefit is obtained when the design speed used for the curve approaches that of the major roadway.

The placement of an intersection at the beginning of a horizontal curve should be avoided. Realignment as shown in Figure below typically provides better visibility and guidance onto the major roadway.

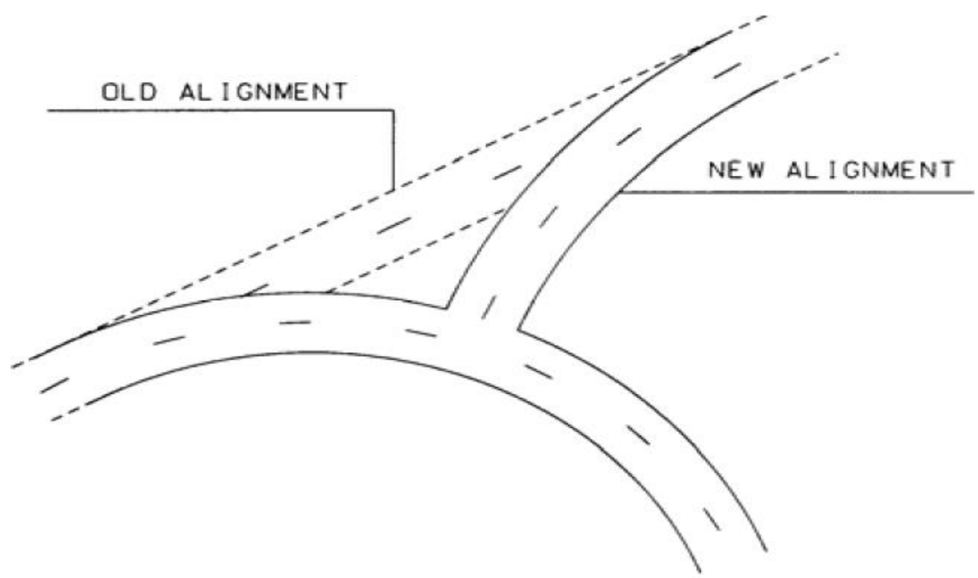

Figure 2.8: Realignment of tangent road way at intersection (Sources: UIDG, 2004)

Super elevation on Low-Speed Facilities (45 mph [72 km/h] or less)

Although super elevation is advantageous for traffic operations, various factors often combine to make its use impractical in many developed areas. These factors include the following:

- wide pavement areas,

- surface drainage considerations,
- frequency of cross streets and driveways, and
- The need to meet the grade of adjacent property.

For this reason, horizontal curves on low-speed streets in urban areas are frequently designed without super elevation, and lateral acceleration is provided solely with side friction.

Super elevation for Turning Roadways at Intersections

In intersection design, turning roadways frequently have curves with relatively sharp radii. When speed is not affected by the presence of other vehicles, drivers on turning roadways anticipate the sharp curves and accept higher side friction than they would accept on open highway curves of the same radii. This behavior appears to stem from their desire to maintain their speed through the curves, although some speed reduction does occur. When other traffic is present, drivers will travel more slowly on turning roadways than on open highway curves of the same radii because they must diverge from and merge with through traffic. Therefore, in designing for safe operation, periods of light traffic volumes and corresponding speeds will generally influence the design. Designs that encourage lower travel speeds will better accommodate pedestrian traffic.

Turning Radius

The design of the corner radius affects how drivers traverse the intersection, including the speeds chosen as well as the path the driver follows. The corner also affects other features such as the provision of islands.

Design Vehicle

The choice of design vehicle greatly influences the selection of an appropriate turning radius or turning roadway width. Consideration should be given to occasional vehicles (i.e., moving vans) as well as the predominant vehicle (i.e., passenger car) in developing an intersection design.

Radius

The relationship between lane width, radius, and intersection angle affects the path vehicles take when turning at an intersection. The selection of the radius at an intersection affects turning-vehicle speeds and lane positioning. Consideration of the type of vehicle used in the design and acceptable lane positioning should be made based on the types of main and cross roadways. Curb radii should be selected to accommodate desired design vehicles (but not necessarily to turn into first lane on a multilane roadway). For intersections with minor roadways it is frequently judged acceptable for infrequent large trucks to occupy both lanes on the minor roadway in the course of completing the turning maneuver. This type of design would be inappropriate for a major crossroad, of course, or where trucks are frequent users of the minor roadway.

Turning Radius Effects

Benefits of Larger Radii

- Accommodates larger vehicles without encroachment
- Permits higher turning-vehicle speeds in free-flow situations
- May allow the presence of islands for traffic control devices and pedestrian refuge areas

Benefits of Smaller Radii

- Reduced vehicle crossing time
- Reduced pedestrian crossing time leads to reduced vehicular delay at signalized intersections.
- Reduced turning speeds can benefit pedestrians
- Reduced pavement area

Corner radii at intersections on arterial streets should satisfy the requirements of the drivers using them to the extent practical and in consideration of the amount of right-of-way available, the angle of the intersection, numbers of and space for pedestrians, width and number of lanes on the intersecting streets, and amounts of speed reductions. The following summary is offered as a guide UIDG 2004:

- Radii of 15 ft [4.5 m] to 25 ft [7.5 m] are adequate for passenger vehicles. These radii may be provided at minor cross streets where there is little occasion for trucks to turn or at major intersections where there are parking lanes. Where the street has sufficient capacity to retain the curb lane as a parking lane for the foreseeable future, parking should be restricted for appropriate distances from the crossing.
- Radii of 25 ft [7.5 m] or more at minor cross streets should be provided on new construction and on reconstruction where space permits.
- Radii of 30 ft [9 m] or more at major cross streets should be provided where feasible so that an occasional truck can turn without too much encroachment.
- Radii of 40 ft [12 m] or more, and preferably three-centered compound curves or simple curves with tapers to fit the paths of appropriate design vehicles, should be provided where large truck combinations and buses turn frequently. Larger radii are also desirable where speed reductions would cause problems.
- Radii dimensions should be coordinated with crosswalk distances or special designs to make crosswalks safe for all pedestrians.

For arterial-arterial urban intersections, turning radii of 75 ft [23 m] or more are desirable if frequent use is anticipated by the WB-62 [WB-19] design vehicle.

The following curb radii are generally recommended:

- ✓ 15 ft [4.6 m] to 25 ft [7.6 m] to accommodate passenger cars and
- ✓ 40 ft [12 m] to 50 ft [15 m] to accommodate heavy volumes of trucks or buses.

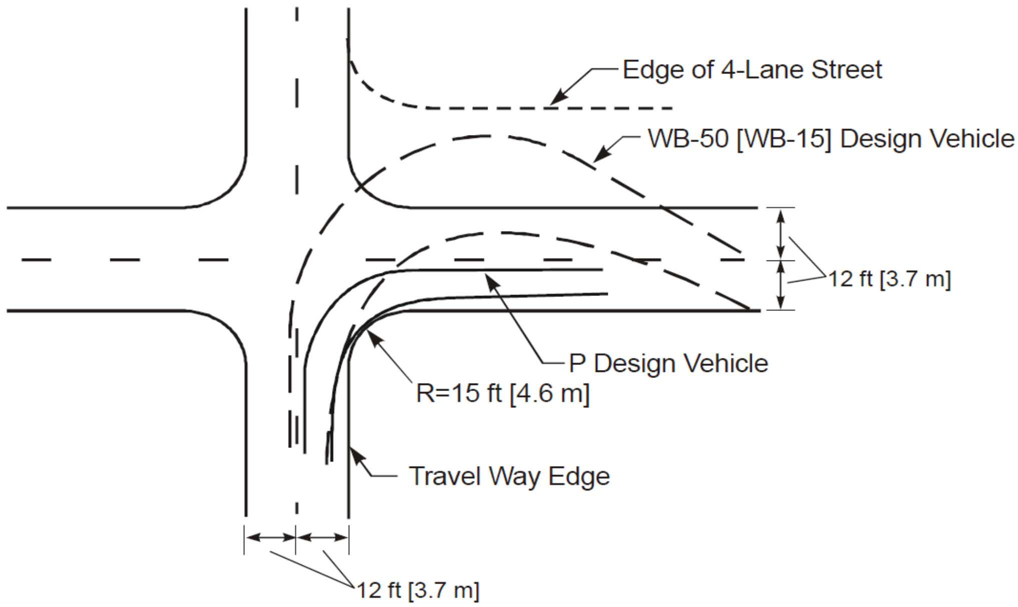

Figure 2.9: Effect of Curb Return Radius on Right Turning Paths (R=15 ft [4.6 m] and R=40 ft [12.2 m] (Sources: FWHA, 2009)

Effects on Pedestrians

The provision of larger radii affects the path of pedestrians at the intersection. Larger radii can increase the distance pedestrians are exposed to traffic and move crosswalks and curb ramps away from the intersection. The selection of a radius should be weighed in light of these effects, and may result in a compromise between pedestrian needs and vehicle needs.

Right of Way

Right of way and corner setback varies with curb radii but is also affected by border width and sight distance. Right of way should be obtained that provides an acceptable border width through the curb radius and permits attaining required intersection sight distance and stopping sight distance on the turning roadways.

Minimum Curb Radius

The minimum curb radius used should be 5 ft [1.5 m] to enable the effective use of street sweepers.

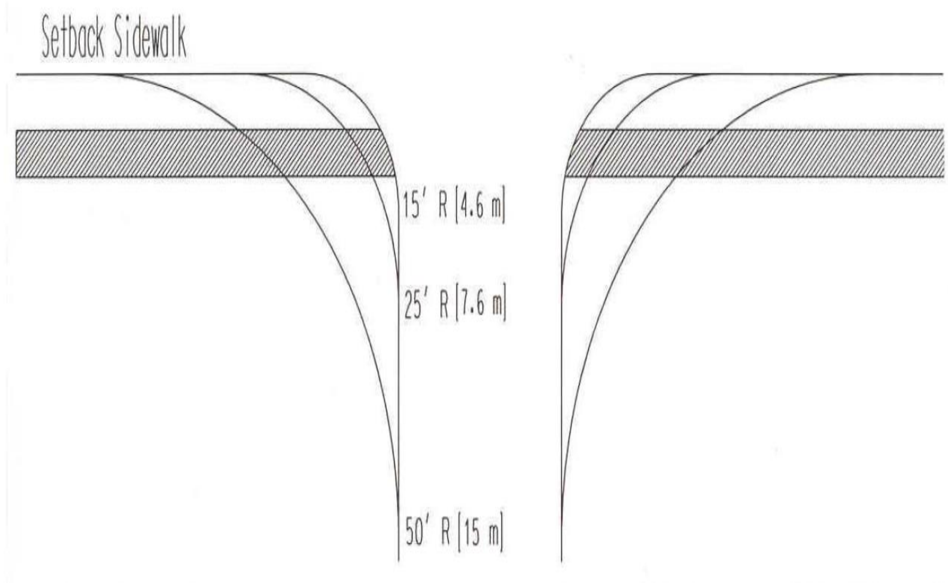

Figure 2.10: Added Crosswalk Distance with Increased Radius (Sources: HCM, 2010)

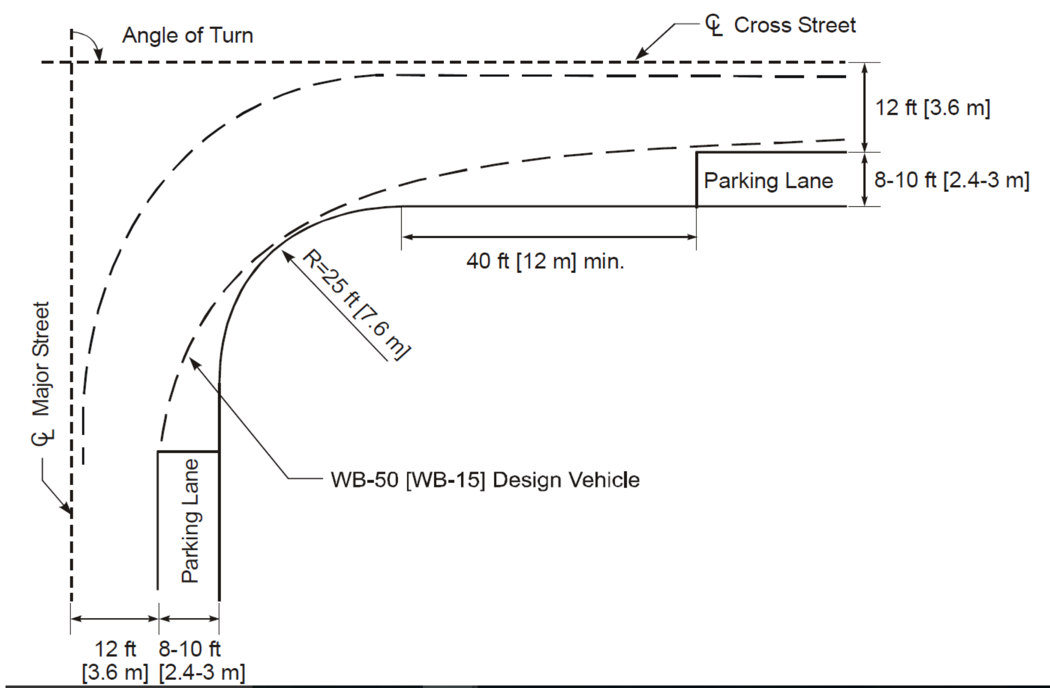

Figure 2.11: Effective Radius with Parking Restriction (Sources: USDG, 2013)

2.6.3. Angle of Intersection

For safety and economy, intersecting roads should generally meet at or nearly at right angles.

General Considerations

The ideal angle of intersection is 90-deg between two roadways. If a 90-deg angle cannot be obtained, the AASHTO 2001 recommends an angle of intersection of no less than 60 deg. Skewed intersections of less than 60-deg should be evaluated for intersection sight distance using adjusted turning paths and criteria.

Older drivers have significantly more problems at skewed intersections than average drivers. Therefore, the Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians Handbook recommend an angle of intersection of no less than 75 deg. If the angle must be less than 75-deg, it recommends that right turn on red be prohibited.

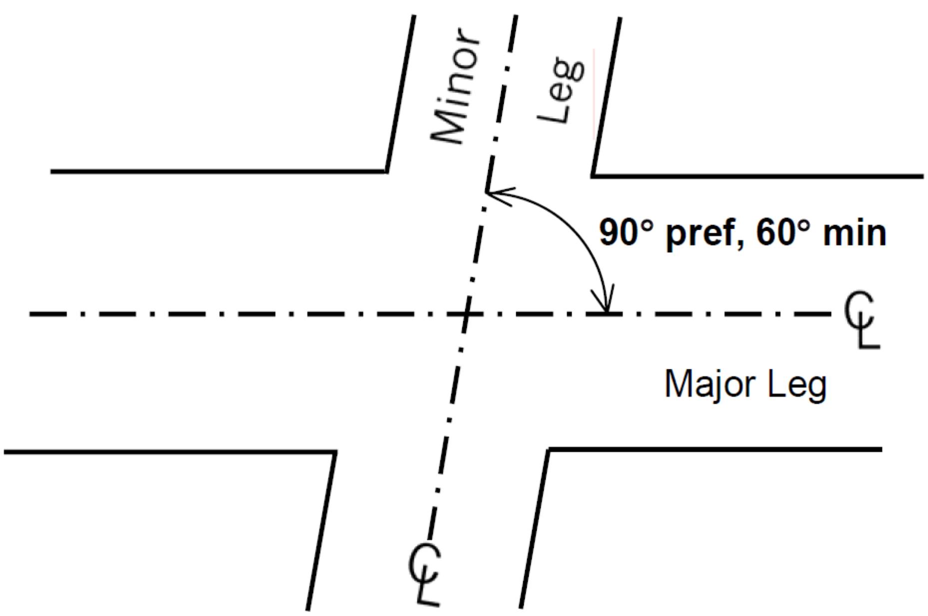

Figure 2.12: Example of Angle of Intersection (Minor Leg Skewed to the Right. (Sources: AASHTO, 2001)

Realigning Intersections

According to AASHTO 2001 when existing intersecting roadways do not meet the desired specifications, redesigning the intersection is recommended. Roads intersecting at acute angles need extensive turning roadway areas and tend to limit visibility, particularly for drivers of trucks. When a truck is on an obtuse angle, the driver has blind areas on the right side of the vehicle. Acute angle intersections increase exposure time for the vehicles crossing the main traffic flow. Realigning roadways as shown in Figure below has been shown to be beneficial**.** The greatest benefit is obtained when the curves used to realign the roads allow operating speeds nearly equivalent to the roadway approach speeds.3 A design exception may be required if curvature and sight distance requirements are not met. It should be noted that options A and B may require a considerable amount of new ROW, option C may present problems if there is a significant through movement on the realigned roadway due to the potential for large left-turn queues on the major roadway, and the separation distance between the intersections in options C and D needs to be sufficient to allow for adequate storage. The design of the profile and alignment should be carefully considered if there is a potential for the signalization of the intersection (or a change in which roadway has a stop condition), since vehicles would enter the intersection at speed rather than from a stop condition.

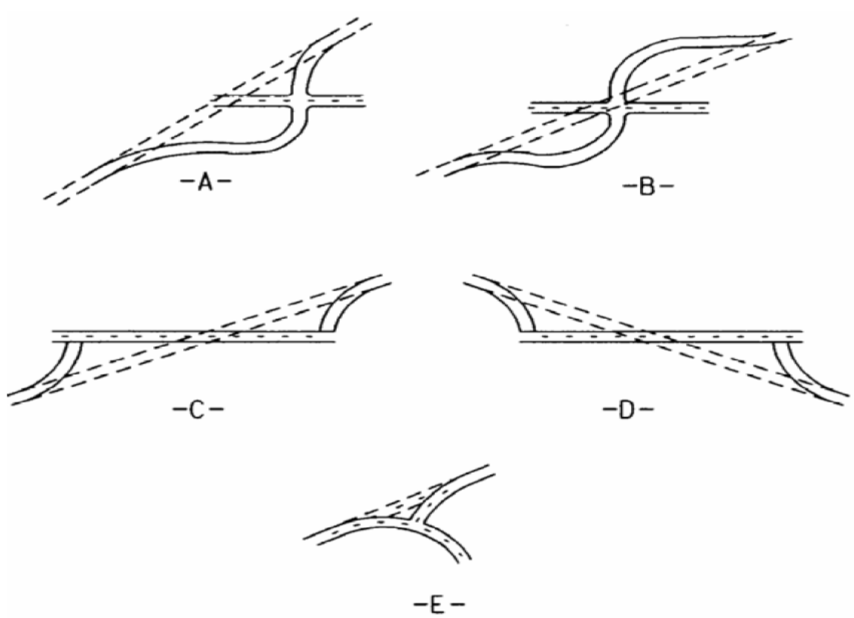

Figure 2.13: Realignment Options at Intersections (AASHTO, 2001)

2.6.4. Vertical Alignment

AASHTO recommend that at intersection, the combination of grade lines of the intersecting roadways should provide a seamless a transition as possible. Substantial grade changes should be avoided at intersections, but that is not always possible. Adequate sight distance along all intersecting roads should be provided. Those sections of roads that are used for storage of stopped vehicles, otherwise known as storage platforms, should have a gradient that is as flat as possible. Where pedestrians are expected, intersections should be "tabled" as much as possible to ensure the cross slope in crosswalks is less than 2 percent.

The alignment and grades are subject to greater constraints at or near intersections than on the open road. At or near intersections, the combination of horizontal and vertical alignment should provide traffic lanes that are clearly visible to drivers at all times, clearly understandable for any desired direction of travel, free from the potential for conflicts to appear suddenly, and consistent in design with the portions of the highway just traveled. The combination of vertical and horizontal curvature should allow adequate sight distance at an intersection. A sharp horizontal curve following a crest vertical curve is undesirable, particularly on intersection approaches (AASHTO, 2001).

Grades

According to AASHTO the intersecting gradients are 3 percent or less, stopping and accelerating distance do not differ substantially from those for level grades. However, if grades are greater than 3 percent, changes in several design elements may have to be made because of the effects of the grades on vehicle performance. Because of these effects and the complexities of intersecting two roadways when one or both are on substantial grades, grades of 3 percent or more should generally be avoided at intersections. If existing conditions require grades above 3 percent, grades up to 6 percent may be retained, although adjustments for the effects of the grades should be made in the geometric design elements (primarily sight distance) of the roadways.

2.7. 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 modelling 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.

2.8. Lists of Some Reviewed Literatures

Some list of reviewed literatures used in the study which have been done in national and international levels is presented in Table below.

Table 2.2: Summary of Some Reviewed Literatures

No	Author	Objective	Factors incorporated in the study
1	Dawit Oluma (2016)	Road Traffic Accident and Safety Evaluation (Addis Ababa)	Black spot criteria identification, analysis and treatment
2	Alemayehu Feyissa (2019)	Effect of road geometric design elements on road traffic crash frequency (Addis Ababa)	Road Traffic Crashes Prediction Models
3	Kiran et al. (2017)	A review of road crash prediction models for developed countries	Traffic flow, lane width, number of accesses, speed and road connectors.
4	Alemu (2016)	Effect of road cross sectional elements on road traffic crashes and injury severity at midblock (Addis Ababa)	Number of lanes, median type, median width, median height, sidewalk width, and road segment length.
5	Obaidat and Ramadan (2012)	Traffic accidents at hazardous locations of urban roads (Jordan)	number of vertical curves, median width, type of road surface

6	Knuiman et al. (1991)	Association of median width with highway crash(Utah and Illinois)	Road length, median width and posted speed limit
7	Zegeer et al. (1981)	Effect of lane and shoulder width on accident reduction on rural, Two-lane road (Kentucky)	Traffic volume, Lane width, shoulder width, and road access point.

3. MATERIALS AND METHODS

3.1. Description of the study area

Shashemene is a town situated in the West Arsi Zone in Oromia Regional state of Ethiopia approximately 250 km south of Addis Ababa, the capital city of Ethiopia. It is located at latitude 7.1973° N and 38.6005° E longitude and it is situated at elevation of 1924 meters above sea level (CSA Ethiopia,2012).

The total population projected for 2013, using the census data of 2007 was 129,084; of which 65,091 (50.4%) were men and 63,993 (49.6%) were women. It was one of the newly emerging towns in the late 1960s; being route of migration and trade located along the main highway connecting Kenya and Ethiopia. Since its establishment, it has been known as a business centre. Consequently, Shashemene attracted many temporary and permanent in-migrants. Wrote that, "A great deal of the growth of Shashemene was caused by net in-migration. Both in 1965 and in 1970, 45 percent of the sample population above 15 years of age claimed to have lived less than 6 years in Shashemene" (Bjerén, 1985).

The town is economically important and expanding quite rapidly compared to other towns. This is perhaps due to its location as a crossroad and a junction point for most towns located in the southern part of the country. It serves as a way through for an international highway connecting Ethiopia and Kenya. The town also lies within the Ethiopian Rift Valley and is close to the lakes and holiday resorts of: Awassa, Langano and the Shala-Abiyata Park. The urban land of Shashemene stretches over 2,058 hectares of land. However, the growth is accompanied with several constraints as it has not been provided with an equal growth in urban transport provisions and is lagged behind the existing demand. Moreover, the sector is expressed by many traffic problems (SULGA , 2004).

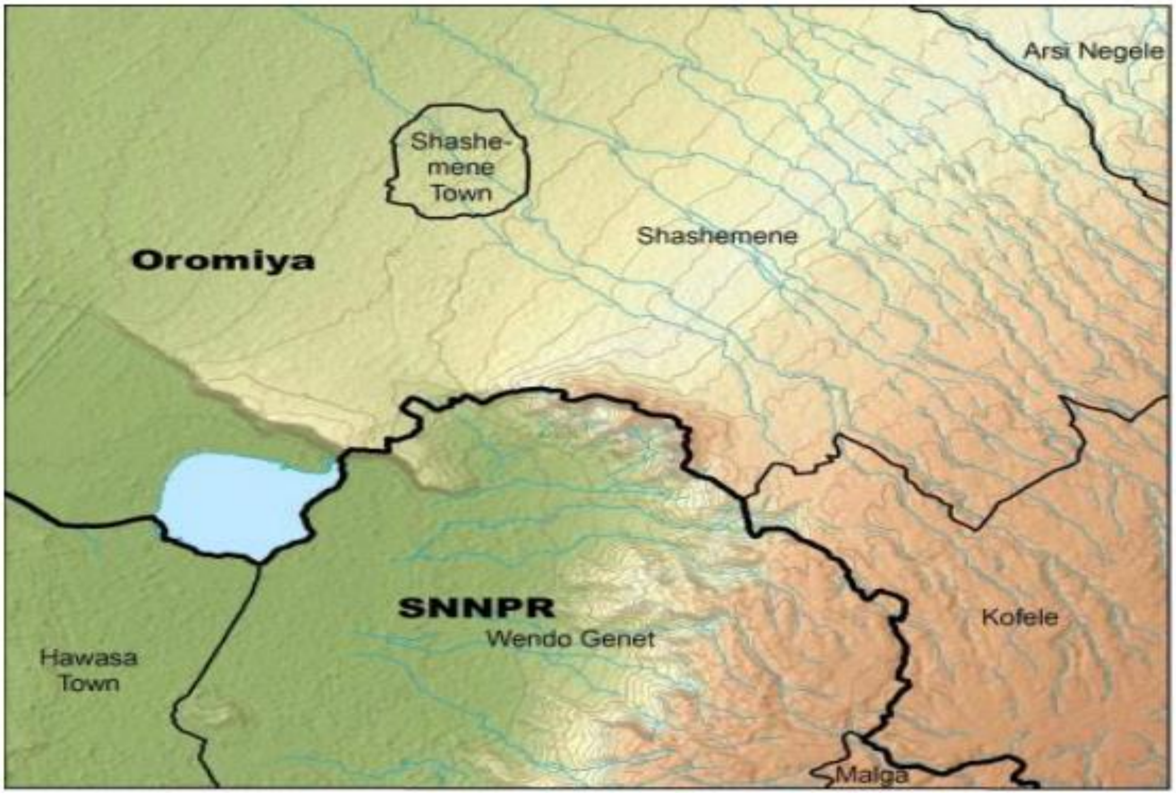

Figure 3.1: Political subdivisions of the Shashemene surrounding areas

(Source: Shashemene Administration Office)

3.2. Subjects of the study and Sampling Techniques

3.2.1. Subjects of the study

This thesis was done on selected eight junctions in Shashemene town those were chosen on areas where traffic accident were frequently observed during peak hours. These intersections are named by the locals as Tekliye, Semaniyaand (81), Zero Amst (05), Mobile, Arada Sefer and Gibrna non signalized intersections and Abosto and Kudus Mikael Signalized intersections. Among the intersections all are four legged except the Mobile intersection which is a T-intersection.

3.2.2. Sampling Techniques

The sampling techniques which used in this study are non- random (non- probability) sampling method of data collection called judgment sampling in which samples are selected deliberately by the investigator. Judgment sampling is non-probability sampling techniques where the researcher selects units to be sampled based on their knowledge and professional judgments. Alternatively, an expert sample selected based on the opinion of an expert. Results obtained from a judgment sample are subject to some degree of bias, due to the frame and population not being identical. However, the researchers try to handle in selecting the scope and frame appropriate for the selected study area (Zewditu Girma;Yoseph Kanaa and Mulegeta Ayalew; et al, 2003).

3.3. Data collection

3.3.1. Primary Data Collection

Primary data are collected by the investigator conducting the research or these are the first hand information obtained by the researcher himself from the field. This is usually obtained when the researcher does a descriptive or survey and uses a number of methods under the case. Primary data are those collected a fresh and for the best of time, this happen to be original in character (Ghauri et al, 2005). For the primary data, the research instruments will use were; Site observation, Site traffic volume count and Field measurement.

Site observation:

Now the study got the geometric component sample of the intersection then we could gone to observe the site. That means we were checked what type of intersection are available, how the society use that intersection appropriately, observe how the driver use the intersection with comfort or with difficulty , how is the traffic flow situation, what reason make the accident; finally take the picture for the observed situation. The data will be collected for the selected intersection in Shashemene town.

Field Measurements

The field measurements have been conducted on the geometric component of the intersections selected. Road intersection geometric characteristics such as lane number, Lane width, super-elevation, gradient, Intersection sight distance, shoulder width, median width, angle of intersection, side walk width, turning radius length, were collected directly through actual measurement from selected road segments in Shashemene town.

Counting traffic volume:

The traffic volume surveys carried out at all selected junctions to get AADT for 12 hours; in the morning from 6:00 AM to 6:00 PM during working days for seven consecutive days by setting up video cameras. The video cameras use for this study because, it is complex to count the traffic volume and the way the vehicles are moving by manual handbook note. The vehicles count carried out in category of vehicle classification system of ERA as Cars, Land Rovers, Small Bus, Medium Bus, Large Bus, Freight Vehicles, Small Truck, Medium Truck, Heavy Truck and Truck and Trailer.

3.3.2. Secondary data collection

The secondary data was mostly obtained from such sources as published and unpublished documents collected from pertinent institutions such as Ethiopian Road Authority (ERA), Addis Ababa City Road Authority (AACRA), Oromiya Road Authority (ORA), Shashemene Transport Authority (STA), Shashemene Traffic Police (STP) the, subject companies' yearly reports, published literatures by authorities and other web based materials.

Accident data

Road accident data were collected from the Shashemene Town Police Station that occurred at selected road intersection. The crashes registered for five years were in hardcopy and it includes 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 a prepared manually and transferred into an Excel file format for the crash frequency analysis.

3.4. Study Methodology

The study started from site selection and after the sites were selected the data like (geometric data, traffic data and accident data) were collected. After all the data were collected and processed the analysis was done by using different methods that used to identify black spot locations. The study used Accident frequency method, Accident rate method, Critical accident rate and Empirical Bayesian methods to identify black spot locations at selected intersections. Crash count statistical modeling techniques is used to know the relationship between road intersection geometric elements and road accidents at selected intersections. 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, interpretation for those statistically significant variables were done.

3.5. Data Management and Analysis

Various quantitative data analysis techniques that were employed for the analysis of accident and geometric data in this thesis are briefly discussed in this section.

3.5.1. Traffic Data Analysis

Video recording was used to collect traffic and pedestrian flow data in a field. This method of data collection relies on video cameras mounted at some height to collect or capture the traffic and pedestrian flows in the field. This method was chosen because of the following conditions:

- It helps to get accurate volume and turning conditions and traffic compositions in the junctions;
- It provides a permanent, easily-review record and shows traffic conditions at any time;
- It permits reading of required parameters in a controlled environment in which plate characters can be closely examined;
- It provides additional information about traffic flow characteristics such as traffic volume and vehicle headways and critical gaps; and
- It provides time for accurate determination of arrival times and has better accuracy than manual counts.

Due to these advantages, the video cameras were arranged in heights that maximizes the visibility of the field site and data's were collected.

The traffic was recorded at morning starting form 6:00 A.M to 6:00 PM for seven consecutive days for each selected intersections (junctions). Of the seven days 24 hour counts were conducted on two days of the week (one week day and one weekend day).The 24-hour counts are used to establish night factors . The traffic counts are done using the recorded traffic at each junction and then trancripted by manual trancription technique using the tally format on the paper format. In carrying out the traffic survey, the vehicle classification system of ERA with slight modification was used as shown in the table below.

Table 3.1: Vehicle Classification :(Sources: ERA manual)

Vehicle classification	**Description**
1. Passenger Vehicles	
1.1. Cars	Small automobiles
1.2. Land Rovers	4WD and utility vehicles
1.3. Small Bus	Buses up to 25 passenger seats
1.4. Medium Bus	Buses with 25 up to 45 passenger seats
1.5. Large Bus	Buses with over 45 passenger seats.
2. Freight Vehicles	
2.1. Small Truck	Trucks of capacity up to 3.5 tons load.
2.2. Medium Truck	Trucks of capacity 3.5 up to 7.5 tons load.
2.3. Heavy Truck	Trucks of capacity over 7.5 tons load.
2.4. Truck and Trailer	Articulated Trucks and tanker trailers of capacity over 12 tons load.

Based on the above procedures, the total traffic volume during survey time was collected on a directional basis for each intersection summarized below.

Table 3. 2: Daily traffic volumes count data for Tekliye intersection.

Day	Left turn	Right turn	Through	Total
01/07/2019	1272	1464	3652	6388
02/07/2019	1522	1343	3966	6831
03/07/2019	1046	965	2741	4752
04/07/2019	1441	1022	3735	6198
05/07/2019	987	1225	2787	4999
*05/07/2019	220	514	1012	1746
06/07/2019	654	725	1467	2846
*06/07/2019	313	239	645	1197
07/07/2019	798	897	1789	3484

Table 3. 3: Daily traffic volumes count data for Kudus Mikael church intersection.

Day	**Left turn**	**Right turn**	**Through**	**Total**
01/07/2019	2589	2988	4555	10132
02/07/2019	2031	3213	4815	10059
03/07/2019	2541	3698	5417	11656
04/07/2019	1981	2549	4124	8654
05/07/2019	1745	2635	3853	8233
**05/07/2019*	419	694	1124	2237
06/07/2019	1524	2457	4758	8739
**06/07/2019*	321	782	1213	2316
07/07/2019	1234	1875	2474	5583

Table 3. 4: Daily traffic volumes count data for Abosto intersection.

Day	**Left turn**	**Right turn**	**Through**	**Total**
08/07/2019	2414	2764	5242	10420
09/07/2019	1955	3212	4915	10082
10/07/2019	2124	3147	5521	10792
11/07/2019	1786	2963	5749	10498
12/07/2019	1998	2573	4978	9549
**12/07/2019*	622	788	1325	2735
13/07/2019	2165	2258	4415	8838
**13/07/2019*	821	784	1421	3026
14/07/2019	1489	1734	3328	6551

Table 3.5: Daily traffic volumes count data for Mobile intersection.

day	**Left turn**	**Right turn**	**Through**	**Total**
08/07/2019	0	1764	5014	6778
09/07/2019	0	2016	4654	6670
10/07/2019	0	2395	5167	7562
11/07/2019	0	2127	4791	6918
12/07/2019	0	1947	4889	6836
**12/07/2019*	0	546	922	1468
13/07/2019	0	1746	4138	5884
**13/07/2019*	0	631	787	1418
14/07/2019	0	1416	2976	4392

Table 3.6: Daily traffic volumes count data for Zero amst (05) intersection.

day	**Left turn**	**Right turn**	**Through**	**Total**
15/07/2019	1157	958	4759	6874
16/07/2019	1474	1024	4587	7085
17/07/2019	2145	887	5114	8146
18/07/2019	1763	1154	4487	7404
19/07/2019	1457	785	4874	7116
**19/07/2019*	548	219	978	1745
20/07/2019	1325	689	3879	5893
**20/07/2019*	645	321	1624	2590
21/07/2019	1023	579	2697	4299

Table 3. 7: Daily traffic volumes count data for Semaniya and (81) intersection.

day	**Left turn**	**Right turn**	**Through**	**Total**
15/07/2019	1123	1297	3784	6204
16/07/2019	1245	1258	3497	6000
17/07/2019	996	1348	3661	6005
18/07/2019	1114	1418	3881	6413
19/07/2019	948	1219	2967	5134
**19/07/2019*	356	479	748	1583
20/07/2019	874	954	1659	3487
**20/07/2019*	412	396	584	1392
21/07/2019	638	749	1978	3365

Table 3. 8: Daily traffic volumes count data for Gibrna intersection.

day	**Left turn**	**Right turn**	**Through**	**Total**
15/07/2019	1478	1024	2135	4637
16/07/2019	1945	1435	1911	5291
17/07/2019	1467	1875	1759	5101
18/07/2019	1120	998	1549	3667
19/07/2019	1289	1045	2012	4346
**19/07/2019*	489	378	579	1446
20/07/2019	1047	941	1852	3840
**20/07/2019*	386	316	443	1145
21/07/2019	786	897	1568	3251

Table 3.9: Daily traffic volumes count data for Arada Sefer intersection.

Day	**Left turn**	**Right turn**	**Through**	**Total**
08/07/2019	1139	1012	1588	3739
09/07/2019	1300	1425	956	3681
10/07/2019	1940	1321	1246	4507
11/07/2019	754	1524	987	3265
12/07/2019	934	1395	1727	4056
**12/07/2019*	200	375	414	989
13/07/2019	1132	1745	735	3612
**13/07/2019*	400	414	367	1181
14/07/2019	945	1322	1124	3391

3.5.2. Traffic Accident Data analysis

A brief review of the various studies on black spot identification is given as follows .We start from data collected from different institutions and complies with a scientific way to make it easily understandable for anyone. The research conducts the following different methods to diagnose the black spot.

- Accident frequency method

Accident frequency is the simplest determination criteria, each accident is located at its point of occurrence on the road network and the total number of accidents reported at each site is added up (Layton, 1996; Mc Millen, 1999).

$frp = \Sigma fi/n$ .... (3.1)

$ir = 2 * frp$ .... (3.2)

Where

frp=accident frequency at site j of a reference population

fi=average accident frequency

n=number of sites

ir=minimum accident frequency that warrants a detailed safety analysis.

- Accident rate

Accident rate is a ratio between a number of accidents and an exposure measure (Layton, 1996; Mc Millen, 1999).

$Rj = fj * \frac{10^6}{365.25 * P * Lj * Qw}$, for the accident rate of each site................................... (3.3)

$Rrp = \sum fj * \frac{10^6}{365.25 * P * Lj * Qw}$, For the average accident rate for the reference population… (3.4)

$Rrp = \frac{\sum(Qj * Lj)}{\sum Lj}$ .... (3.5)

$Ir = 2 * Rrp$ .... (3.6)

Where

Rj =accident rate of site j (acc/Mveh-km)

Rrp = average accident rate (acc/Mveh-km)

fj =accident frequency at site j

P =period of analysis (year)

Lj =section length of site j (km)

$\sum Lj$= total length of section j (km)

Qj=average annual daily traffic of site j (AADT)

Qw = weighted average annual daily traffic (AADT)

Ir =minimum accident frequency that warrants a detailed safety analysis

- Critical accident rate

It comprise the accident rate at a site with the average accident rate calculation in a group of site having similar character and also comparing the accident rate and accident rate at each site .A detail safety analysis is justified when the accident rate is higher than the critical rate. We concluded the location is hazardous site (Hauer et al, 2002).

$$Rcj = Rrp + \frac{k\sqrt{Rrp*10^6}}{365.25*P*Lj*Qj} + 1 * \frac{10^6}{730.5*P*Lj*Qj} \quad (3.7)$$

Where

Rcj =critical accident rate at site j (acc/Mveh-km)

Rrp =average accident rate at similar sites (acc/Mveh-km)

K=statistical constant

1.036 For a level of confidence of 85%

1.282 For a level of confidence of 90%

1.645 For a level of confidence of 95%

2.326 For a level of confidence of 99%

P =period of analysis (year)

Lj =section length of site j (km)

Qj =average annual daily traffic of site j (AADT)

- Empirical Bayesian methods

The first has been computed based on the accident frequency reported at the site over a relatively short period of time or accident period (Hauer et al, 2002).

EB method of moment

EB method of moment required calculating the populations mean accident frequency and its variance; those two statistics are then used to adjust the accident frequency at the site.

$$FEBj = fj + \frac{frp(frp - fj)}{s^2} \quad (3.8)$$

$$frp = \frac{\Sigma fj}{n} \quad (3.9)$$

$$S^2 = \frac{\Sigma(fj - frp)^2}{n-1} \quad (3.10)$$

Where

$FEBj$ =EB adjusted accident frequency at site j

fj=accident frequency at site j

frp =average accident frequency (reference population)

n =number of sites

S^2=variance of accident frequency (reference population)

This research shows briefly the review of the study of road traffic accident analysis done on the previous 5 years data from Shashemene town documentation office.

Table 3.10: The average of five years collected data and severity index for the selected road intersection in Shashemene town.

Street No.	Street Name	Average Fatalities (F)	Average Injuries (I)	Average Property damages (P.D)	Average Total accidents	Severity Index (S.I)	High Accident Location
1	Tekliye	12	49	97	158	118	Black-spot
2	Abosto	7	27	102	136	82	Black-spot
3	Kudus Mikael	8	38	124	170	104	Black-spot
4	Mobile	2	31	54	87	55	Black-spot
5	Zero Amst	-	15	24	39	23	-
6	Semaniya And	9	51	165	225	133	Black-spot
7	Gibrna	-	3	21	24	10	-
8	Arada Sefer	3	29	121	153	79	Black-spot

3.5.3. Geometric Data Analysis

To gather geometric data that are used as input for geometric design of road intersections are collected by using measuring Tape and Visual observations.

Several Statistical models were developed to quantify the relationship between road geometric elements and road accidents, such as linear regression, Poisson models, Poisson-gamma models, negative binomial models, generalized estimating equation, random-parameters, and bivariate and multivariate models. Linear regression models were considered and developed in earlier studies to find the relationship between road accidents and road geometry elements, however it was reported that using conventional linear regression models showed unsatisfactory results as the properties of linear regression are normally distributed, which can generate negative or non-discrete values of accident rates (Jovanis and Chang, 1986; Saccomano and Buyco, 1988; Miaou et al., 1991). As a result, Poisson and negative binomial models were suggested to be used instead.

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 encompasses 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 segments or intersections. Crash data are nonlinear, random, and non-negative (count data) which approximately follow the Poisson distribution.

Poisson regression models are generalized linear models with 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) Tom and Elke (2014) were used the models previously discussed on rural and urban road intersections of the form given in equation 3.11 and 3.12.

$$E(\mu i) = \beta o Q^{\beta} e^{\Sigma \beta i x i} \qquad (3.11)$$

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

βo = Intercept (Estimate)

Q = Traffic Volume (ADT)

B = effect of traffic volume on the expected number of accidents and is modelled 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 modelled 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 provide 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

$$f(yi, \mu i, \varphi) = ((\mu i/1 + \varphi \mu i)^{\wedge} yi\ (1 + \varphi \mu i)^{\wedge}(yi\text{-}1))/yi\ e^{\wedge}([\mu i(1 + \varphi \mu i/1 + \varphi \mu i]) \ldots (3.12)$$

Where;

yi= 0,1,2,3…….

$$\mu i = \mu i(xi) exp(\sum_{i=0}^{k} xi\beta j)$$

Is the i-th row of covariance matrix X and $\beta = \beta1, \beta2..., \beta k$ are unknown k-dimensional column vector of parameters. The model in equation 3.11 is based upon the generalized Poisson distribution and the mean of yi is given by μi and the variance of yi is given by μi (1+φμi) 2. Moreover, it is an extension of the Poisson regression model. When $\varphi = 0$, the generalized Poisson distribution model reduces to the Poisson regression model. When $\varphi > 0$, the GPR model is used to model count data that exhibits over dispersion and when $\varphi < 0$, 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)

g (yi; $\mu i, \tau) = ((\_yi\text{^}(yi + 1/\tau - 1)))(\ 〚1/1 + \tau\mu i)〛\text{^}(1/\tau)\quad 〚(\tau\mu i/1 + \tau\mu i)〛\text{^}yi.$(3.13)

Where; yi=0,1,2,3……..

Where μi is defined in equation 3.12 that the mean of yi is given by μi and the variance of yi is given by μi (1+ τμi) 2. The model in equation 3.13 reduces to the Poisson regression model when $\tau \rightarrow 0$. It can be used to model count data with over dispersion when $\tau > 0$.

As per the requirement of the analysis, the collected geometric data include; lane number, lane width (m), super-Elevation, (%), gradient (%),intersection sight distance (m) shoulder width (m), median type, median width(m), angle of Intersection (degree) ,side walk width (m) and turning radius length (m) for selected junction. These data are summarized in Table 3.11.and 3.12.

Table 3.11: Geometric Conditions Data of the Selected Intersection

Intersection No	Intersection Name	Lane Number	Lane width (m)	Super-Elevation (%)	Gradient (%)	Intersection sight distance (m)
1	Tekliye	2	3.2	1.4	1.6	68
2	Abosto	2	3.5	1.7	1.4	59
3	Kudus Mikael	2	3.5	1.6	1.5	65
4	Mobile	2	3.25	1.3	1.6	70
5	Zero Amst	2	3.5	1.4	1.2	80
6	Semaniya And	2	3.25	1.3	1.5	53
7	Gibrna	2	3.5	1.2	1.3	94
8	Arada Sefer	2	3.5	1.4	1.2	87

Table 3.12: The Additional Geometric Conditions Data of the Selected Intersection

Intersection Name	Shoulder width (m)	Median type	Median width (m)	Angle of Intersection (degree)	Side walk width (m)	Curve Radii (m)
Tekliye	0.75	No	-	80	0.9	149
Abosto	0.75	No	-	80	1.1	120
Kudus Mikael	0.8	No	-	80	1.0	140
Mobile	0.85	Painted	0.5	90	1.3	155
Zero Amst	1.2	Painted	0.5	80		170
Semaniya And	0.8	No	-	75	0.75	128
Gibrna	1.5	Raised	0.7	90	1.5	175
Arada Sefer	1.5	Raised	0.5	90	1.4	160

4. RESULTS AND DISCUSSIONS

4.1. Determination of Annual Average Daily Traffic

The annual average daily traffic (AADT) of the selected road intersection was determined based on the traffic count data from counting stations by considering the night and seasonal adjustment factors in to consideration. Night factors were applied to convert the 12 hour count data to an equivalent 24 hour count data, ADT. The night factor for each intersection is obtained by taking the ratio of the number of vehicles for the 24 hour counts to the corresponding 12 hour counts on the days when 24 hour counts were conducted. To get reasonable values of night factors, the average values of the two days 24 hour counts were used.

The annual average daily traffic (AADT) of the road intersection by the year 2019 is computed by multiplying the ADT of the count period with seasonal adjustment factors. The seasonal adjustment factor is calculated by reviewing past traffic data.

The tables below show the Average day (12 hrs) traffic data obtained from the traffic count, the night factor, seasonal correction factor and the AADT.

Table 4.1: Adjusted Average Annual Daily Traffic for Tekliye road intersection

	Tekliye road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1103	1092	2877	5072
Night factor	1.33	1.39	1.39	
Seasonal factor	0.83	0.87	0.91	
AADT, 2019	1218	1321	3640	6179

Table 4.2: Adjusted Average Annual Daily Traffic for Kudus Mikael road intersection

	Kudus Mikael church road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1950	2774	4286	9010
Night factor	1.23	1.29	1.28	
Seasonal factor	0.86	0.84	0.93	
AADT, 2019	2063	3006	5103	10172

Table 4.3: Adjusted Average Annual Daily Traffic for Abosto road intersection

	Abosto road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1990	2665	4879	9534
Night factor	1.35	1.33	1.30	
Seasonal factor	0.85	0.84	0.91	
AADT, 2019	2284	2978	5772	11034

Table 4.4: Adjusted Average Annual Daily Traffic for Mobile road intersection

	Mobile road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	0	1916	4519	6435
Night factor	0	1.32	1.19	
Seasonal factor	0	0.78	0.87	
AADT, 2019	0	1973	4679	6652

Table 4.5: Adjusted Average Annual Daily Traffic for Zero Amst road intersection

	Zero Amst (05) road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1478	868	4343	6689
Night factor	1.42	1.37	1.30	
Seasonal factor	0.81	0.78	0.85	
AADT, 2019	1700	928	4800	7428

Table 4.6: Adjusted Average Annual Daily Traffic for Semaniyaand(81) road intersection

	Semaniya and (81) road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	992	1178	3061	5231
Night factor	1.43	1.41	1.29	
Seasonal factor	0.80	0.77	0.96	
AADT, 2019	1135	1279	3791	6205

Table 4.7: Adjusted Average Annual Daily Traffic for Gibrna road intersection

	Gibrna road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1305	1174	1827	4306
Night factor	1.38	1.35	1.27	
Seasonal factor	0.85	0.77	0.93	
AADT, 2019	1531	1221	2158	4910

Table 4.8: Adjusted Average Annual Daily Traffic for Arada Sefer road intersection

	Arada Sefer road intersection			
	Left turn	Right turn	Through	Total
Average of 12 hour data	1164	1392	1194	3750
Night factor	1.30	1.26	1.32	
Seasonal factor	0.88	0.82	0.91	
AADT, 2019	1332	1439	1435	4206

4.2. Analysis of black spot with accident frequency, accident rate, Critical accident rate and Empirical Bayesian methods

On this type of traffic identification analysis, the amount of AADT is mandatory and it is priority to calculate all accident identification method. The second stage would be counting the accident frequency from secondary data source such as from police station documentation office. The data taken from Shashemene town police traffic accident documentation office for traffic accident data and AADT the data taken from the above tables for each road intersection.

Table 4.9: traffic accident diagnosis using accident frequency, accident rate, Critical accident rate methods and empirical Bayesian method for road intersection **(**Source: own calculated and road safety manual reference)

Shashemene town road intersections accident identification and diagnosis							
No	Name of intersection	AADT, (2019)	Accident frequency	Individual accident rate(acc/M veh)	Average accident rate(acc/Mv eh)	Critical rate (acc/Mve h-km)	F_{EB}(adjusted accident frequency)
1	Tekliye	6179	29	4.29	25.56	27.64	26.54
2	Abosto	11034	23	1.90	14.30	15.46	22.65
3	Kudus Mikael	10172	27	2.43	15.52	16.78	25.25
4	Mobile	6652	19	2.60	23.73	25.66	17.95
5	Zero Amst	7428	15	1.85	21.25	22.98	12.55
6	Semaniya And	6205	31	4.56	25.44	27.51	27.85
7	Gibrna	4910	7	1.30	32.15	34.77	1.75
8	Arada Sefer	4206	22	4.78	37.53	40.59	22
		Total=	173				

4.2.2. Traffic accident priority ranking for Shashemene main road junction

One of the main processing on black spot identification is giving a traffic accident priority ranking for the most dangers road selecting to give attention for putting a black spot location.

Table 4.10: Traffic accident priority ranking for main junction

Traffic accident priority ranking for Shashemene main road junction					
Section	Name of road junction	Rank	Section	Name of road junction	Rank
6	Semaniya and	1	8	Arada Sefer	5
1	Tekliye	2	4	Mobile	6
3	Kudus Mikael	3	5	Zero Amst	7
2	Abosto	4	7	Gibrna	8

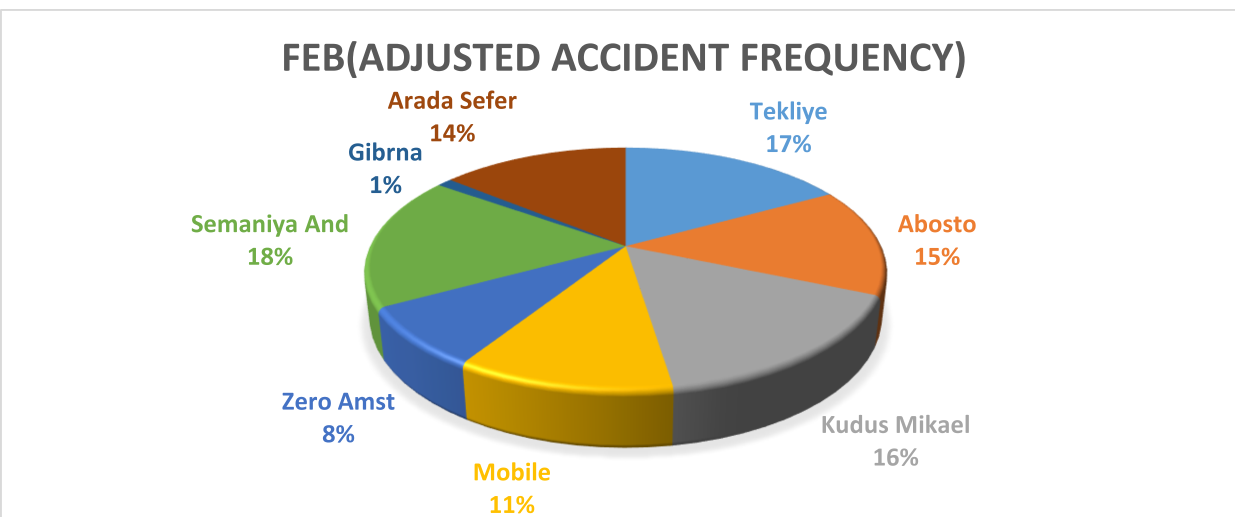

Figure 4.1: Traffic accident priority ranking for main junction by percent of F_{EB}

4.5. Discussion of black spot location (after black spot analysis)

4.5.1. Semaniyaand road intersection

To assess this junction, there is some reason to increase the number of the road traffic accident for Semaniyaand road intersection as compared to the other main junction. For this road intersection according to the previous analysis of road traffic accident, this junction shows the highest accident rate of 4.56 acc/M-vehicle and FEB amount is 27.85. Because of the geometric design problem of these road intersection needs a permanent change of road geometry and pavement to reduce accident compared to the other main intersection which is found in Shashemene town and the following point shows some evaluation about this junction.

- Inadequate visibility in both the horizontal and vertical planes
- Thus drivers of vehicles approaching an intersection along a minor road have obstructed views to the left and right along the major road for a distance (at least not equal to the safe stopping sight distance)
- Lane and crosswalk markings and signs are not clearly visible and understandable from a desired distance.
- The road signs are not installed in the appropriate locations, and most signboards have been thoroughly worn out.
- The horizontal and vertical alignments were not suitable for the design speed of vehicles.
- Missing channelizing island which serves as to control and direct traffic movement, to divide opposing or same direction traffic streams and to provide refuge for pedestrians.
- Corner radii not designed based on the minimum turning path of design vehicles at locations requiring minimum space.
- Missing left turn lane which reduce rear end crash.
- Uncontrolled pedestrian crossing
- Inappropriate intersection traffic control
- Inadequate visibility of the intersection or regulatory traffic control devices
- Missing Curb extensions which increase the overall visibility of pedestrians by aligning them with the parking lane and reducing the crossing distance for pedestrians, creating more time for preferential treatments, such as leading pedestrian interval and transit signal prior it.

4.5.2. Tekliye road intersection

In evaluation of Tekliye road intersection about there is a number of factors that cause road traffic accident and black spot junction. Due to the result of previous analysis of main road junction Tekliye road intersection shows on accident rate is 4.29 acc/M-vehicle and FEB amount of 26.54 is the highest one compare to the other junction found in Shashemene town. Thus Tekliye junction needs a permanent change of road geometry and pavement to reduce accident and the following point shows some evaluation about this junction.

- Insufficient sight distance from the minor road to and along the major road
- The motorists' ability to see an upcoming intersection and/or the intersection traffic control sign along that approach is limited.
- Motorists do not have sufficient visibility of oncoming vehicles on both approaches of the intersecting street to safely enter or cross the intersection.
- Motorists are not provided sufficient information in the form of signs or markings to identify or navigate the intersection.
- Lack of pavement markings to guide conflicting movements within the intersection crossover.
- Users on the minor street frequently experience long delays in making crossing or turning maneuvers because of the lack of safe gaps in the major road traffic flow.
- Insufficient corner radius between two adjacent legs of the intersection that means the radius is too small, longer vehicles likely encroached into the opposing lane.
- Vehicles approaching an intersection have no definite paths hence no of accidents will be more.
- Missing channelizing island which serves as a refuge for pedestrians and makes pedestrian crossing safer and also forces the driver to reduce the speed and becomes more cautious while maneuvering the intersection.

4.5.3. Kudus Mikael road intersection

From the above black spot identification criteria the Kudus Mikael junction is high traffic accident compare to others main junction in Shashemene town with accident frequency is 2.43 acc/M-vehicle and it is a significant amount of FEB value is 25.25 due to different reason some of them are the following

- Motorists do not have sufficient visibility of oncoming vehicles on both approaches of the intersecting street to safely enter or cross the intersection.
- The traffic sign are not on the proper places or destroyed by car crash
- The road marking is removed from road pavement and the drivers and pedestrian could use this road is difficult.
- No speed limit
- Not space is provided for motorists to stop occasionally to consult road maps or for other reasons.
- Curb extensions increase the overall visibility of pedestrians by aligning them with the parking lane and reducing the crossing distance for pedestrians, creating more time for preferential treatments, such as leading pedestrian interval and transit signal priorit
- Missing channelizing island which provided the driver will have high tendency to reduce the speed while entering the intersection from the carriageway.
- Missing Curbs which serve for the following purposes: drainage control, roadway edge delineation, right-of-way reduction, aesthetics, delineation of pedestrian walkways, reduction of maintenance operations, and assistance in orderly roadside development.
- Missing Medians it is a portion of roadway that separates opposing streams of traffic.
- Motorists are not provided sufficient information in the form of signs or markings to identify or navigate the intersection.
- Narrow shoulder width
- Missing auxiliary lane

4.5.4. Abosto road junction

In evaluation of geometry design of Abosto junction there is a number of factors that cause road traffic accident. Due to the result of previous analysis of black spot of main road junction in Shashemene town Abosto junction shows on accident frequency is 29 and PI EB amount of 22.65 is high compare to the other junction. Thus Abosto junction needs a permanent change of road geometry and pavement to reduce accident and the following point shows some evaluation about this junction.

- No speed limit

- Users on the minor street frequently experience traffic accident in making crossing or turning maneuvers because of the lack of safe gaps in the major road traffic flow; this can also apply to motorists desiring to turn left from the major street.
- Missing channelizing island
- The corner radius between two adjacent legs of the intersection is insufficient.
- Uncontrolled pedestrian crossing.
- No provision of road shoulder in case of an emergency situation to be used by vehicles
- Some sections of the pavement surface traced with old patched, and potholes of varying dimensions were believed to be the main contributory of the dramatic increase in traffic accidents.

4.6. Effects of road intersection geometric design elements on traffic accidents

Some of the predictor variables were found statistically insignificant in the analysis of the model. Explanatory variables such as; carriageway width, cross slopes or camber length of road intersection and median height were systematically removed from the model and then, interpretation for those statistically significant variables was done.

The final model is done based on the statistical significance of each predictor (explanatory) variables 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 4.11 the explanatory variables such as lane width, super elevation, gradient, and intersection sight distance, shoulder width, median type, and median width, angle of intersection, side walk width and curves radius 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 4.11: Software analysis output by Poisson Regression Model

Description	Poisson Regression Model				
	Estimated Coefficient	Standard error	95% confidence interval		P-value
Constant	1.997	1.9957	-1.914	5.909	0.317
Road intersection characteristics					
Lane number	0.057	0.0153	-0.089	-0.029	0.008
Lane width	-3.589	0.4738	-4.518	-2.660	0.000
Super-Elevation	-2.528	1.1901	0.196	4.861	0.034
Gradient	0.393	0.1597	0.080	0.706	0.014
Intersection sight distance	-1.927	0.0135	0.066	0.119	0.003
Shoulder width	-0.422	0.2275	-0.024	0.868	0.064
Median type	0.0113	0.0430	0.029	0.197	0.008
Median width	-1.505	0.4009	0.719	2.291	0.000
Angle of Intersection	-0.100	0.0148	0.071	0.129	0.000
Side walk width	-6.014	0.5926	4.852	7.175	0.001
Curves Radii	-0.047	0.1130	-0.175	0.268	0.005

Table 4.12: Software analysis output by Negative Binomial Regression Model

Description	Negative Binomial Regression Model				
	Estimated Coefficient	Standard error	95% confidence interval		P-value
Constant	1.823	1.8332	-4.109	7.755	0.092
Road intersection characteristics					
Lane number	0.045	0.2301	-0.499	0.404	0.081
Lane width	-3.583	4.1019	-11.622	4.457	0.076
Super-Elevation	-2.686	2.5822	-4.027	6.654	0.067
Gradient	1.186	1.2163	-1.198	3.570	0.013
Intersection sight distance	-0.092	0.1293	-0.161	0.346	0.087
Shoulder width	-0.470	1.3639	-2.203	3.143	0.051
Median type	0.107	0.7547	-1.375	1.587	0.04
Median width	-1.645	2.3008	-2.864	6.155	0.047
Angle of Intersection	0.132	0.1505	-0.1630	0.427	0.077
Side walk width	-5.965	5.7649	-5.334	17.264	0.030
Curves Radii	-0.586	0.7374	-2.031	0.859	0.063

4.6.1. Discussion of Software analysis output

Number of lanes

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 Addis Ababa supports this findings that vehicles on mid-block segments with more lanes run at higher speed and more traffic flow leading to more crashes and also, vehicles travel along the midblock segment with more number of lanes have more lane changing and overtaking opportunities (Alemu, 2016). The 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)

A considerable number of investigations indicate that lanes number is associated with road accidents (Deo, Chimba, 2004). In a study of road geometrics, velocity and volume relationships with road accidents; lane volume was found to affect accidents occurrences positively (Garber, 2000). In a similar manner, a research finalized that urban highways lanes number increase raises accidents rates (Abdel-Aty et al., 2000). Noland, R., and Oh.L. (2004) concluded similar outputs of lane number positive influence on road accidents. Generally, various studies carried out suggest corresponding findings ranging from two to six-lane roadways.

Lane Width

The Estimated coefficient for width of lanes is negative. It implies that the road intersection with wider of lane had decreased number of crash occurrence. This is due to vehicles on road intersection segments with wider lane run at free traffic flow leading to less crashes. Another reason is vehicles travel along the intersection with a wider lane have more lane changing and overtaking opportunities. These factors may have contributed to having less crashes occurred on them.

Generally speaking, freeway flow speeds are of higher values on lanes with ideal widths; therefore, incidents are less possible, which is also stated by (HCM) especially for multilane freeways (Jerry et al., 2009). While it might be rationally presumed that wider lanes reduce the effect of incidents generating from driver mistakes, it can be argued that high operating speeds can oppose this effect. The use of an optimum lane width value of typically 3.5 m to 3.6 m was suggested by most researchers. A more reliable approach should be implemented such as consideration of more cross sectional elements related to traffic flow rates. Other studies highlighted that to some extent a wider lane slightly increases road accidents (Hearne, 1976). On the other hand, another research implies a drastic decline of road accidents with respect to wider lanes of the range 4.0 -7.0 meters or more than that (Hedman K., 1990). However, several studies indicated that a much lower accidents occurrence is associated lane widths from 3.4 m - 3.7 m (Zegeer et al., 1981; Mclean, 1985; Zegeer and Council, 1993).

Similarly, NCHPT in the report 197, 1978 it was found that lower accident rates occur when the lane width is 3.35 m or 3.65 m. In a study conducted by Hughes (1995) of rural characterized by low traffic flow rates, it was concluded that lanes wider than 3.65 m reduce incidence occurrence. However, a lane wider than 3.7 m does not necessarily imply safety provided other factors for instance, passing from carriageway to another (Transportation Research Board, 1987). In addition, higher operating speeds of wider lanes can result in more accidents. A wider lane than the minimum required results in a higher speed which is a measure of driving comfort (Yager and Van Aerdo, 1983). It was noted that free flow speed of highways of 3.3 m up to 3.8 m tend to be slower by 5.7 km/hr with respect to lane width decrement of 1 m (O'Cinneide, 1995). Also, cross sections of 7.5 m or less showed a noticeable decline in road accident rate as examined in a study by Lamm et al. (1999). Moreover, a research on anticipation of road accidents occurring on non- intersection segments of four states in US concluded that wide cross sections have a remarkable impact on accidents reduction of approximately 14% decline per 1 m increase in width, while some states showed a higher percentage of 34 % (Council and Steward, 2000). In terms of accident costs 3 m increase in width is linked to lower accident costs (Elvik, and Vaa, 2004).

Super elevation

The model includes super elevation as one of road intersection geometric characteristics which used as predictor parameter. As shown in the model the estimated coefficient is negatively affecting total number of crashes. The result indicated that as value super elevation increase average total crashes decrease. This is due to the purpose of acting against a centrifugal force that influences the vehicle's running on curves. Also, to enhance the stability of traveling vehicles and comfort of drivers.

According to Zhang Yingxue 2009) the super elevation traverse slope should be between 2.0 % to 3.0 %. Super elevation is a function of road horizontal alignments, design speed, natural conditions and curve radius. He also mentioned that the use of proper super elevation value can mitigate incidents which could contribute to accident severity. Some studies have indicated that super elevation and horizontal alignment have an influence on traffic safety on roads.

A study conducted by Ali Aram (2000) on two-lane highways concluded that sharper horizontal curves drastically increase the rate of accidents occurrence; which is explained furthermore by the fact that sudden changes in horizontal alignments along the road, declines drivers' expectancy which, therefore, accordingly, raises the probability of accidents occurrences. To reduce unexpectancy, few have stated that consistent design speed can help maintain the attention of drivers to different road elements. Hence, design speed criteria may differ for the same curve based on the maximized super elevation for each criterion, as highlighted by AASHTO's Washington, D.C.'s conference (2001). A correlation of both actual and advised super elevation values is used by some two-way roadways design criteria, particularly, a difference of more than 0.01.

Gradients

The coefficient for gradient variable has positive relationship with road traffic crash occurrence on the junction segments in the model. Consequently, steep gradient causes more traffic accident when it compare with mild gradient roads.

According to some studies conducted, roads with steep gradients found to be related to higher accident rates. Hedman (1990) quoted from a Swedish study done on road gradients and accident rates that the results showed that road with 2.5 % grade can increase road accidents by around % whereas roads with 4% grade can increase the accident rates by approximately 20 % compared to near-horizontal roads. Glennon et al. (1987) investigated the results obtained for several studies performed in US and concluded that roads which were designed with grade sections have a higher road accident rates compared to roads which were designed with level sections. They also observed that higher accident rates were found in steep gradient in comparison with mild gradient roads, it was also noted that down-grade roads have more potential accident rates compared to up-grade roads. In conclusion, the road gradient is significantly related to accident rates on roads as the increase in road gradients results in an increase of road accident rates.

Shoulder Width

The width of shoulder has a negative correlation in the coefficient of estimated model, which implies that the less the width of shoulder, the higher road traffic crashes at road junction segments. . A study conducted by Jerry more space provided by road shoulders allow for high free flow speed because drivers may have a perception that when they lose control over their vehicles there is a room for gaining control again. In addition, several studies agreed on shoulder width impact on accident rates on roadways. Particularly, lane width is linked together with should width with respect to road conditions (Deo Chimba, 2004). Studies carried out had different findings on the effect of shoulder width on accident occurrence. Zegeer et al. (1981) stated that wider shoulders result in lower accident rates and found that a decline up to about 20 % of incidence occurrence is attributed by shoulder widths of 0.9 m – 2.7 m and they suggested that the optimum road shoulder width should be 1.5 m.

Turner et al. (1981) mentioned that shoulder width below 2.0m tend to decrease accidents occurrence in comparison with shoulder widths of more than 2.0 m (Hedman, 1990). US Department of Transportation (2007) reported that an increase of 0.3 m width, can reduce both incidents by 1.0 % to 3.0 % and severities by 2.0 % to 4.0 %. According to Miaou (1996), an increase of shoulder width of 0.3 m can also result in 8.8 % reduction of accident rates.

Median Width and Type.

The coefficient for a width of median variable is negative, which implies that less crashes occur on a road segment with more width of median in it. This result makes sense because when width of median increase this creates less opportunity for conflicts, and thus tend to cause less crashes. According to The Road Directorate of Denmark (1981), a road segment to reduce accident rates is only to some extent of the median width up to 3 m. On the other hand, other studies suggested a decline of accident rates for medians wider than 12 meters (Hughes, 1995).

In term of design, both median width and type are associated with median existence (Jerry et al., 2009). When it comes to median type a study conducted by Hadi Et al. (1995) found that raised curb, crossover resistance and stripped medians attribute to decline of road safety. Moreover, physical narrow medians which have an impact if only vehicles crash into them are less effective than wide medians. Also, land use along with median type highly influences accidents rate (Sawalha and Sayed, 2001). It was concluded that on two-lane or multilane roadway with high design speeds, the road safety is positively impacted by road medians as they can help avoid head-on crashes (Srinivasan, 1982).

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 (or fully) 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 lane 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).

Intersection sight distance

The intersection sight distance has negative coefficient. This explains that when intersection sight distance in a given road intersection increases, road traffic crash frequency decrease which affect road safety. The finding is consistent with study conducted in Addis Ababa, which found that the intersection sight distance in road intersection 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 for sight distance (Tefera, 2015).

The study conducted by Martin R. inadequate sight distance can cause higher accident rates as it is related reaction and decision to be taken by the driver to handle and deal with any unforeseen circumstances or objects which the driver may encounter on the road junction. Sight distances shall be taken into consideration during the design of the road horizontal and vertical alignments in order to assure and provide sufficient and safe roadway design. The possibility of accidents occurring is higher in some road sections with a poor visual distance due to a small radius of horizontal and vertical curves and also with road sections where the sight distance of overtaking is not adequate to the drivers (Zhang, 2009). Sight distances involve stopping and passing sight distances. Although there is a lack of information on the influence of stopping sight distance on the road safety, it is widely accepted that the provision of shortstop sight distance can cause accidents on roads (O'Cinneide, 1995). Martin R. (2003) published a book on highway engineering and he recommended different values of stopping and passing sight distance at different design speed in order to ensure road safety, however he stated that there is no evidence to prove that there is a relationship between accidents occurrence and passing sight distance.

Several studies were conducted in order to investigate the impact of different radii which correspond to various sight distances. Transportation Research Board (1987) reported that roads which have shorter sight distances because of crest vertical curves, the frequency of accidents occurrence is 52%. On the other hand, Hall and Turner (1989) stated that insufficient stopping sight distance doesn't necessarily indicate that accidents will happen. Glennon et al. (1985) pointed out that the improvement of sight distance on crest vertical curves are not significantly effective unless the traffic volume on the road is high. Lamm et al. (1999) in their handbook on traffic safety and highway design mentioned that higher road accidents frequency was observed on road sections with sight distances shorter than 0 m and there is no further effective improvement on safety for sight distances above 150 m. Another study done by Elvik and Vaa (2004) also concluded that having 200 m or more than 20m sight distances can increase the possibility of accident risks on roads which means it can adversely affect the road safety.

Sidewalk width

Sidewalk width is another a 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. A study conducted in Addis Ababa support the findings that it explained the city uses walking as the primary means of transportation accounting for about 60% of the total trips within the city. 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).

Curves Radii

The length of curve radius has a negative correlation in the coefficient of estimated model, which implies that the long the curve radius, the less road traffic crashes at road intersection. Curve radius is a primary element of roads geometric design that is associated with horizontal curve design and it is related to traffic accidents as the smaller the curve radius, the higher the possibility of accidents to occur on roads.

Based on the theory of vehicle steering, vehicle transverse stability which includes the slippage and overturns determines the curve radius value to be selected when designing road horizontal curves (Zhang Yingxue, 2009). Zhang computed the radius mean and curvature degree for all categories used in his research and then he regressed them against the mean of accident rates in every category, his findings supported some previous studies which found and stated that the curve sharpness has a significant impact on the accident rates. Brude et al. (1980) carried out a study on Swedish roads with a speed limit of 90 km/hr, the study aim was to develop accidents prediction model to compare accident rates which occur due to horizontal curves to base accident rate and it was concluded that the curve radius becomes significant factor when the curve radius is about 200 m. Similarly, a study which was conducted by Department of Transportation, UK (1984) pointed out that results showed a significant increase in accident rates when the curve radius reduces.

Other studies showed that the increase in accident rates becomes significant with roads which have curve radius below 200 m. Simoson and Kerman (1982) noted that small radius curves can result in shorter overall curve lengths and the overall impact on accident rates is not as awful as it might be expected, however there is still an impact of curve radius on accident rates. Several previous studies performed by Glennon et al. (1985), Glennon (1987), and Zegeer et al. (1991) showed that sharper curves are associated with higher accident rates compared to milder curves which are associated with lower accident rates. It was also found that horizontal curves have more accidents such as roll-over crashes, opposite direction sideswipe crushes, etc. than other road sections (Ali Aram, 20). Different opinions were found in terms of determining at which radius curve value the impact on road accident can reduce. For instance, Oecd (1976) suggested that the critical curve radius to reduce the impact on accident rates is 430 m and he concluded that the most accidents occur in curves are run-off accidents because of driving dynamic aspects. On the other hand, Glennon et al. (1985) pointed out that greater curve radii can increase the accident rates and costs and it was also concluded that road safety would decline when the road curve radius is above 400 m. To conclude, all studies have pointed out that there is a significant influence of curve radius on road accident rates and concluded that small radius curves are more associated with higher accident rates and severity, however different views were encountered in determining the curve radius value that can reduce the accident rates.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The following general conclusions were developed based on the findings of the study:

The study used Accident frequency method, Accident rate method, Critical accident rate and Empirical Bayesian methods to identify black spot locations at selected intersections. The analysis shows Semniyaand, Tekliye and Kudus Mikael intersections are identified as the hazardous junctions in the Shashemene town.

The study has developed crash prediction statistical models on investigated the effects of road intersection geometric design elements on traffic accident in Shashemene using crash counting model (Poisson log-linear regression and negative binomial regression) model based on five years crash records. Selected road geometric parameters in the study were: lane number, lane width, super elevation, gradient, and intersection sight distance, shoulder width, median type, and median width, angle of intersection, side walk width and curves radius. The study used eight representative road intersection to achieve the stated objectives using convenience sampling method from Shashemene town based on the requirements to obtain a sample of road intersection incorporating a different road geometric design elements.

The model shows that road traffic crash frequency in selected road junction in the town is influenced by lane width, super elevation, gradient, and intersection sight distance, shoulder width, median type, and median width, angle of intersection, side walk width and curves radius.

However, carriageway width, cross slopes or camber length of road intersection and median height were found statistically insignificant in the output of the model.

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 lanes and gradient positively affected road traffic crashes that occurred on the selected intersections. 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, lane width, super elevation, and intersection sight distance, shoulder width, median type, and median width, angle of intersection, side walk width and curves radius had negative coefficient. This indicates that as these variables increase the chance for potential crash risk is reduced.

5.2 Recommendation

Based on the 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 intersection.

- The Shashemene Town Road 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.
- Changing painted medians to raised medians is recommended since they were more effective on road safety than the painted median.
- Providing well-constructed sidewalk on the both sides of road segments for pedestrians.
- Providing Proper provision of sight distance
- Widening lane or carriageway width or shoulders up to a certain extent and Installing Medians
- Improving curve radius based on design vehicle and speed
- The transport authority should consider about road safety issues while designing the street, new project and the expansion of the existing road geometric design elements.

Based on the study, the following are recommended for future work

- Crash data used in this study did not have enough information for classifying crashes by movement type and direction of traffic. Such data, if available, can provide more detailed direction-specific analysis.
- Finally, in this study I have considered small size sample due to limitation of time frame and cost. Future studies should consider larger sample sizes and data from different areas in order to validate the results obtained in this study and evaluate their transferability to other locations.

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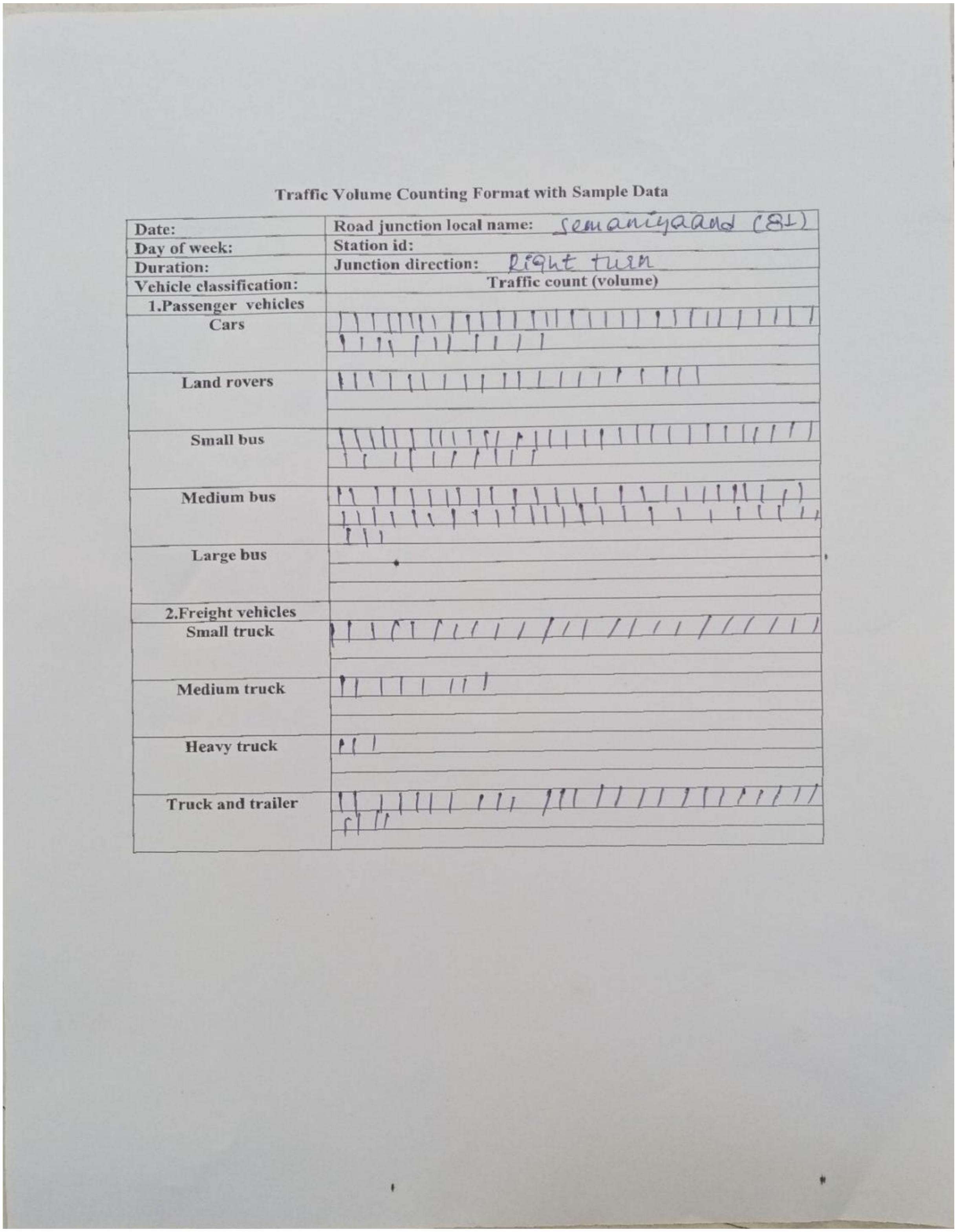
APPENDICES

Appendix I



Traffic Volume Counting Format with Sample Data

Date:	Road junction local name: Semaniyaand (SL)
Day of week:	Station id:
Duration:	Junction direction: Right turn
Vehicle classification:	Traffic count (volume)
1.Passenger vehicles	
Cars	
Land rovers	
Small bus	
Medium bus	
Large bus	
2.Freight vehicles	
Small truck	
Medium truck	
Heavy truck	
Truck and trailer	

Appendix II

Twelve -Hour Traffic Volume Counts Summary Format

Period	Time	Vehicle Type								
		Ca	L.R	S.B	M.B	L.B	S.T	M.T	L.T	T.T
MORNING	6:00-6:30									
	6:30-7:00									
	7:00-7:30									
	7:30-8:00									
	8:00-8:30									
	8:30-9:00									
	9:00-9:30									
	9:30-10:00									
	10:00-10:30									
	10:30-11:00									
	11:00-11:30									
	11:30-12:00									
AFTERNOON	12:00-12:30									
	12:30-1:00									
	1:00-1:30									
	1:30-2:00									
	2:00-2:30									
	2:30-3:00									
	3:00-3:30									
	3:30-4:00									
	4:00-4:30									
	4:30-5:00									
	5:00-5:30									
	5:30-6:00									
Total										

Appendix III

Road Geometry Inspection Checklist with Sample Data.

No	Black Spot Station ID:				
	Junction local name: Abosto			Leg local name: Shewaber	
1	Type	☑ One way	☐ Two way	☐ Three way	☐ Four way
2	Road layout	☑ Straight segment	☐ Vertical curve	☐ Horizontal curve	
3	Entry lane number	☑ Two	☐ Three	☐ Four	
4	Number approach of lanes	☑ Two	☐ Three	☐ Four	
5	Traffic Lane width	3.50 meter			
6	Presence of median	☐ Yes	☑ No		
7	Media type	☐ Flat	☐ Raised	☐ Flushed	
8	Median width				
9	Design speed				
10	Grade				
11	Super elevation				
12	Presence of channelization islands	☐ Yes	☑ No		
13	Channelization islands diameter				
14	Angle of intersection	90^0			

15	Carriageway width	7.10 meter				
16	Intersection sight distance	☐ Adequate	✓ No adequate			
17	Presence auxiliary lanes	☐ Yes	✓ No			
18	Auxiliary lanes width					
19	Presence of shoulder	✓ Yes	☐ No			
20	Shoulder width	0.75.0 meter				
21	Turning radius length	10.0 meter				
22	Cross slopes or Camber	1.7 %				
23	Pedestrian crossing	☐ Controlled	✓ Uncontrolled			
24	Foot path or Side walk width	1.10 meter				
25	Presence Parking lane	☐ Yes	✓ No			
26	Width of parking lane					
27	Obstruction	☐ Masts	☐ Signs	Trees	Stones	✓ Others
28	Message signing	Availability		State		
		☐ Yes	✓ No	Poor	Fair	Good
29	Message marking	Availability		State		
		✓ Yes	☐ No	✓ Poor	Fair	Good