EFFECT OF ROAD GEOMETRY AND SPEED ON ROAD SAFFTY AND IDENTIFICATION OF HAZARDOUS ROAD SECTION (CASE STUDY ON THE WUKRO-ADIGRAT-ZALAMBESA ROAD)

MSC THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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SCHOOL OF GRADUATE STUDIES

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This is to certify that the thesis entitled" **EFFECT OF ROAD GEOMETRY AND SPEED ON ROAD SAFFTY AND IDENTIFICATION OF HAZARDOUS ROAD SECTION (CASE STUDY ON THE WUKRO-ADIGRAT-ZALAMBESA ROAD)"** submitted in partial fulfillment of the requirements for the degree of **Master's** with specialization in **road and transport,** the Graduate Program of the **Department/School of civil engineering,** and has been carried out by **RAHMA AHMED EBRAHIM,** Id. No **PGRo/029/08**, under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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EFFECT OF ROAD GEOMETRY AND SPEED ON ROAD SAFFTY AND IDENTIFICATION OF HAZARDOUS ROAD SECTION (CASE STUDY ON THE WUKRO-ADIGRAT-ZALAMBESA ROAD)

RAHMA AHMED EBRAHIM

A THESIS SUBMITTED TO THE
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Name of the candidate: RAHMA AHMED EBRAHIM Department: **Civil Engineering**

School : graduate studies Specialization**: Road and Transport Engineering**

Thesis Title: Effect Of Road Geometry And Speed On Road Safety And Identification Of Hazardous Road Section (Case Study On The Wukro-Adigrat-Zalambesa Road)

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1. Comment on thesis preparation and defense

2. Suggestions made by Board of Examiners

3. Modification(s) to be made

4. Final decision by the Board of Examiners

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Name of Student : <u>Rahma Ahmed Ebrahim</u>

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DECLARATION

This thesis is my original work, has not been presented for a degree in any other University and that all sources of
material used for the thesis have been duly acknowledged.

Name: RAHMA AHMED EBRAHIM

Signature: ____________________

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ACRONYMS

AADT	Average Annual Daily Traffic
AMF	Accident Modification Factor
CSA	Central Statistical Agency
EB	Empirical bays
ERA	Ethiopian Road Authority
GDP	Gross Domestic Product
GLM	Generalized Linear Model
GRSP	Global Road Safety Partnership
HSM	Highway Safety Manual
NB	Negative Binomial
NMV	Non- Motorized Vehicles
PDO	Property Damage Only
PI	Potential Improvement
UNECA	United Nation Economic Commission for Africa
RSAR	Road Safety Annual Report
RTC	Road Traffic crash
RTI	Road Traffic Injury
SPSS	Statistical Package for Social Sciences
TRL	Transport Research Laboratory
WHO	World Health Organization

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ABSTRACT

In Ethiopia road traffic crashes are causing heavy loss of human and economic resources with the relatively low road network and motorization level. The risk is increasing with the increase in population, the road network expansion with little consideration of safety, and the increase in motorization with the vehicle fleet generally in poor conditions.This thesis deals with the most essential issue of road traffic accident related to geometric characteristics, flow and speed and identification of hazardous road section on the Eastern Tigray Zone (Wukro-Adigrat-Zela'ambesa) two lane road. The main objective of the study is to develop a prediction model for road traffic crashes occurring on a two lane road and to identify the hazardous road section.The study area has a total length of 96 km. Data such as crash data, traffic flow data, speed data, roadway characteristics and road geometry data was collected from offices and the site. Two models were developed one for the geometric characteristics of the road and flow model, the second for the speed model. The statistical analyses were performed using statistical software package SPSS version 20. The Generalized Linear Model (GLM) with Poisson regression and Negative Binomial (NB) the error structure was used to estimate the model parameters. From the two models the negative binomial model was fit to the data. The results show that number of vertical curve, number of vertical grade, no of horizontal curve, speed, shoulder width, were found to be statistically significant explanatory variables ($p < 0.05$) for crash involvement and when the crash rate relates to the speed it is statically significant for the crash rate. After calibration the model was validated using data from similar road on Mekelle-AbiAdi road. And the result has shown it is not validate on the similar road. For the identification of hazardous road section Empirical bays method was used. Results indicate that from the total 96 km road sections 25 sections were highly prone to accidents with PI EB values. Possible solutions are using traffic signs, user awareness campaigns, policy revisions, and permanent geometry and pavement modifications.

Keywords: Traffic Crash, Road geometry, speed, Crash prediction models, Hazardous road section and SPSS.

1. INTRODUCTION

In Ethiopia road traffic crashes are causing heavy loss of human and economic resources with the relatively low road network and motorization level. The risk is increasing with the increase in population, the road network expansion with little consideration of safety, and the increase in motorization with the vehicle fleet generally in poor conditions. Considering the severity of traffic crash problem, the importance of road transport in this country and the rate at which the road network is expanding, road safety is a vital issue to be addressed. (UNECA, 2009)

1.1 Background of the research

Road crashes kill about 1.3 million people worldwide every year and severely injure an estimated 50 million. Out of ten lives lost in traffic, nine are lost in low- and middle- income countries. But the number of road deaths is on the rise again even in some countries with impressive road safety improvements. The increasing share of vulnerable road users such as seniors, pedestrian, cyclists and motorcyclists that become victims of road traffic raises particular concerns. (RSAR, 2017)

Low-income and middle- income countries have higher road traffic fatality rates (21.5 and 19.5 per 100 000 population, respectively) than high-income countries (10.3 per 100 000). Over 90% of the world's fatalities on the roads occur in mortality low-income and middle-income countries, which have only 48% of the world's registered vehicles (WHO, 2015).

In Ethiopia also shows that about 3% of Ethiopian population meets traffic crash and this is equivalent to about 3 million people who meet traffic crash in 2015. There is almost the same in the involvement of road traffic crash in the urban (2.8%) and rural (2.6) %roads.(Bekele,2015)

1.2. Statement of the problem

Road traffic accident in Ethiopia is a cause of significant losses of human and economic resources. Ten years ago police reported traffic crash in Ethiopia was (2007/8),15,086, which caused the losses of 2,161 lives and over ETB 82 million equivalent to US$7.3 million cost estimate of property damage by police (UNECA, 2009). But traffic crash is doubled after ten years to 36,636 in 2016. It would be impossible to attach a value to each case of human sacrifice and suffering, add up the values and produce a figure that captures the national social cost of road crashes and injuries. However, the economic costs of road traffic accidents are, evidently, a heavy burden for the national economy.

In the Tigray region also the number of RTCs increased annually 800 crashes in 2013/2014 to 1088 in 2015/2016 and 2904 a total RTCs on the past 3 years. From this 782 fatal, 917 serious injury 170 slight injuries and 1035 PDO were recorded by Tigray Regional traffic police commission. Consequently in the Eastern Tigray zone (Wukro-Adigrat-Zela'ambesa) 411 total RTCs from 2013/2014 up to 2015/2016 in the past 3 years.

Hence, the issue of RTCs on Eastern Tigray zone is worthy of investigation since research on the specific area is not conducted in the study zone and the researcher observes serious and recurrent traffic accidents that result in fatal ,serious, slight injuries and property damage involves loss of life repeatedly. In the past 3 year period accident in this segment is also about 10 % of the total accident in Tigray region.

Even though training and awareness is given by traffic police officers and related authorities to the public the rate of Road Traffic Accident alarmingly increases ahead of time. Crash Prediction Models (CPMs) have been used elsewhere as a useful tool by road Engineers and Planners. There is however no study on the prediction of road traffic crashes on The Wukro-Adigrat- Zela'ambesa rural highways .Therefore the result of this study could provide statistical evidences and will serve as baseline information to undertake studies on similar setting, helpful in raising awareness for Highway Engineers, drivers, pedestrians and passengers and making causes and consequences of road traffic accident more visible to policy makers traffic police and other concerned bodies. It also may help to contribute in filling gaps on the existing road traffic regulation and implementation practices in the country.

1.3. Objectives of the study

1.3.1. General Objective

The main objective of the study is to develop a prediction model for road traffic crashes occurring on the two lane trunk road and to identify the hazardous road section by using Empirical bays method.

1.3.2. Specific Objectives

- ✓ To correlate geometric design of the road, speed and flow rate with road traffic crash.
- ✓ To identify the most important road traffic crash variables.
- ✓ To identify the best fit model to analyze the road traffic crash.

- ✓ To explore the nature and characteristics of accidents on Eastern Tigray Zone road.
- ✓ To identify locations with high number of road traffic accidents (black spot) areas.

1.4 Scope of the study

This study focuses on the geometric characteristics that significantly affects crash rate on the two lane rural and urban trunk road in Eastern Tigray zone(Wukro-Adigrat- Zela'ambesa).

- ✓ Coverage**:** The present study is for rural and urban two-lane roads in Eastern Tigriay zone (Wukro-Adigrat-Zela'ambesa) which is approximately 100 KM and each segment lengths has1KM and total number of segment is 96. Requisite data on crashes, geometric and traffic were collected for each segment.
- ✓ Geometric Characteristics: The study investigated specific characteristics such as lane width, shoulder width, number of horizontal curve, driveway density, and number of vertical curve/grade.
- ✓ Speed data; using a case control method spot speed data was collected for 24 sections from the total 96 sections.

1.4 Thesis Organization

This thesis is organized into five chapters. The first chapter consists of background of the study, objectives of the research, statement of the problem, scope of study and structure of the thesis. The second chapter presents the previous findings of the literature review on the topic. It provides information on theories, models, and techniques used in this research. Chapter three explains the research methodology clearly and in detail about how this research was conducted, which includes gathering of information and data, as well as processing and analysis of data. Chapter four consists of the results obtained from the research. Chapter five consists of the conclusions and recommendations, the writer draws conclusion for the whole research based on the findings of the results and linking it with the aim and objectives of the research.

1.5 limitations

There was some limitation during investigation in this study. There was no radar for measurement of the spot speeds therefore the measurement of the speed was done measuring the distance and time. Another limitation was the difficulty of locating traffic crashes recorded by traffic police office on specific road segments. The developed crash prediction model was validated for only the blackspot areas of from Mekelle-Abiadi road due to data limitations.

2. LTERATURE REVIEW

The literature reviewed in this thesis focuses on the objectives presented in Chapter 1. The various causal factors affecting crash rate have been reviewed from various literatures and discussed below.

2.1. Magnitude of Road Traffic Crash in Africa

In many researches Africa has the world's highest death rate per population (28.3 per 100,000 of the population when corrected for under-reporting). Road traffic deaths and injuries impose a huge economic burden on developing economies, amounting to 1-2% of GDP in most countries. (UNECA, 2009)

As WHO,2015 also stated that Africa has the highest road traffic fatality rate per 100,000 population.

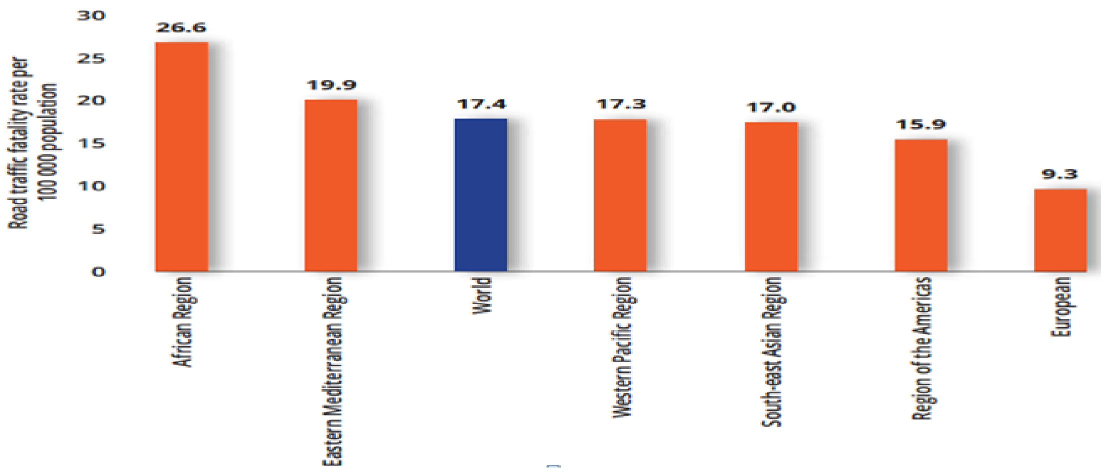


Figure 2.1. Road traffic fatality rate per 100,000 population.

Source: WHO Global status report on road safety 2015

Like many low-middle-income countries, Ethiopia has an unacceptably large number of road traffic deaths, with approximately more than 25 people per every 100,000 people killed in road crashes. Although Ethiopia has extensive road safety legislation, enforcement is low and there is no application of vehicle standards promoting safety features.(WHO ,2015)

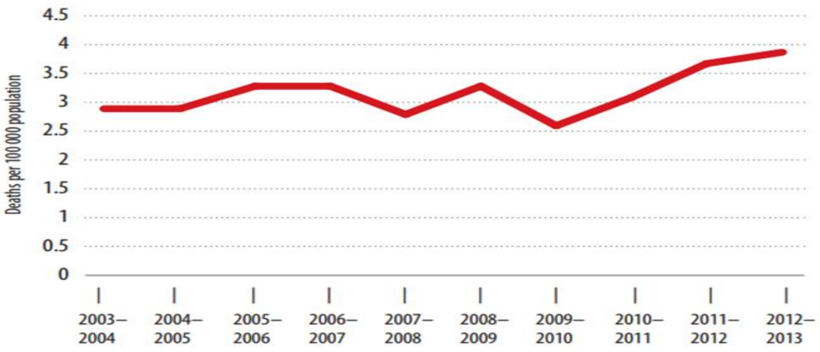


Figure 2.2.Trends in reported traffic death in Ethiopia

Source: WHO, 2015

Another research also shown that the rate of road traffic crash (RTCs) in Ethiopia is very high; because of road transport is the major transportation mechanism along with poor road infrastructure, poor enforcement of traffic laws and other factors (Debebe, 2014)

2.2 Review of Traffic crash related to ,flow and Geometric characteristics and speed

- ✓ **Relationship between Traffic crash and speed**

Research has shown that the greater a vehicle speed deviation is from the average speed, the greater the probability of that vehicle being involved in a crash. This relationship is often referred to as being "U-shaped" and has been verified in research (Durham, 1970). Another study has found that speed variance decreases as the average speed increases. They also found that the average speed is dependent on the design speed, and therefore speed variance is also dependent on the design speed. A study in France was performed by Lassarre also in which models were developed for predicting the severity of crashes based on traffic volume, speed, standard deviation of speed, and the wearing of seat belts In this study, the models indicate that only a small influence upon safety is brought about by changes in average speeds(Garber and Ravi, 1988).And a study in Virginia also shows that an increase in the crash rate as the standard deviation of speed increases(Nicholas and Garber,2009).

- ✓ **Relationship between Traffic crash and flow**

The available literature shows that there is a positive relationship between traffic accident and traffic volume i.e crash rates should increase with increasing volumes. Previous research on the relationship between crash rates and hourly traffic volume has indicated a "U"-shaped function encompassing broad ranges of traffic volumes. This indicates that during low volume periods, such as those that occur during the early morning and late day hours, higher crash rates are observed than when the volumes of the road are greater.(Gwynn and David

,1967). Another study found that a slight decrease in the crash rate as the flow per lane increases, although this effect is not very significant.(Nicholas and Garber,2009)

- ✓ **Relationship between traffic crash and Geometric Characteristics**

Study on the Washington shows that relationship between the number of lanes and the crash rate has been developed, which suggests that as the number of lanes increases, the crash rate decreases(Lundy, 1965).results have also been found for the relationships between crash rates and lane widths. Based on the results of an extensive literature review on the safety aspects of two-lane roads, an inverse relationship was found between crashes and pavement width in that crash rates tend to decrease with increasing pavement width (Choueiri, and et al,1994). In the Addis Ababa- Shasemene road also shows that 52 % of the accidents occurred at tangent and level sections of the road similarly, 48 per cent occurred on horizontal curves or grades. This is associated with speed limit violation. The results of the study indicated increase in accident with grade and sharpness of curves. ADT, numbers of lanes and grade have positive relationships with accident rates i.e. the section with less traffic, lanes and grades resulted in less accident rates whenever these variables increased. Whereas, sharp curves resulted in highest accident rate as compared to gentle curves. However, the number of lanes increased with that of accident rates because of the non existence of pedestrian facilities in town sections. (Segni, 2007).

2.3 Review Crash Prediction Modeling

Crash prediction models, typically developed from statistical analysis of historical crash data, are used to predict the expected number of crashes at any specific road segment, and can also be used to derive crash reduction factors that measure the effectiveness of safety countermeasures. Prerequisite to crash modeling include developing a crash database (with roadway characteristics such as traffic volumes, geometric design features, traffic control features, and crash history), selecting an appropriate functional form, and using regression analysis to estimate the values of the model parameters(Samuel, 2006).With regard to the model form and parameter estimation method, a review of available literature revealed that three main model types (Poisson, Negative Binomial, and Non-linear) have been used in the past for crash prediction modeling.

2.3.1 Poisson Models

Poisson regression is one of the most suitable techniques for crash prediction modeling because highway crashes are discrete rare events and crash counts are non-negative integer variables. Poisson regression models also provide an easy linkage between crash occurrence and the concept of probability. This is because the number of crashes in a given space-time region can be considered as a random variable with probabilities that are Poisson distributed.

Poisson model has been used in a number of studies. Miaou et al. [1993], for example, used a Poisson model to estimate the frequency of truck crashes along a set of highway segments. Another group of researchers, Saccomanno et al. [2001], developed a Poisson model for estimating expected crash frequency along a highway section in southern Italy. For the Saccomanno model, the "section length" variable was used to represent crash exposure due to uniformity of AADT over the entire road length. Although all the variables in the model were found to be significant at the 5% significance level, the obtained scale-deviance of230.35 for the model suggests a fair degree of Poisson over dispersion in the crash data. This implies that a large number of the section-specific crash frequencies remain unaccounted for by the model.

Thus the Poisson model form may not provide a complete picture of the long-term crash occurrence at highway segments when over dispersion exists in crash data. This seems to support arguments proffered by critics of the Poisson approach who have suggested that the underlying Poisson assumption that the mean equals the variance is unduly restrictive because in reality, the estimated variance-to-mean ratio typically exceeds unity (that is, 1.0). In the present study therefore, Poisson models were not used for the crash prediction modeling except in cases where the numbers of observations are very small, such as fatal crash frequencies(Samuel , 2006).

2.3.2 Negative Binomial Models

As noted in the preceding sub-section, a weakness of the Poisson approach is the unduly restrictive assumption that the mean and the variance of crash distribution are equal. In most crash data, however, it is seen that the variance is greater than the mean, giving rise to the over dispersion phenomenon. To address this problem, the Negative Binomial model, a variant of the Poisson, has often been proposed for crash prediction modeling. The Negative Binomial model allows for additional variance representing the effect of omitted variables.

In a study for Indiana, Brown et al. [1998] developed crash prediction models for crash rates on road segments based on geometric and access control characteristics. The data used for that study was from the Indiana crash and road inventory database covering the period 1991 to 1995. In the Brown study, over dispersion factors of 1.049, 1.157, and 1.105 were obtained for total crashes, fatal/injury and PDO models, respectively. The study concluded that the number of crashes on roadway segments increases as the access density and proportion of signalized access points increase. Also, the presence of an outside shoulder, two-way left-turn lane, or median without openings between signals were found to be associated with lower crash numbers.

For intended use in the crash prediction module of FHWA's Interactive Highway and Safety Design Model (IHSDM), rural two-lane highway crash prediction models were developed by Vogtand Bared [1998]. The model was developed using an "extended" negative binomial regression analysis of data from 619 rural two-lane highway segments in Minnesota and 712 roadway segments in Washington. An advantage of the extended negative binomial model is that it permits local variation along a roadway to be taken into account so that crashes occurring on sub-segments with invariant geometric conditions are considered separately. Considered a better alternative to summing all the local effects or averaging them over an entire segment, the ENB modeling technique offers scale independence of the model form thereby allowing segment decomposition into sub-segments or aggregate adjacent segments without any changes to the model form. The variables found to have significant influence on crashes were lane width, shoulder width, roadside hazard rating, driveway density, degree of horizontal curvature, vertical grade and traffic exposure. The model had a high predictive power and explained 65% of the variation in the dataset. An over-dispersion factor of 0.33was obtained for the model suggesting a good fit. Other variables that were investigated included posted speed limit, truck percentage, and intersection density (i.e., number of intersections per mile).Posted speed limit was found to be negatively correlated with crash frequency while truck percentage and intersection density were positively correlated with crash frequency. None of these three variables were statistically significant at 95% level of confidence.

In a subsequent review of the Vogt and Bared model, Harwood et al., [2000] averred that the model could be calibrated and adapted for use in all the states. The present study adopted a similar but modified technique: as much as possible, sections were chosen such that within each section there was reasonable constancy of geometric features. Then each section was treated as an observation in the modeling dataset. The present study considered the use of the Negative Binomial model for injury, PDO, and "total" crash analysis. For fatal crashes, the Poisson model was used.

2.3.3 Non-Linear Models

Zegeer et al. [1986] developed non-linear crash models using crash, traffic, roadway, and roadside data collected on 1,944 road sections covering 4,951 miles of rural two-lane roads in seven states. The purpose of that study was to quantify the benefits of lane widening, shoulder widening, side slope flattening etc. The model was developed for single vehicle crashes, head-on crashes, and sideswipe crashes (of same and opposite directions).

The least-squares approach was used to estimate the regression coefficients. This was based on the assumption that the residuals would follow a normal or log-normal distribution. However, because crash distributions are typically skewed to the right, normality of the residuals may not be a tenable assumption for crash prediction models(Samuel L, 2006).

2.3.4 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 [Hauer et al., 2002]. The EB model assumes that the number of observed crashes on a 23 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 amore 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 models. The Bayesian adjusted/estimated number of crash involvement per year is expressed as a combination of the estimated/predicted number of crashes, E(m)I and the observed number of crashes (Xi) as follows:(Highway Safety Manual[HSM), 2000)

$\text{N expected} \;=\; \text{w x N predicted} + (1 - \text{w}) \text{ x N observed} \ldots\ldots\ldots$equation (1)

$\text{w} \;= \dfrac{1}{1 + \text{k} \times (\sum_{\text{all study years}} \text{N Predicted})} \ldots\ldots\ldots$equation (2)

Where,

k = over dispersion parameter from the associated SPF $(\text{k} = \frac{0.236}{\text{L}})$ L= segment length

N expected = expected average crashes frequency for the study period.

N predicted = predicted average crash frequency predicted using a SPF for the study period under the given conditions.

w = weighted adjustment to be placed on the SPF prediction.

N observed = observed crash frequency at the site over the study period

2.4. Black spot identification

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

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).

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, Frequency-Rate Method, Crash Severity Method, Safety Indices, Severity-Rate Method, Rate-Quality-Control Method, and Bayesian Approach. Each of these methods is explained in the following sections.

- **Crash Frequency Method**

The Crash Frequency Method summarizes the number of crashes by location. The main advantage to this method is that it is simple to use and doesn’t require additional information beyond number and location of crashes. Locations are ranked by descending crash frequency and those with more than a predetermined number of crashes are classified as high-crash locations to be further scrutinized for statistical significance (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997). It is useful initially to identify locations for further analysis and ranking. The main disadvantage is that exposure (traffic volume) is not accounted for. Without being able to account for variations in traffic volume, locations that have high crash frequency due to high traffic volumes rather than some deficiency may be misidentified as high crash locations (Homburger et al., 1996; Traffic Institute, 2000). The Crash Frequency Method tends be biased towards high traffic volume locations (Layton, 1996; McMillen, 1999).

- **Crash Density Method**

The Crash Density Method is closely related to the crash frequency method, the crash density method summarizes the number of crashes per mile for highway sections. Sections are defined as a minimum length of roadway with consistent characteristics, with the minimum distance used frequently being one mile. Locations are ranked by descending crash density and those with more than a predetermined density of crashes are classified as high-crash locations to be further scrutinized for statistical significance (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997; Ogden, 1996).

- **Crash Rate Method**

The crash rate method does account for both exposure and the total number of crashes. For links, crash rate is a function of the number of crashes, traffic volume, and the length of the segment. At nodes, crash rate is a function of the number of crashes and daily entering vehicles. Crash rate is typically expressed as the number of crashes per million vehicle miles travelled for road segments and number of crashes per million daily entering vehicles for intersections (Homburger et al., 1996; Traffic Institute, 2000).

The main advantage of this method is that locations with a disproportionate number of crashes in relationship to volume can be identified avoiding the bias towards high volume roadways. However, locations with only few crashes but low volumes will result in high crash rates. As a result, this method may be biased towards low volume roadways (Layton, 1996; McMillen, 1999).

- **Frequency-Rate Method**

This method is a combination of the Crash Frequency and Crash Rate Methods. Locations are first ranked by Crash Frequency and the worst locations re-ranked using Crash Rate (Homburger et al., 1996; Traffic Institute, 2000). The rational of combining Crash Frequency and Crash Rate is to eliminate or minimize the bias of the two individual methods (Traffic Institute, 2000; McMillen, 1999). The frequency-rate method is a combination of crash frequency/crash density methods and the crash rate method. Locations are classified as high-crash locations if they have more than the prescribed minimum crash frequency or crash density and higher than the minimum crash rate. The crash frequency/crash density methods and the crash rate methods have deficiencies that limit their effectiveness. However, if these methods are combined, as they are in the frequency-rate method, it appears possible to eliminate or minimize the effects of the deficiencies (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997; Ogden, 1996).

- **Crash Severity Method**

The Crash Severity Method accounts for monetary losses of crashes by considering and then weighting crashes at a location based on the resulting degree of injury (Layton, 1996). Fatal and injury crashes are usually weighted more heavily than possible or minor injuries and property damage only (PDO) crashes. This allows severity of accidents to be considered.

Safety agencies and the general public are often most concerned with severe crashes. The main advantage of this method it is frequently biased towards locations with major injuries and fatalities (McMillen, 1999). Targeting safety funds toward improvements to reduce the most serious accidents may result in significant benefits.

The main disadvantage is that this method is likely to rank locations with a single fatality or major injury over those with numerous but less serious accidents. A location with a single fatal crash resulting from driver error rather than roadway features would be ranked higher than a location with numerous minor injury or property damage only crashes, resulting in poor allocation of resources. Fatalities, in particular, may overwhelm the process. This method may also favour rural areas (Layton, 1996).

- **Safety Indices**

Tamburri and Smith introduced the concept of a Safety Index. The concept is based on the idea that locations with severe crashes deserve more immediate improvement but recognizes that due to the random nature of crashes, a certain number crashes are “expected”. In this method, each road type is assigned an “expected” mix of crash severity (i.e., each roadway type is considered to have a certain percentage of fatalities, a certain percentage of injuries, and a certain percentage of PDO crashes). A weight is also assigned to each severity for each road type (Tamburri and Smith, 1970).

Taylor and Thompson (1977) have suggested a ranking approach that uses a hazard index for each location. The index is a weighted sum of the following factors: crash frequency, rate, severity, volume-to-capacity ratio, sight distance, conflicts, erratic maneuvers, and driver expectancy. The weights assigned each variable were proposed by state highway safety personnel.

- **Severity-Rate Method**

This method combines the Crash Severity and Crash Rate methods and has been considered to be the most meaningful method by various state and local agencies. In this method, an equivalent property damage only (EPDO) number is calculated (as in crash severity method) and then divided by volume (e.g., MEV or MVM) to obtain an EPDO rate for each location (Stokes, 1996).

- **Rate-Quality-Control Method**

The rate quality control method consists of a simple statistical test that is applied to the crash rate at a particular location (intersection/roadway) to determine whether it is significantly different (abnormally high) than the average crash rate of other similar locations (Homburger, 1996; Traffic Institute, 2000; Layton, 1996). The critical crash rate is determined using the following:

$$\mathrm{Rc} = \mathrm{Ra} + \mathrm{K} * \sqrt{\frac{\mathrm{Ra}}{\mathrm{M}}} + \frac{1}{2\mathrm{M}} \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (3)}$$

where

Rc = Critical crash rate

Ra = Average crash rate for locations of similar characteristics

M = Millions of vehicle miles (MVM) for segments or millions of total daily

entering vehicles (MEV) for intersections

K = probability constant based on the desired level of significance

This equation is based on the assumption that traffic crashes are Poisson distributed (Traffic Institute, 2000). If the actual crash rate of a location is greater than the critical crash rate, it is considered to be a high crash location (Hauer, 1996; Barbaresso et al., 1982). This method recognizes the variation in the occurrence of crashes for both low and high volume roadways.

The main disadvantages are that it does not address crash severity (McMillen, 1999) and by only comparing locations to other locations with the same physical characteristics, safety problems inherent to those physical characteristics are masked.

- **Empirical Bayes Method**

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

2.6 Summary

Road traffic injuries claim more than 1.2 million lives each year and have a huge impact on health and development. They are the leading cause of death among young people aged between 15 and 29 years, and cost governments approximately 3% of GDP (WHO,2015).

Research has shown that the greater a vehicle speed deviation is from the average speed, the greater the probability of that vehicle being involved in a crash. This relationship is often referred to as being "U-shaped" and has been verified in research(Durham, 1970).The available literature shows that there is a positive relationship between traffic accident and traffic volume i.e crash rates should increase with increasing volumes. Previous research on the relationship between crash rates and hourly traffic volume has indicated a "U"-shaped function encompassing broad ranges of traffic volumes. This indicates that during low volume periods, such as those that occur during the early morning and late day hours, higher crash rates are observed than when the volumes of the road are greater(Durham, 1970).Study on the Washington shows that relationship between the number of lanes and the crash rate has been developed, which suggests that as the number of lanes increases, the crash rate decreases(Lundy R, 1965).

Crash prediction models, typically developed from statistical analysis of historical crash data, are used to predict the expected number of crashes at any specific road segment, and can also be used to derive crash reduction factors that measure the effectiveness of safety countermeasures. Prerequisite to crash modeling include developing a crash database (with roadway characteristics such as traffic volumes, geometric design features, traffic control features, and crash history), selecting an appropriate functional form, and using regression analysis to estimate the values of the model parameters(Samuel L, 2006).With regard to the model form and parameter estimation method, a review of available literature revealed that three main model types (Poisson, Negative Binomial, and Non-linear) have been used in the past for crash prediction modeling.

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

3. RESEARCH METHODOLOGY

3.1 Description of the Study area

The study was conducted in the northern highlands of Ethiopia in East Tigray zone (Misrakawi zone) in Tigray Regional State, traversing through KilteAwlalo, SaesiTsaedaem, Ganta Afeshum and GuloMekheda woredas. It serves directly these four woredas and indirectly further three of the seven woredas in the Eastern zone.

As shown in the Figure below, altitudes are ranging from around 2,100 m at Wukro to about 2,750 m at IdagaHamus (~km 46.5), 2,400 - 2,500 meter near Adigrat (km 61.5 - 67.2) to about 2,400 near Zalambesa (km 100).(Era, Northern district, (2010))

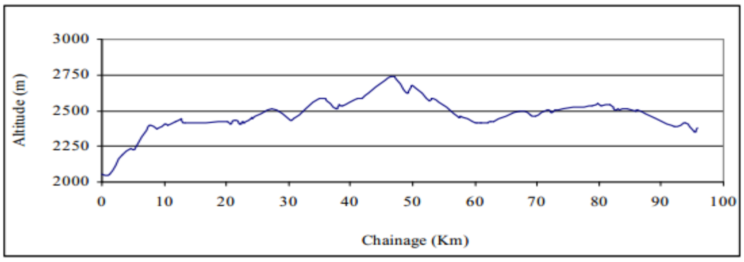


Figure 3.1 longitudinal profile of the road

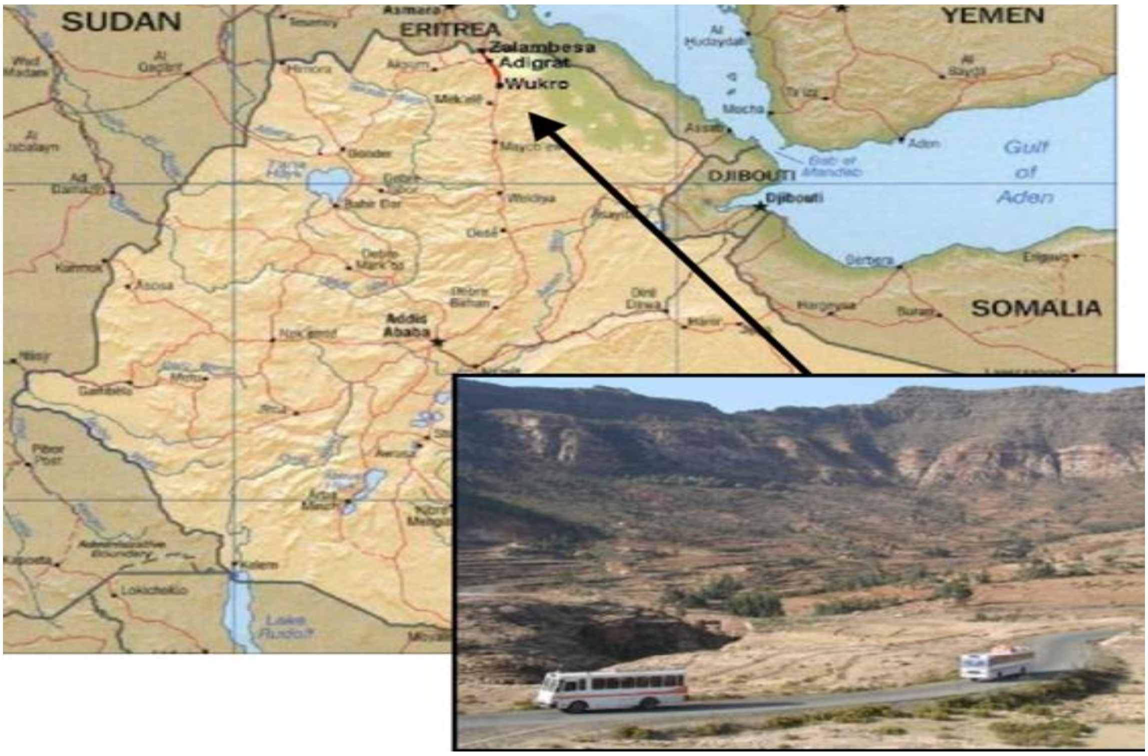


Figure 3.2 .map of the study area

Source: Google map

3.2 Data Collection

In order to achieve the objectives of the study, both primary and secondary data was used. The necessary reliable data that was collected are crash data, road data, traffic data, and speed data.

3.2.1 Crash data

The crash data for three different year (2013/14-2015/16) was collected from Tigray Regional Traffic Police commission. The crash data contained descriptions on the following:.

- Date, day and time of accident,
- Vehicle type and ownership,
- Driver sex, age and education,
- Weather, road, and illumination condition,
- Accident type,
- Degree of severity, and
- Number of victims (driver, passenger, and pedestrian), sex, age, severity; and
- Location of accident.

3.2.2 Traffic Data

Traffic studies will be required to determine current and future traffic volume AADT expected to use the different road section of the road project, on other hand the purpose of traffic study on this research is important predict accident rate and identify the black spot location in different road section.

3.2.3. Road Data

The road factors being investigated in the geometric design includes horizontal curvature, road width, shoulder width, and grade of the road. Road data is available the Ethiopian Roads Authority as-built drawing of the road plan and profile. These will be substantiated through actual measurements and visual inspection, which will be made on the road site. The gathered road data consisted of:

- ✓ Lane width
- ✓ Shoulder width
- ✓ Section length
- ✓ Horizontal curvature(no of horizontal curve per KM)
- ✓ Vertical alignment (no of vertical curve/grade per KM)

- ✓ Access point per Km
- ✓ Median width

3.3.4 Speed data

A case-control study design, define as the speeds of cars involved in casualty crashes were compared with the speeds of cars not involved in crashes but travelling in the same direction, at the same location, time of day, day of week, and time of year. The conditions imposed on the selection of case vehicles were designed to ensure that the study would yield valid estimates of the relative risk of a car travelling at a free speed in a 60 km/h zone becoming involved in a casualty crash compared to the risk for a car travelling at 60 km/h. (Kloeden and et al., 1997)

The control speed will be measured using video cameras. Methods of conducting the spot speed data were using Stopwatch method because there was no Radar in the study area. Procedures for the collecting spot speed data were

- Measure a length of the selected location with the help of tape
- Fix the stop watch or video camera at centre of the section to Observe both ends of the section at which the observer can see
- Draw two lines across the road by using chalk
- Start stopwatch when the vehicle crosses the line and stop when it crosses the last line at the mark.

Finally we have distance and time we can simply get the spot speeds in the selected section.

3.3 Choice of variables

3.3.1Choice of Response Variable for the Models

On the basis of the form of response variable, past studies on roadway crash prediction can be broadly classified into two groups: those that used crash rates and those that used crash frequencies but in this thesis crash rate were used.

Crash rate are expressed as crashes per unit exposure, such as crashes per mile, crashes per traffic volume, or crashes per vehicle-miles-of-travel

$$Crash\ rate(MVM) = (Number\ of\ crash) * 〖10〗^6)/(AADT * length * year \ldots\ldots \text{Equation (4)}$$

3.3.2 Choice of Independent Variables for the Models

The independent variables for developing the crash prediction model can be categorized as follows:

- ✓ Exposure: One of the most important independent variables affecting crashes at two lane roads is the volume of vehicular traffic (often represented by AADT).
- ✓ Geometric Characteristics: Road geometry is also an important variable that affects crash occurrence on rural two-lane roads. Geometric variables that were considered include the following:
  - ✓ Lane width
  - ✓ Shoulder width
  - ✓ Section length
  - ✓ Horizontal curvature(no of horizontal curve per KM)
  - ✓ Vertical alignment (no of vertical curve/grade per KM)
  - ✓ Access point per Km
  - ✓ Median width

3.4 Choice of Model Form

The choice of model form for statistical modeling typically depends on the nature of the response variable and its relationships with the explanatory variables. Linear models have been found to be unsuitable for crash modeling because of the non-negative and discrete nature of crash data.

Model forms such as the Poisson and negative binomial models have become well accepted for modeling discrete rare events such as crash occurrence (Miaou et al.,1993).

The Poisson Model and negative binomial for Predicting Fatal and total injury Crash rate was used.

There are two strong assumptions for Poisson model to be checked: one is the events that occur independently over time or exposure period, the other is the conditional mean and variances are equal. In practice, counts have greater variance than the mean are described as over dispersion. This indicates Poisson regression is not adequate. There are two common causes that can lead to over dispersion: additional variation to the mean or heterogeneity, a negative binomial model is often used. The general form of the Poisson probability function is given by(Getahun ,2015).

$p(yi) = \frac{-e^{\mu i} * \mu i^{yi}}{y!}$ …………… Equation (5)

$$Yi = 0,1,2 \ldots \ldots$$

Where, $\mu > 0$ represents the expected number of occurrences in a fixed period of time. The mean and variance of the Poisson regression model is given as follows:

$E(yi) = var(yi) = \mu i$…………… Equation (6)

This model is known as the Poisson regression model or log-linear model. To find the maximum likelihood function of , we define the likelihood function as follows:

Taking log on both sides and we get :(Getahun ,2015).

$\prod_{i=1}^{n} \frac{-e^{\mu i} * \mu i^{yi}}{y!}$ …………… Equation (7)

The limitation of the Poisson regression model is that the mean and variance of the outcome variable is not identical. Another alternative solution to overcome this problem is negative binomial regression model. It is obtained from the mixture of Poisson and Gamma distribution called Poisson-Gamma distribution. Negative binomial model allows extra variation, relative to the standard Poisson model. In this case the variance of negative binomial model is significantly greater than the mean.

The general form of the Poisson probability function is given by(Getahun ,2015).

$$f(y_i;\mu_i,\delta) = \frac{\Gamma\left(y_i + {}^{1}/_{\delta}\right)}{\Gamma\left({}^{1}/_{\delta}\right) y_i!}(1 + \delta\mu_i)^{-1/\delta}\left(1 + \frac{1}{\delta\mu_i}\right)^{-y_i}, \; y_i = 0, 1, 2, \ldots$$

with mean and variance, respectively, given by:

$E(Y_i) = \mu_i = exp(x_i^T \beta)$, and $Var(Y_i) = \mu_i(1 + \delta\mu_i)$ …………… Equation (8)

The term (read as delta) is called the dispersion parameter and assumed not to depend on a covariate. If the dispersion parameter then the negative binomial model reduces to the classical Poisson model. The likelihood function of the negative binomial model based on a sample of independent observation is given by:

$$\ell(\mu_i, \delta; y_i) = \prod_{i=1}^{n}\left(\frac{\Gamma\left(y_i + \frac{1}{\delta}\right)}{\Gamma\left(\frac{1}{\delta}\right) y_i!}(1 + \delta\mu_i)^{-1/\delta}\left(1 + \frac{1}{\delta\mu_i}\right)^{-y_i}\right)$$ …… Equation (9)

and the log-likelihood function is

$$\mathcal{L} = log \;\; \ell(\mu_i, \delta; y_i)$$

$$= \sum_{i=1}^{n}\left\{-\log(y_i!) + \log\left(\frac{\Gamma\left(y_i + \frac{1}{\delta}\right)}{\Gamma\left(\frac{1}{\delta}\right)}\right) - \frac{1}{\delta}\log(1 + \delta\mu_i) - y_i\log\left(1 + \frac{1}{\delta\mu_i}\right)\right\}$$

3.5 Hypothesis Tests for Significance of the Variables

For each developed crash prediction model, the statistical significance of each variable was tested at a95% level of confidence. This was done to investigate whether any specific variable significantly influences crash occurrence at the specified degree of confidence. Because the reported crash rate are average values over a stretch of road section, the distribution of crashes was considered as sampling distributions of means, and the population of crash frequencies was assumed to be normally distributed. Taking βi as the estimated coefficient of any crash factor or variable i, the hypothesis for testing the significance of that variable was formulated as follows:

H0: $\beta i = 0$ (variable coefficient is statistically equal to 0, i.e., variable iis not significant)

H1: $\beta i \neq 0$ (variable coefficient is statistically not equal to 0, i.e., variable iis significant)

This is a two-sided hypothesis test with the "rejection regions" in the lower and upper tails. Therefore, the critical value of the test statistic is $Z\alpha/2 = Z0.025= 1.96$

3.6 Methods of Analyses

After collecting the necessary information, data processing and interpretations was done using Statistical Package for Social Sciences (SPSS) software. The black spot area was be identify by using EB method to select the exact hazardous location.

Hauer (1997) proposed two EB methods these are

1) Method of sample moment and

2) Method of multivariate regression.

In the first method, a simple sample mean is used to estimate the value of N predicted (also referred here as mean) and Var (N) (also referred here as variance of N predicted) which together are used to determine the weight . While this method is simple to apply with very few assumptions made, however, it does not, account for possible effects of safety related factors that could explain variation in crashes between sites.

This issue was addressed by using the second method of regression approach. This approach takes into account of effects due to site-specific factors by developing their relation with crash frequency. All steps are from highway safety manual (High way safety manual (HSM), 2008).

To predict crash rate Poisson distribution and negative binomial method was used and select the best model. P-value below 0.05 (95% confidence interval) was considered as statistically significant for the crash rate.

Step 1 predicted average crash frequency for base condition

$\mathrm{Nspfrs} \;=\; \mathrm{AADT} \times \mathrm{L} \times 365 \times 10^{-6} \times \mathrm{e}^{(-0.312)}$.............. Equation (12)

Where,

Nspfrs= estimated total crash frequency for roadway segment base conditions;

AADT = average annual daily traffic volume (vehicles per day);

L = length of roadway segment (miles).

Table 3. 1: base condition

Source: highway safety manual

Input data	Base condition
Lane width	3.66 m
Shoulder width	1.83 m
Shoulder type	Paved
Length of horizontal curve	0
Radius of curvature	0
Spiral transition curve (present/not present)	not present
Super elevation variance	<0.01
Grade (%)	0
Driveway density (driveways/mile)	5
Centerline rumble strips(present/not present)	not present
Passing lanes (present/not present)	not present
Two-way left-turn lane (present/not present)	not present
Roadside hazard rating (1-7	3

Step 2 Accident modification factor for each road parameter

Accident Modification Factors (AMFs) are used to adjust the SPF estimate of predicted average crash frequency for the effect of individual geometric design and traffic control features, as shown in the general .The AMF for the SPF base condition of each geometric design or traffic control feature has a value of 1.00. Any feature associated with higher crash frequency than the base condition has an AMF with a value greater than 1.00. Any feature associated with lower crash frequency than the base condition has an AMF with a value less than 1.00. (HSM, 2008)

Step 3 calibration factor

The general level of crash frequencies may vary substantially from one jurisdiction to another for a variety of reasons including climate, driver populations, animal populations, crash reporting thresholds, and crash reporting system procedures. These variations may result in some jurisdictions experiencing substantially more reported traffic accidents on a particular facility than in other jurisdictions. In addition, some jurisdictions may have substantial variations in conditions between areas within the jurisdiction (e.g. snowy winter driving conditions in one part of the state and only wet winter driving conditions in another part of the state)

$\mathrm{Cr} = \frac{\sum_{\text{all site}} \text{observed crash}}{\sum_{\text{all site}} \text{predicted crash}}$.............. Equation (13)

Cr=calibration factor

Step 4 predicted average crash frequency

$$\text{N predicted rs} = \text{N spf rs} \times \text{Ci} \times (\text{AMF1r} \times \text{AMF2r} \times \ldots \times \text{AMF12r})$$

Where,

N predicted int= predicted average crash frequency for an individual roadway segment for the selected year;

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

Cr= calibration factor for roadway segments of a specific type developed for a particular jurisdiction or geographical area;

AMF1r …AMF12r = Accident Modification Factors for rural two-way two-lane roadway segments

Step 5 weighed adjustment to be placed

$$w = \frac{1}{1 + k \times (\sum_{\text{all study years}} N \text{ Predicted})} \ldots\ldots\ldots\ldots\ldots \text{ Equation (14)}$$

Where,

k = over dispersion parameter from the associated SPF $(k = \frac{0.236}{L})$ L= segment length

step 6 expected crash frequency(EB regression method)

$$N \text{ expected} = w \text{ x } N \text{ predicted} + (1 - w) \text{ x } N \text{ observed} \ldots\ldots\ldots\ldots\ldots \text{ Equation (15)}$$

Where,

N expected = expected average crashes frequency for the study period.

N predicted = predicted average crash frequency predicted using a SPF for the study period under the given conditions.

w = weighted adjustment to be placed on the SPF prediction.

N observed = observed crash frequency at the site over the study period

Step 7potential improvement (identification of hazardous location)

$$PI\ i = N \text{ expected } i - N \text{ predicted } i \quad \ldots\ldots\ldots\ldots\ldots \text{ Equation (16)}$$

where

PI i= potential improvement at site i

N expected i = expected average crashes frequency for the study period at site i.

N predicted i=predicted average crash frequency predicted using a SPF for the study period under the given conditions at site i

Step 8 ranking of locations

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

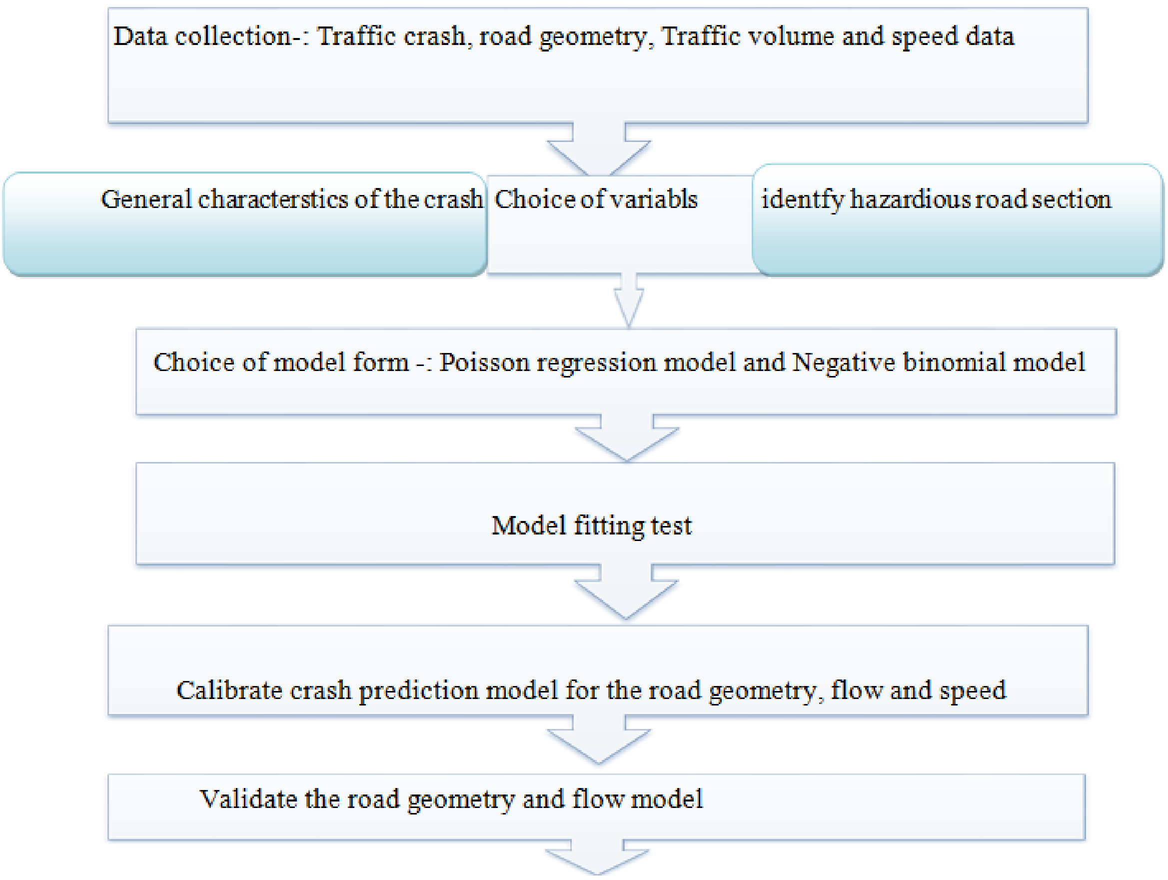


Figure 3.3; Research methodology flow chart

4. RESULT AND DISCUSSION

This chapter included that the result and discussion of the research and has three main sub topics. First it was try to generalize the distribution of road traffic crash and the second was model prediction for the geometric characteristics and flow, for the speed model and validation of model and finally identify hazardous road section using EB method and ranking of sections.

4.1 Characteristics of the road traffic crash

A total of 411 (fatal, injury and PDO) number of road traffic crash data were taken and calculate the crash rate AADT is as exposure for each year, for each segment and for each severity type. We can get total 667 crash rate. All drivers (100%) were male. The mean age of drivers was found to be 31.6+-8.34(SD), ranging from 18-62 years. From this total number of vehicular accident,95 (31.4%) fatal, 98 (32.13%) serious injury 112 (36.7%) slight injury were recorded.

$Crash\,rate = number\ of\ crash\,per\ km * 10\text{^}6/AADT * 365 * year$……Equation (16)

$fatal\ = no\ of\ fatal\ per\ km * \frac{10^6}{AADT*365*year}$……Equation (17)

$Injury(srious\ and\ slight) = no\ of\ injury\ per\ km * \frac{10^6}{AADT*365*year}$……Equation (18)

$$PDO = no\ of\ PDO * \frac{10^6}{AADT * 365 * year} \ldots\ldots \text{Equation (19)}$$

4.1. Distribution of traffic crash by Sex

As the chart below shows, most of male can create a traffic accident. From the total crash rate 438(69.8%) were found that male and 30.16%were female.

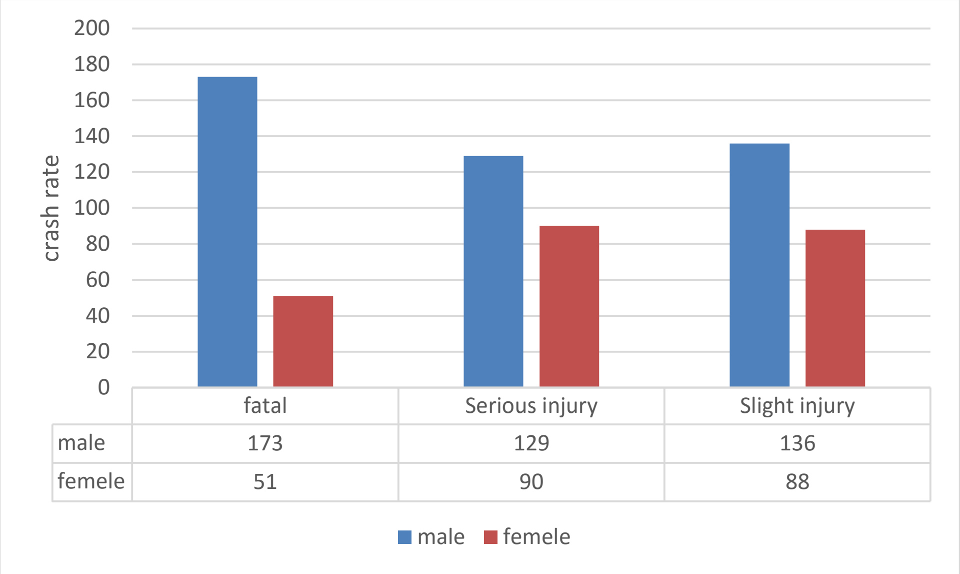


Figure 4.1, Distribution of traffic crash by Sex

As the chart below also shows that there are higher traffic crash rate among males on every year were male in 2006

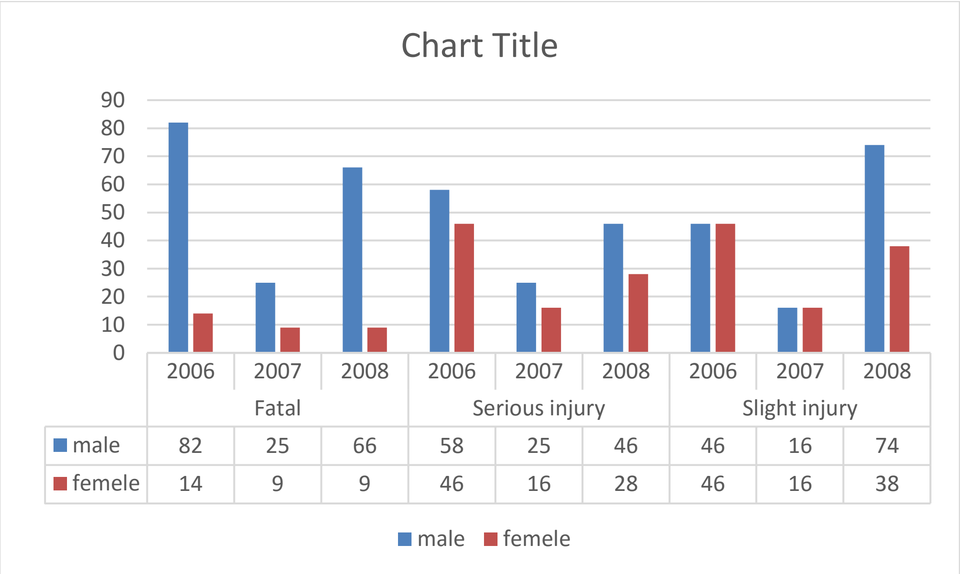


Figure 4.2, Distribution of traffic crash by Sex and year

4.1.2 Distribution of traffic crash by Age group

The following chart shows there is a higher number of crash by younger people age group of 19-30 years, On this age group, 33.1% fatal and total injury were found and the second higher traffic accident age group were found 31-50 which has 32.4% .the lowest age group for traffic accident were below age 7. Generally, the current study concluded that the number of drivers who suffered in deaths, serious injuries and light injuries have increased as the age below 7 to19-30 and decreased as the age becomes above 50 years old .

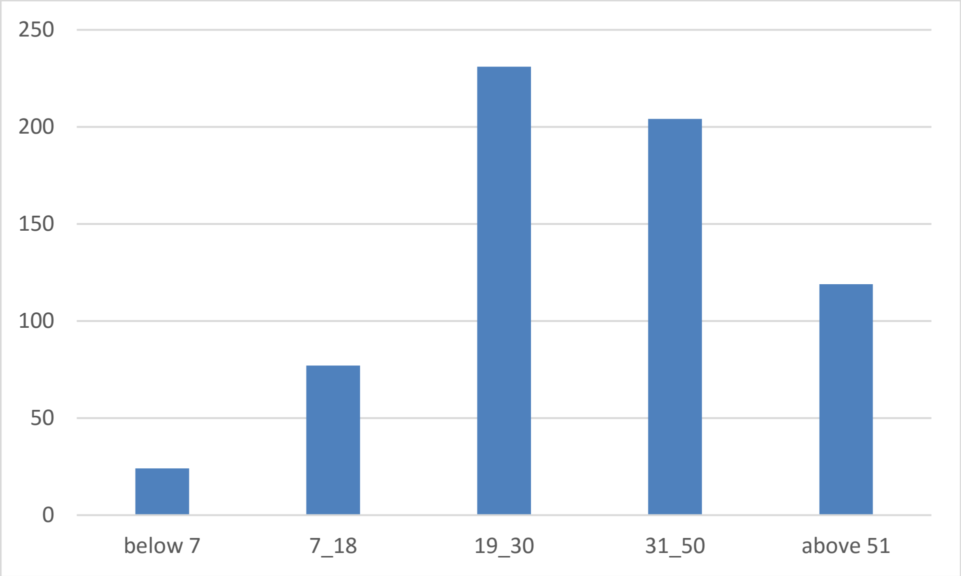


Figure 4.3, distribution of traffic crash t by age group

4.1.2 Distribution of traffic crash by Age group and year

This chart shows that there are higher traffic crashes in 2006 and 2008. And the age group is higher traffic crash on 19-30 and 31-50.

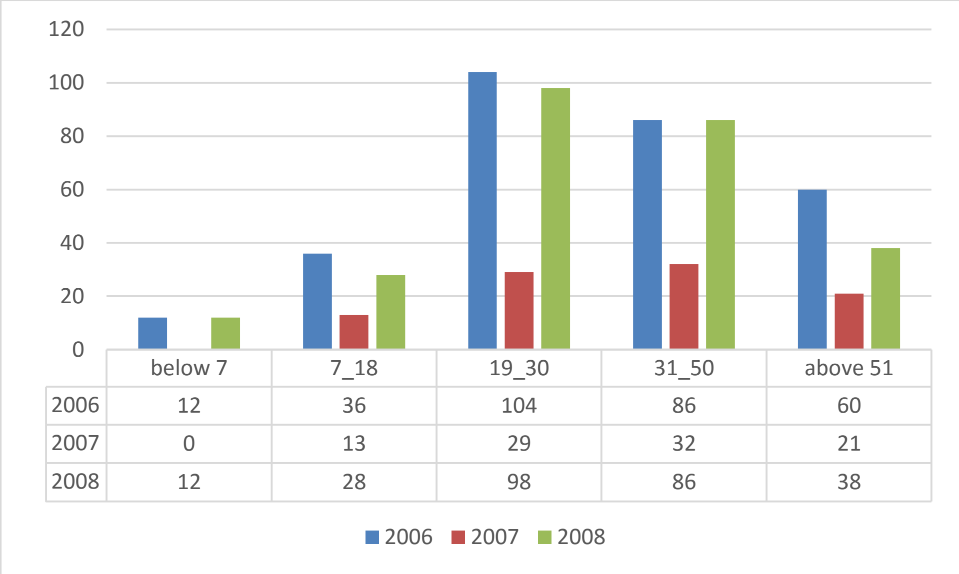


Figure 4.4, Distribution of traffic accident by Age group and year

4.1.3 Distribution of traffic crash **by collision type**

The collision type is often a good indication of crash contributing factors. The chart below shows that collision with pedestrian and rolling down are the most dominant type of collisions which frequently occurred in the region i,e 17% and 16% respectively, from the total number of fatal and all injury. collisions like head on collision ,front-back collision , front and side collision have medium crash rate, Whereas ,collision types like collision with animals, fall from vehicles, crash with stationary vehicle, crash with animate object and others have very low number of crash reports.

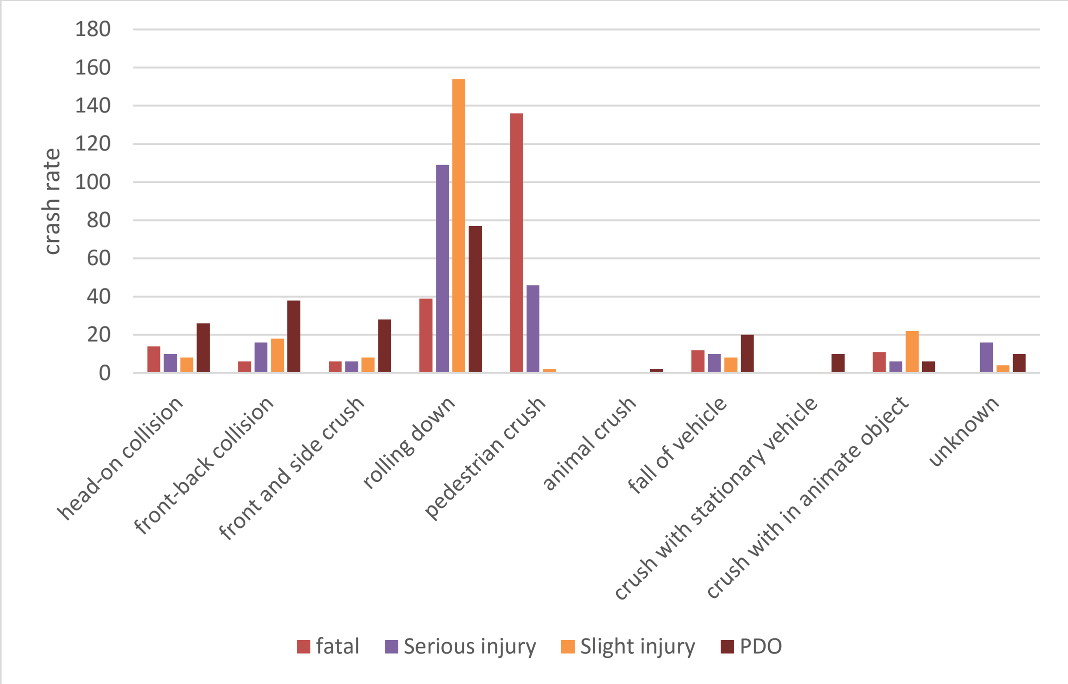
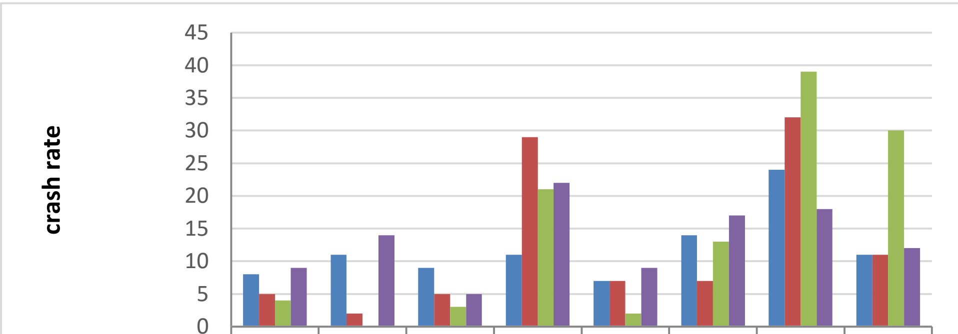


Figure 4.5, Distribution of traffic crash by collision type

4.1.5 Distribution of traffic crash by day of week

The following chart shows detail road traffic crash data distribution for daily amount of traffic crash that occurred in the past 3 years in each day. According to this chart, there are a large number of accidents occurring on Sunday through out a year. This needs further study to identify the reason behind the accidents on Sunday.



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Unknown
Death	8	11	9	11	7	14	24	11
Serious injury	5	2	5	29	7	7	32	11
Slight injury	4	0	3	21	2	13	39	30
PDO	9	14	5	22	9	17	18	12

Figure 4.6, Distribution of traffic crash by day of week

4.1.6 Distribution of traffic crash by month

The following chart shows that there are a high number of fatal traffic crash on month of November and low traffic crash on the month August.

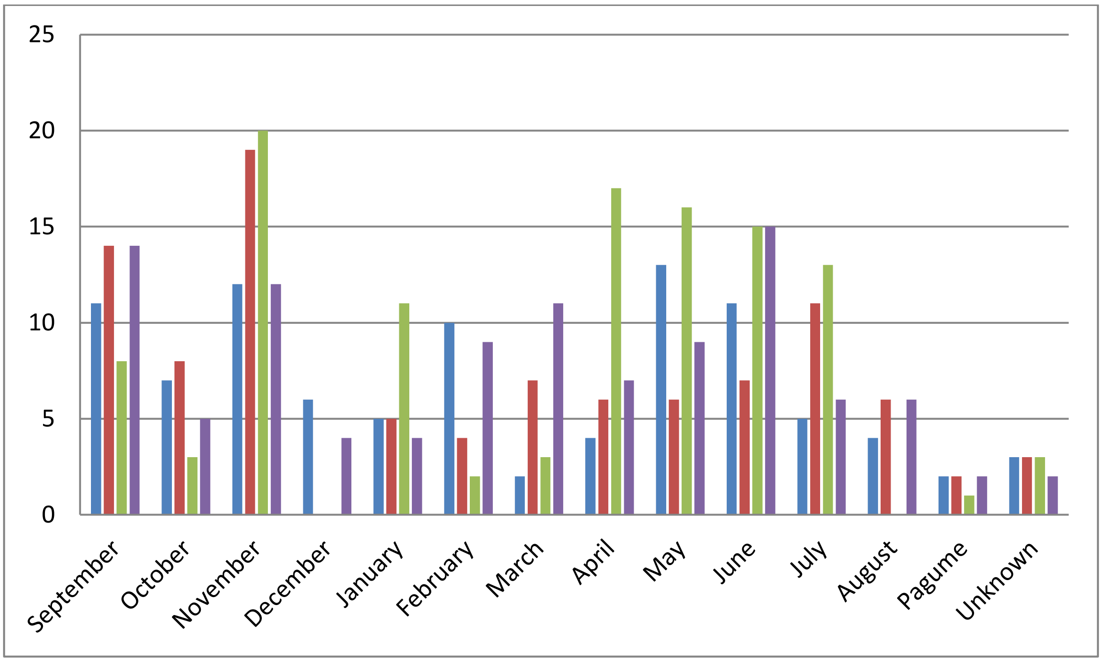
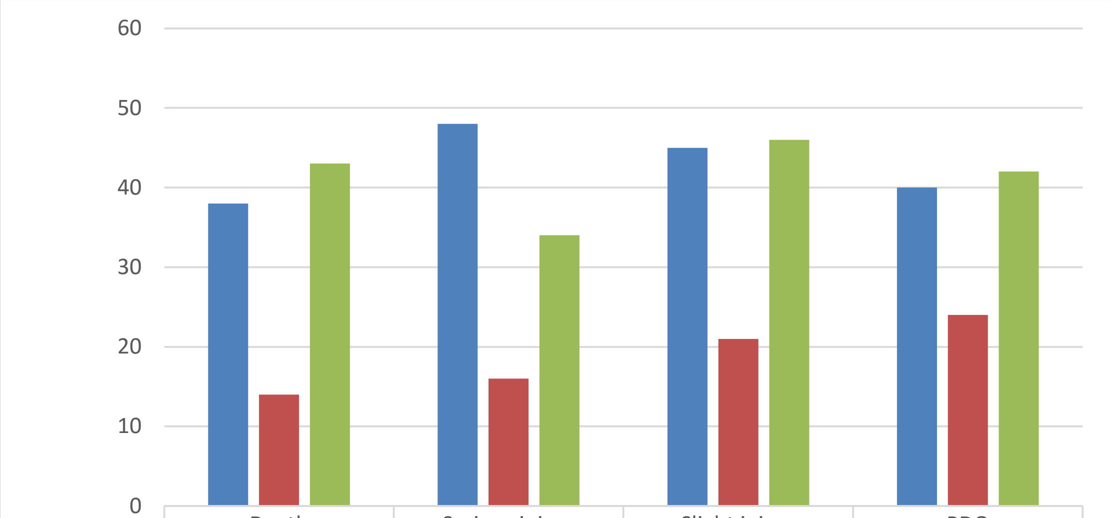


Figure 4.7, Distribution of traffic crash by month

4.1.7 Distribution of traffic crash by year

Depending on the year number of crash were been found decreased in 2007 and increased in the 2008. That's why crashes are rare and random events; it is not linearly increased or decreased.

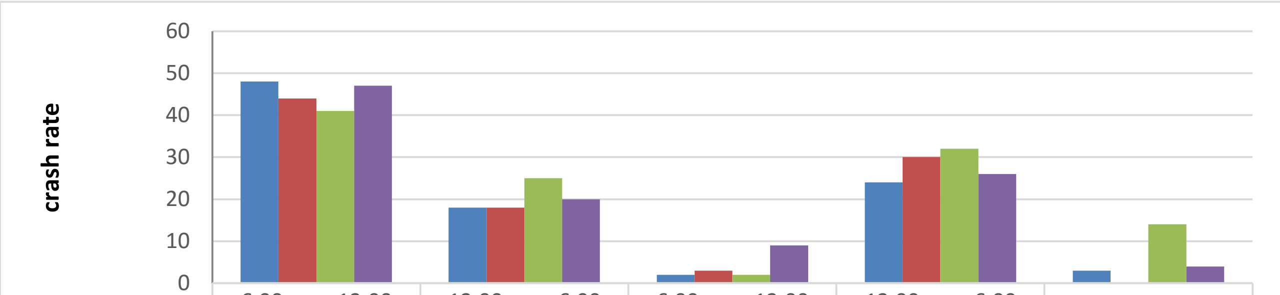


	Death	Serious injury	Slight injury	PDO
2006 E.C	38	48	45	40
2007E.C	14	16	21	24
2008E.C	43	34	46	42

Figure 4.8, Distribution of traffic crash by year

4.1.7 Distribution of traffic crash by hour of day

Road traffic crashes vary by hours of a day; with maximum crashes when mobility of pedestrians, passengers, and drivers frequency increases. The next chart shows, distribution of traffic accident with time difference throughout a day and the chart shows the most critical time for traffic accident is from morning 12:00am-6:00am up to afternoon 6:00am-12:00pm.



	6.00 am - 12.00 pm	12.00 pm - 6.00 pm	6.00 pm - 12.00 am	12.00 am - 6.00 am	Unknown
Death	48	18	2	24	3
Serious injury	44	18	3	30	0
Slight injury	41	25	2	32	14
PDO	47	20	9	26	4

Figure 4.9, Distribution of traffic crash by hour of day

4.1.8 Distribution of traffic crash by vehicle type

The chart below shows that the most dominant type of vehicle which frequently occurred in the region is minibus and public bus up to 45 seat. vehicles like heavy truck have medium crash rate, Where as ,other vehicle types are low number of crash rates.

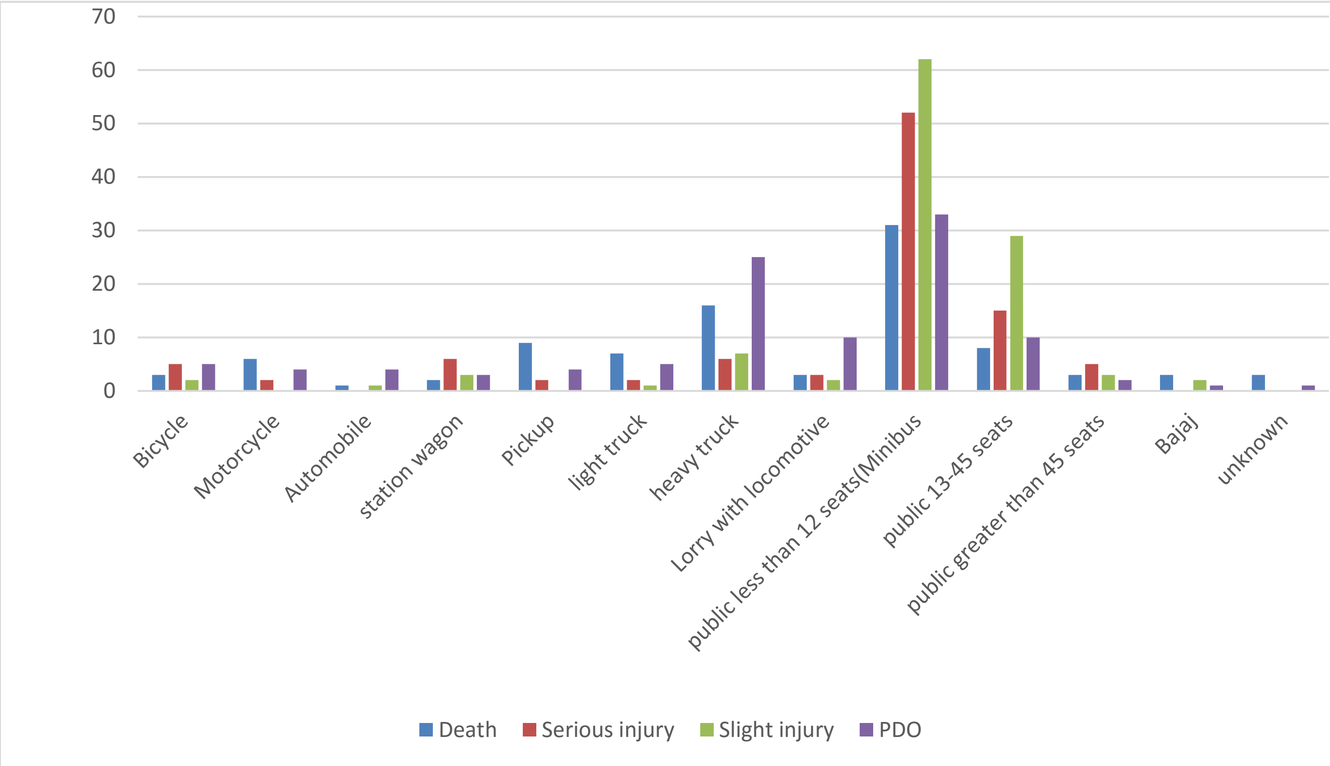


Figure 4.10, Distribution of traffic crash by vehicle type

4.2 crash prediction models

This section presents and discusses the results of the crash prediction modeling for the rural two-lane roads on the Eastern Tigray region (Wukro-Adigrat-Zalambesa) road. The engineering factors that affect crash rate on these roads are identified and the magnitudes of their impacts were estimated and finally two models were developed these are:-

- ✓ **For the geometric characteristics of the road and flow**: - this model relates crash rate and geometric characteristics of the road and traffic flow for the whole section.
- ✓ **For the speed model**:- this model relates traffic crash at some selected section (using case control method the corresponding spot speed was collected for two months during the study period) and crash rate.

In this study the analysis pertains to search the significant factors. The Poisson and negative binomial were used to analyze the data. The statistical analyses were performed using statistical software package called SPSS version 20.

4.2.1. Variable Selection

In this study it can use Stepwise variable selection which is a combination of backward elimination and forward selection to identify the predictors in the model. This was done on Poisson regression model as it is the bench mark for the negative binomial regression model. Stepwise selection method addresses where variables were added or removed with respect to the p-value in the process.

First select the dependent and independent variable

- Crash rate as dependent variable

$$\text{Crash rate(MVM)} = \frac{\text{Number of crash} * 10^6}{\text{AADT} * \text{length} * \text{year} * 365}$$

- Independent variable
    - ✓ Flow (AADT)
    - ✓ Lane width
    - ✓ Shoulder width
    - ✓ Horizontal curvature(no of horizontal curve per KM)
    - ✓ Vertical alignment (no of vertical curve/grade per KM)
    - ✓ Access point per Km
    - ✓ Median widths are included in the models at 5% level of significant.

Section length were rejected from the model because the whole section length were the same 1km long and does not affect crash rate.

4.2.2 For the geometric characteristics of the road and flow model

First lets see the variable description to know whether the mean and variance is approximately the same or not.

Table 4.1 : Variable description

Dependent and Independent variable	Variable symbol	Minimum	Maximum	Mean	Std. Deviation
Crash rate	CR	0	21	2.79	4.954
No of vertical grade per km	NVG	0	11	1.84	2.183

No of vertical curve per km	NVC	0	12	2.73	2.259
No of horizontal curve per km	NHC	0	18	2.94	2.247
No of Accesses point per km	NAP	0	24	.50	2.517
Average Annual Daily Traffic	AADT	557.00	1303.00	1155.3542	298.78829
Lane width per km	LW	6.20	7.00	6.9387	.16293
Shoulder width per km	SHW	.50	3.00	1.5521	.42599

As we see in the table above the mean and the variance of the dependent variable was not equal. This shows that the assumption of Poisson distribution model was not accepted

4.2.2.2 Parameter estimation

The Table below presented parameter estimates with their corresponding standard error of the Poisson and negative binomial (NB) regression models and the variable information of the two models .the assumption of Poisson regression method the men and the variance of the crash data are equal but the variable information shows there are big difference between them

Table 4.2: parameter estimation for Poisson regression

Dependent variable	B	Std.error	Sig.
Intercept	-17.845	8.8488	.044
No of vertical curve per km	1.363	.3450	.000
No of vertical grade per km	-1.263	.3489	.000
No of horizontal curve per km	.306	.0316	.000
Median width in m	.167	.0894	.061
No of Accesses point per km	-.046	.0794	.566
Average Annual Daily Traffic	.000	.0003	.100
Lane width per km	2.951	1.3273	.026
Shoulder width per km	-1.507	.3260	.000

Table 4.3: parameter estimation for negative binomial

Dependent variable	B	Std.error	Sig.
Intercept	-25.341	18.4028	.169
No of vertical curve per km	1.671	.6906	.016
No of vertical grade per km	-1.510	.6771	.026

No of horizontal curve per km	.353	.0890	.000
Median width in m	.382	.1986	.054
No of Accesses point per km	-.122	.1592	.443
Average Annual Daily Traffic	.000	.0004	.606
Lane width per km	4.098	2.7041	.130
Shoulder width per km	-1.751	.5364	.001

4.2.2.3Comparison of Models

Poisson and negative binomial regression models are designed to analyze count data. However, Poisson and negative binomial regression models differ in terms of their assumptions. Poisson model assume, that the mean and variance of the outcome variable are equal while negative binomial regression model does not assume an equal number of mean and variance.

In order to select the best model which fits the data well, two different models were considered, namely; Poisson and negative binomial models. In this study, different model selection criteria were considered like the variance to mean relationship and Omnibus test. Omnibus test for the Poisson model

Likelihood ratio chi-square	Df	Sig
139.406	8	.000

Omnibus test for the Negative binomial model

Likelihood ratio chi-square	Df	Sig
32.415	8	.000

Even though the omnibus test for both models are significant As we see in the result negative binomial was best fit for the this model because the assumption for the Poisson model is the mean and variance should be approximately the same but it is not approximately equal. There for the best model for the data was negative binomial model.

4.3.2.4 Results from the negative binomial

Geometric characteristics

For the model selection two types of models are important as stated in the literature the Poisson and the negative binomial but for this data the negative binomial were fitted.

These assumptions of Poisson distribution were not significant because the mean and variance are not equal.

The next paragraphs discuss the general results of all the models, on a variable-by-variable basis.

- Number of Vertical curve (NVC), was found to be it is significant for the crash severity types. The model indicates that there is a positive relationship between crash rate and number of vertical curve, crash rate increase with increasing number of vertical curve.
- Number of vertical grade, also found to be it is significant factor for crash rate this finding shows that as the number of vertical grade increases the crash rate will be decreased.
- Number of Horizontal Curve (NHC), was a significant factor in the crash models. This finding suggests that sections with higher number of curve per KM experience higher crashes, which is consistent with expectation. A wider horizontal curve radius provides smoother transition between tangent section and leads to reduction of centrifugal forces on vehicles negotiating the curve, thereby reducing the risk of overturning
- The Section Length variable (L), was consistently found to be it is not significant at the specified degree of confidence, because in all section there the same length.
- Traffic Volume variable (AADT), turned out to be it is not significant variable in the crash models.
- Lane Width variable (LW), was found to be it is not significant factor in the crash models because the lane width is almost the same in the road .This result is consistent with expectation because wider lanes serve as buffer zones offering more opportunity for errant vehicles to recover or for vehicles to seek temporary refuge to avoid an errant oncoming vehicle and there fore reduce the risk of collision.
- Shoulder Width (SW), variable was shown to have a significant influence on crashes, a consistent result for the road classes and crash severity types. The negative sign of the coefficient suggests that for two-lane roads, increasing shoulder width is

associated with decreasing in number of crashes, all other factors remaining the same. This result is expected and can be explained by the fact that for rural two-lane roads, wider shoulders enhance safety by providing additional buffer zone where operators of stray vehicles can regain control, recover from error and resume normal travel.

- Median width (MW) and Access point (AP), was found to be it is not significant for the crash severity types.

Table 4.4: significant variables for the model

Dependent variable	B	Sig.
No of vertical curve per km	1.671	.016
No of vertical grade per km	-1.510	.026
No of horizontal curve per km	.353	.000
Shoulder width per km	-1.751	.001

Finally the model is presented below

$$\mathbf{lnCR = 1.671lnNVC - 1.51lnNVG + 0.353lnNHC - 1.751lnSW}$$

Where

LnCR =predicted number of crash rate

NVC= number of vertical curve

NVG= number of vertical grade

NHC= number horizontal curve

SW=Shoulder width

4.3.3Validation of the model

After calibrated the model we were try to validate the model in approximately the same road geometry .The data used for validation was taken from previous research in tigray region (Mekelle –AbiAdi rural two lane road), this road is almost the same terrain type with the study area.

Variables used for validation model were used Road crash data, number of vertical curve, number of vertical grade, number of horizontal curve and shoulder width (in meter) at the black spot locations because there was no enough crash data from Mekelle-AbiAdi Road.

Some of the necessarily data from the total section was shown below in the table (Araya ,2009)

$$\mathrm{lnCR = 1.671lnNVC - 1.51lnNVG + 0.353lnNHC - 1.751lnSW}$$

Table 4.5; variables used for validation the model from Mekelle-AbiAdi road

specific area of the crash	Observed No of crash	Observed crash rate	AADT	NHC	NVG	NVC	SW	crash rate from the model
Endamedihanialem	2	1.732907	1.581	2	3	2	1.5	0.380624
Mihono	11	9.530989	1.581	3	2	3	1.5	1.595153
Menewe	16	13.86326	1.581	10	9	9	1.5	1.578691
Agbe	2	1.732907	1.581	3	3	2	1.5	0.439194
Adinifas	3	2.599361	1.581	2	2	1	1.5	0.220482
Romanat	2	1.732907	1.581	2	3	3	1.5	0.749453
Gerbgiba	2	1.732907	1.581	2	3	2	1.5	0.380624

As we see in the above tables the observed crash rate from Mekelle-AbiAdi road at the black spot was much greater from the model.

4.3.4 For the Speed model

The spot speed data were collected over the study area at list for two months using the case control method .in this short period there are 22 sections that occur traffic crash and for these sections it is possible to relate traffic crash and the corresponding spot speed.

The spot speed data was collected as follows:

1. Select the crash on the two consecutive months(October and November) with all necessary descriptions

Table 4.6: description of the selected data for the spot speed

Name of the section	Section length	month	date	year	Time	Weather condition	fatal	Serious injury	Slight injury	PDO	Total
belesa	5	Nov	5	6	9:50	Gentle air condition	0	0	0	1	1
belesa	6	Nov	24	6	10:30	Gentle air condition	0	0	0	1	1
kalhable	8	Oct	20	6	1:00	Gentle air condition	3	8	3	1	15
arato	5	Nov	6	6	1:00	gentle air condition	0	3	1	1	5
guumsa	30	Nov	21	7	11:30	gentle air condition	1	0	0	1	2
01/kebele	36	Nov	5	7	9:00	gentle air	1	0	0	1	2

						condition					
sinkata aangul	32	Nov	12	7	1:00	gentle air condition	0	2	0	1	3
hadish hiwet	48	Oct	14	7	7:30	gentle air condition	0	4	9	1	14
01 kebele	75	Oct	22	8	6:20	gentle air condition	0	1	0	0	1
agoro	60	Nov	6	8	10:30	gentle air condition	2	4	3	1	10
aynalem	112	Oct	15	8	1:00	gentle air condition	1	0	0	0	1
mdriba	85	Nov	1	8	1:00	gentle air condition	0	1	1	2	4
belesa	4	Nov	29	8	5:00	Rainy	0	0	0	1	1
mobil	75	Nov	19	8	10:00	gentle air condition	1	0	0	0	1
hadishadi	75	Nov	15	8	9:00	Rainy	0	1	0	1	2
may nesesti	81	Nov	20	8	8:00	gentle air condition	1	1	0	1	3
tsebat	20	Nov	5	6	9:50	gentle air condition	0	0	0	1	1
kulela	20	Nov	24	6	10:30	gentle air condition	1	0	0	0	1
hadishadi	55	Oct	20	6	1:00	gentle air condition	1	0	0	0	1

From the above table measure the spot speed for the 22 sections expect the two section because the weather condition at that moment was gentile air condition but the crash occurs when it is rainy that's why the one of assumption of the case-control method is at the same weather condition**.**

2. Measure spot speed over 54 meter at least for 25 vehicle and calculate the spot speed

   Measure 54 m length

   Record the time using stop watch

Speed=Distance/time

3. Relate speed with the corresponding crash rate

Table 4.7: spot speed and Total crash

Total crash	Spot speed(km/hr)
1.00	75.00
1.00	85.00
5.00	95.00
1.00	70.00
15.00	100.00
1.00	75.00
1.00	90.00
2.00	95.00
3.00	75.00
2.00	60.00
1.00	65.00
14.00	110.00
1.00	75.00
6.00	85.00
10.00	100.00
1.00	90.00
9.00	95.00
1.00	70.00
1.00	70.00
2.00	65.00
1.00	70.00
3.00	75.00
4.00	85.00
1.00	70.00

4. Predicted the model

Table 4.8: variable description

Dependent and Independent variable	Minimum	Maximum	Mean	Std. Deviation
Crash rate	1.00	15.00	3.6250	4.19951

Speed	60.00	110.00	81.0417	13.34974

As the above table shows that the variable description of the dependent variable crash rate and the independent variable the speed.

Parameter estimation

Table 4.9: parameter estimation using poison model

Dependent variable	B	Std.error	Sig.
Intercept	-4.067	.7716	.000
Speed	.062	.0083	.000

Table 4.10: parameter estimation using Negative binomial

Dependent variable	B	Std.error	Sig.
Intercept	-3.561	1.4832	.016
Speed	.056	.0174	.001

Comparison of models

For this model was also used the Poisson and negative binomial regression models t:his data also the assumption of Poisson model was not follow there fore negative binomial is best fit for the speed model.

Results from the negative

Speed was highly significantly affected for the crash rate i,e there is positive relation between crash rate and the speed. As the speed increases the crash rate also increases.

And finally the model is shown below:

$$\mathbf{LnCR = -3.561 + 0.56lnSP}$$

Where

CR=number of crash rate

SP=speed

4.3 Identification of hazardous road section

The second result shows identification of road section and ranking of locations by using EB method.

The result shows that from the total 96 section the hazardous road section were be found 25 sections and the rest 71 sections were not dangerous section. There are steps how to calculate the expected crash frequency to identify the most hazard road section and ranking those locations.

Step 1 predicted average crash frequency for base condition

$$\text{Nspfrs} = \text{AADT} \times \text{L} \times 365 \times 10^{-6} \times e^{(-0.312)}$$

$$N\,spfrs =$$

- ✓ We have 6 different AADT for the past 3 years

2006 from Wukro to Adigrat=1384

2006 from Adigrat to zelambesa=489

2007 from Wukro to Adigrat=1452

2007 from Adigrat to zalambes=558.5

2008 from Wukro to Adigrat=1074

2008 from Adigrat to zalambesa=622.5

- ✓ Length of each section is=1km

We can calculate the predicted crash frequency by substitute each variables,

$Nspfrs\ for\ 2006\ from\ Wukro\ to\ Adigrat = 0.37$

$Nspfrs\ for\ 2006\ from\ Adigrat\ to\ zalambesa = 0.131$

$Nspfrs\ for\ 2007\ from\ Wukro\ to\ Adigrat = 0.388$

$Nspfrs\ for\ 2007\ from\ Adigrat\ to\ zalambes = 0.15$

$Nspfrs\ for\ 2008\ from\ Wukro\ to\ Adigrat = 0.287$

$Nspfrs\ for\ 2008\ from\ Adigrat\ to\ zalambesa = 0.166$

Step 2 Accident modification factor for each road parameter

Calculate the AMF for all parameter and all road section (see in the APPINDX)

Step 3 calibration factor

$$\text{Cr} = \frac{\sum_{\text{all site}} \text{observed crash}}{\sum_{\text{all site}} \text{predicted crash}}$$

Cr=calibration factor

$$No\ predicted\ = 100.3954242$$

$$No\ of\ observed\ crash = \ 411$$

Cr=411/100.4=4.16

Step 4 predicted average crash frequency

$$\mathrm{N\ predicted\ rs\ =\ N\ spf\ rs\ \ \times Ci\ \ \times\ (AMF1r\ \times\ AMF2r\ \times\ ...\times\ AMF12r)}$$

Step 5 weighed adjustment to be placed

$$\mathrm{w}\ = \frac{1}{1\ +\ \mathrm{k}\ \times\ (\sum_{\text{all study years}} \text{N Predicted})}$$

Where,

k = over dispersion parameter from the associated SPF $(\mathrm{k} = \frac{0.236}{\mathrm{L}})$ L= segment length

$$k = \frac{0.236}{1} = 0.236$$

$$w = \frac{1}{1 + 0.236(\sum Npredicted)}$$

step 6 expected crash frequency(EB regression method)

$$\mathrm{N\ expected\ \ \ = \ w\ x\ N\ predicted} + \ (1\ -\ \mathrm{w)\ x\ N\ observed}$$

Step 7potential improvement (identification of hazardous location)

$$\mathrm{PI\ i\ \ =\ \ N\ expected\ i - N\ predicted\ i}$$

where

PI i= potential improvement at site i

N expected i = expected average crashes frequency for the study period at site i.

N predicted i=predicted average crash frequency predicted using a SPF for the study period under the given conditions at site i

Table4.11:site specific EB method work sheet

Section	Predicted crashes	Observed crashes	Over dispersion parameter	W	N expected	PI	Dangerous/not
1	4.755031	39	0.236	0.471212	22.86336	18.10833	Dangerous
2	4.578919	8	0.236	0.480625	6.355743	1.776825	Dangerous
3	5.042895	18	0.236	0.456595	12.08385	7.040952	Dangerous
4	4.755031	21	0.236	0.471212	13.34518	8.590146	Dangerous
5	5.107256	28	0.236	0.453451	17.61927	12.51202	Dangerous
6	7.018083	1	0.236	0.376468	3.265616	-3.75247	Not
7	6.160848	0	0.236	0.407505	2.510574	-3.65027	Not
8	4.861051	17	0.236	0.465721	11.34664	6.485585	Dangerous
9	4.776612	0	0.236	0.470084	2.245408	-2.5312	Not
10	4.671161	6	0.236	0.475648	5.36794	0.696779	Dangerous
11	4.402807	10	0.236	0.490421	7.255016	2.852209	Dangerous
12	4.690003	0	0.236	0.474644	2.226083	-2.46392	Not
13	4.543136	0	0.236	0.482584	2.192443	-2.35069	Not
14	4.537769	0	0.236	0.482879	2.191192	-2.34658	Not
15	4.578919	1	0.236	0.480625	2.720117	-1.8588	Not
16	4.578919	0	0.236	0.480625	2.200742	-2.37818	Not
17	4.526621	0	0.236	0.483493	2.188589	-2.33803	Not
18	4.577292	1	0.236	0.480714	2.719653	-1.85764	Not
19	4.577292	0	0.236	0.480714	2.200366	-2.37693	Not
20	4.578919	3	0.236	0.480625	3.758868	-0.82005	Not
21	4.755031	1	0.236	0.471212	2.769415	-1.98562	Not
22	4.578919	17	0.236	0.480625	11.03012	6.451201	Dangerous
23	4.402807	4	0.236	0.490421	4.197545	-0.20526	Not
24	4.489462	0	0.236	0.485552	2.179866	-2.3096	Not
25	4.600849	1	0.236	0.479432	2.726363	-1.87449	Not
26	4.990317	0	0.236	0.459197	2.291538	-2.69878	Not
27	4.577292	0	0.236	0.480714	2.200366	-2.37693	Not
28	5.416954	0	0.236	0.438904	2.377524	-3.03943	Not

29	4.871153	0	0.236	0.465205	2.266082	-2.60507	Not
30	4.871153	5	0.236	0.465205	4.94006	0.068907	Dangerous
31	4.578919	0	0.236	0.480625	2.200742	-2.37818	Not
32	4.516299	3	0.236	0.484063	3.733984	-0.78231	Not
33	5.35503	0	0.236	0.441738	2.365518	-2.98951	Not
34	5.577984	0	0.236	0.431704	2.408036	-3.16995	Not
35	5.008214	0	0.236	0.458308	2.295305	-2.71291	Not
36	4.764516	3	0.236	0.470715	3.830585	-0.93393	Not
37	4.546293	0	0.236	0.48241	2.193178	-2.35312	Not
38	4.690003	3	0.236	0.474644	3.80215	-0.88785	Not
39	4.457624	1	0.236	0.48733	2.685002	-1.77262	Not
40	4.578919	8	0.236	0.480625	6.355743	1.776825	Dangerous
41	4.947766	1	0.236	0.461324	2.8212	-2.12657	Not
42	4.489462	1	0.236	0.485552	2.694314	-1.79515	Not
43	4.572529	6	0.236	0.480973	5.313425	0.740895	Dangerous
44	4.992539	0	0.236	0.459086	2.292007	-2.70053	Not
45	6.310569	3	0.236	0.40172	4.329923	-1.98065	Not
46	5.201263	0	0.236	0.448934	2.335025	-2.86624	Not
47	4.46567	0	0.236	0.486879	2.174241	-2.29143	Not
48	5.421703	32	0.236	0.438688	20.34041	14.9187	Dangerous
49	5.514651	0	0.236	0.434507	2.396156	-3.11849	Not
50	5.35503	9	0.236	0.441738	7.38988	2.034849	Dangerous
51	5.042895	0	0.236	0.456595	2.302562	-2.74033	Not
52	5.30201	0	0.236	0.444193	2.355115	-2.9469	Not
53	5.522756	2	0.236	0.434146	3.529392	-1.99336	Not
54	4.578919	1	0.236	0.480625	2.720117	-1.8588	Not
55	5.051566	15	0.236	0.456169	10.46183	5.410266	Dangerous
56	4.892608	0	0.236	0.464111	2.270715	-2.62189	Not
57	4.755031	0	0.236	0.471212	2.240627	-2.5144	Not
58	4.717872	0	0.236	0.473167	2.232342	-2.48553	Not
59	4.543136	0	0.236	0.482584	2.192443	-2.35069	Not
60	4.546293	41	0.236	0.48241	23.41437	18.86807	Dangerous

61	4.529718	0	0.236	0.483322	2.189313	-2.3404	Not
62	4.564169	6	0.236	0.48143	5.308747	0.744578	Dangerous
63	6.062478	0	0.236	0.411397	2.494082	-3.5684	Not
64	4.701472	0	0.236	0.474035	2.228664	-2.47281	Not
65	6.423991	14	0.236	0.397447	10.98894	4.564951	Dangerous
66	5.078163	0	0.236	0.454867	2.309887	-2.76828	Not
67	4.829349	0	0.236	0.467349	2.256994	-2.57236	Not
68	4.703938	0	0.236	0.473905	2.229218	-2.47472	Not
69	4.498155	0	0.236	0.485069	2.181913	-2.31624	Not
70	4.498155	8	0.236	0.485069	6.301365	1.80321	Dangerous
71	4.671161	3	0.236	0.475648	3.794885	-0.87628	Not
72	4.590101	9	0.236	0.480016	6.883178	2.293077	Dangerous
73	4.894243	0	0.236	0.464028	2.271067	-2.62318	Not
74	5.112653	37	0.236	0.453189	22.54901	17.43636	Dangerous
75	4.636325	1	0.236	0.477516	2.736402	-1.89992	Not
76	2.571488	0	0.236	0.622327	1.600308	-0.97118	Not
77	2.031553	1	0.236	0.675928	1.697256	-0.3343	Not
78	2.01081	0	0.236	0.678173	1.363676	-0.64713	Not
79	2.046861	0	0.236	0.674282	1.380161	-0.6667	Not
80	1.971051	1	0.236	0.682516	1.662758	-0.30829	Not
81	2.088149	3	0.236	0.669881	2.389168	0.30102	Dangerous
82	2.046861	0	0.236	0.674282	1.380161	-0.6667	Not
83	2.600933	1	0.236	0.619648	1.992014	-0.60892	Not
84	1.875312	0	0.236	0.693205	1.299977	-0.57534	Not
85	1.971051	4	0.236	0.682516	2.615211	0.64416	Dangerous
86	1.983194	0	0.236	0.681183	1.350918	-0.63228	Not
87	2.088149	2	0.236	0.669881	2.059049	-0.0291	Not
88	1.86136	0	0.236	0.694791	1.293257	-0.5681	Not
89	1.96625	0	0.236	0.683044	1.343035	-0.62321	Not
90	1.950884	1	0.236	0.68474	1.651108	-0.29978	Not
91	2.130396	1	0.236	0.665436	1.752207	-0.37819	Not
92	1.943792	0	0.236	0.685525	1.332519	-0.61127	Not

93	2.014267	0	0.236	0.677797	1.365265	-0.649	Not
94	1.935814	0	0.236	0.686411	1.328765	-0.60705	Not
95	2.395262	7	0.236	0.638863	4.058205	1.662943	Dangerous
96	2.169211	9	0.236	0.661405	4.482084	2.312873	Dangerous

Step 8 ranking of locations

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

Table 4.12: ranking of locations

Section	PI	Rank
1	18.10833	2
2	1.776825	17
3	7.040952	7
4	8.590146	6
5	12.51202	5
8	6.485585	8
10	0.696779	22
11	2.852209	12
22	6.451201	9
30	0.068907	25
40	1.776825	18
43	0.740895	21
48	14.9187	4
50	2.034849	15
55	5.410266	10
60	18.86807	1
62	0.744578	20
65	4.564951	11
70	1.80321	16
72	2.293077	14
74	17.43636	3

81	0.30102	24
85	0.64416	23
95	1.662943	19
96	2.312873	13

As the above table shows that section 60 is the highest traffic crash this section is around belesa , negashi village .These all hazardous sections should get recurrent solution.

5. CONCLUSION AND RECOMMENDATION

Conclusion

According to findings revealed about Road Traffic crash related to road geometry ,flow and speed and identification of hazardous road section in Eastern Tigriy region the following conclusions are drawn.

The main objective of the study is to develop a prediction model for road traffic crashes occurring on the two lane trunk road and to identify the hazardous road section by using Empirical bays method. The relationship between the crash rate and the contributing factors was analyzed in this study. For the use of the model variables was selected, crash rate as dependent variable road geometry, flow and speed as independent variables.

The dependent variables used for the model was speed, AADT, number of vertical curve, number vertical grade , number of horizontal curve, no of access point , Median width, lane width and shoulder width and crash rate was as independent variable.

Speed Data was collected using a case-control study design, the speeds of cars involved in casualty crashes was compared with the speeds of cars not involved in crashes but travelling in the same direction, at the same location, time of day, day of week, and time of year in the Wukro-Adigrat – Zela'ambesa. And from the total 96 section speed data was collected for 22 sections and correlate with the crash rate.

The choice of model form for statistical modeling typically depends on the nature of the response variable and its relationships with the explanatory variables. Linear models have been found to be unsuitable for crash modeling because of the non-negative and discrete nature of crash data. The Generalized linear model was used for crash prediction; these are Poisson regression model and Negative binomial model. And negative binomial model was best fit for the road geometry and flow model and for the speed model.

Finally the most significant variables for the crash rate was found to be number of vertical curve, grade, number of horizontal curve, shoulder width, speed and the other variables such as AADT, number of access point, median width, lane width and median width was not significant on the model.

Number of horizontal curve and number of vertical curve were found to be positively related to the crash rate this means if the number of horizontal curve and number of vertical curve increases the crash rate also increases, whereas the number of grade and shoulder width have negatively related if the shoulder width increases crash rate is decreased and as number of Grade increases crash rate decreases.

After calibrated the model we were try to validate in the Mekelle- AbiAdi road. The dependent variable and independent variable data’s used in the model was taken from Mekelle-AbiiAdi road. Substitute to the model and we can compare the observed crash rate with the calculated crash rate from model. Result shows that the model was not validated on the Mekelle-AbiAdi black spot areas.

For the identification of the most hazardous road section was addressed by using the EB method of regression approach. This approach takes into account of effects due to site-specific factors by developing their relation with crash frequency. From the total 96 section 24 section was selected as hazardous road section.

Recommendation

The data used for the model was secondary data i,e it is not accurate data but if the data's are accurate it's possible to develop accurate prediction model for crash road and validate the model in the same characteristics but in this case all the necessarily Traffic crash data, road data and AADT that we used for the model was secondary data .

As we see in the final result number of horizontal curve and number of vertical curve highly affected the crash rate, therefore highway designers should consider the effect of crash rate on geometry of the road.

As the model result also shows that speed was highly affected the crash rate therefore drivers should have behavioral awareness about traffic crash and the government must set speed lime.

Planners and designers should also consider the effect shoulder width and other road geometry on road safety. Implementing the existing road traffic safety rule and regulation to satisfy the present road traffic safety condition. Including some of international standard recognized traffic rule and regulation.

For the previous identified hazardous road section putting a black spot sign for all black spot location, and give awareness about black spot location and put an appropriate traffic sign for all road section. Road traffic accident and safety education campaign should be given for all society including for pedestrian ,drivers and traffic police too, and give a gradual examination for drivers how made a frequently crossing laws of traffic rule and regulation.

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7. APPENDIX

A. characteristics of the road

- ✓ Based on sex

Sex	Death	Serious injury	Slight injury	Total
Male	71	58	66	195
Female	23	38	41	102
Unknown	1	2	5	8
Total	95	98	112	305

- ✓ Based on sex and year

Sex	Death			Serious injury			Slight injury			Total
	2006	2007	2008	2006	2007	2008	2006	2007	2008	
Male	30	11	29	27	11	20	21	9	37	195
Female	7	3	13	19	5	14	20	2	19	102
Unknown	1	0	0	2	0	0	5	0	0	8
Total	38	14	42	48	16	34	46	11	46	305

- ✓ Based on age

Age	Death and total injury
Below 7	8
Between 8-18	33
Between 19-30	101
Between 31-50	99
Above 51	55
Unknown	9
Total	305

- ✓ Based on age and year

Sex	Death and total injury			Total
	2006	2007	2008	
Below 7	4	0	4	8
Between 8-18	16	5	12	33
Between 19-30	40	13	48	101

Between 31-50	44	13	41	98
Above 51	27	9	19	52
Unknown	1	0	8	9
Total	132	40	132	305

- ✓ Based on collision type

No	Collision type	Death	Serious injury	Slight injury	PDO	Total
1	head-on collision	7	4	4	13	28
2	front-back collision	3	10	10	18	41
3	front and side crush	3	3	4	14	24
5	rolling down	18	53	77	37	185
5	pedestrian crush	38	13	1	0	52
6	animal crush	0	0	0	1	2
7	fall of vehicle	6	5	4	9	24
8	crush with stationary vehicle	1	2	1	5	9
9	crush with in animate object	0	0	0	5	5
10	crush with animate object and animal crush	3	3	11	2	19
11	Unknown	16	5	0	2	23
12	Total	95	98	112	106	411

- ✓ Based on geometric characteristics

Road position	Death	Serious injury	Slight injury	PDO	Total
straight and flat	11	12	32	8	63
Straight and slightly inclined	18	20	18	16	72
slightly/highly spiral (Zigzag	23	10	12	27	72
straight downward	22	22	18	23	85
straight upward	21	34	32	32	119
Total	95	98	112	106	411

- ✓ Based on day of week

Day	Death	Serious injury	Slight injury	PDO	Total
Monday	8	5	4	9	26
Tuesday	11	2	0	14	27
Wednesday	9	5	3	5	22
Thursday	11	29	21	22	83
Friday	7	7	2	9	25
Saturday	14	7	13	17	51
Sunday	24	32	39	18	113
Unknown	11	11	30	12	64
Total	95	98	112	106	411

- ✓ Based on year

Year	Death	Serious injury	Slight injury	PDO	Total
2006 E.C	38	48	45	40	171
2007E.C	14	16	21	24	75
2008E.C	43	34	46	42	165
Total	95	98	112	106	411

- ✓ Based on month of year

Month	Death	Serious injury	Slight injury	PDO	Total
September	11	14	8	14	47
October	7	8	3	5	23
November	12	19	20	12	63
December	6	0	0	4	10
January	5	5	11	4	25
February	10	4	2	9	25
March	2	7	3	11	23
April	4	6	17	7	34
May	13	6	16	9	44
June	11	7	15	15	48
July	5	11	13	6	35
August	4	6	0	6	16
Pagume	2	2	1	2	7
Unknown	3	3	3	2	11
Total	95	98	112	106	411

- ✓ Based on hour of day

Time	Death	Serious injury	Slight injury	PDO	Total
6.00 am - 12.00 pm	48	44	41	47	180
12.00 pm - 6.00 pm	18	18	25	20	80
6.00 pm - 12.00 am	2	3	2	9	114
12.00 am - 6.00 am	24	30	32	26	16
Unknown	3	0	14	4	21
Total	95	98	112	106	411

- ✓ Based on vehicle type

Vehicle type	Death	Serious injury	Slight injury	PDO	Total
Bicycle	3	5	2	5	15
Motorcycle	6	2	0	4	12

Automobile	1	0	1	4	6
station wagon	2	6	3	3	14
Pickup	9	2	0	4	15
light truck	7	2	1	5	15
heavy truck	16	6	7	25	54
Lorry with locomotive	3	3	2	10	18
public less than 12 seats(Minibus	31	52	62	33	180
public 13-45 seats	8	15	29	10	62
public greater than 45 seats	3	5	3	2	13
Bajaj	3	0	2	1	5
Unknown	3	0	0	1	4
Total	95	98	112	106	411

B. dependent and independent variables

no of crash	crash rate	no of vertical curve per KM	no vertical grade per KM	no of horizontal curve per KM	median width	access point per KM	AADT	lane width	shoulder width
39	17	3	4	3	0	0	1303	7	1.5
8	6	2	3	3	0	0	1303	7	1.5
18	12	1	2	4	0	0	1303	7	1.5
21	1	2	3	3	0	0	1303	7	1.5
28	21	0	1	10	0	2	1303	7	1.5
1	0	10	11	18	0	1	1303	6.7	0.5
0	0	15	16	4	0	0	1303	7	1.5
17	10	2	3	2	0	0	1303	6.7	0.5
0	0	3	4	2	0	0	1303	7	1.5
6	2	0	1	4	0	3	1303	7	1.5
10	5	0	1	2	0	0	1303	7	1.5
0	0	2	3	3	0	0	1303	7	1.5
0	0	1	2	2	0	0	1303	7	1.5
0	0	1	2	5	0	0	1303	7	1.5
1	1	1	2	2	0	0	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
1	0	1	2	2	0	0	1303	7	1.5
0	0	3	4	3	0	0	1303	7	1.5
3	1	2	3	3	0	0	1303	7	1.5
1	2	0	1	3	0	0	1303	7	1.5
14	14	1	2	4	0	0	1303	6.7	0.5
4	3	0	0	0	0	0	1303	7	1.5
0	0	3	4	2	0	0	1303	7	1.5
1	0	3	4	2	0	0	1303	7	1.5
0	0	0	1	2	0	0	1303	7	1.5
0	0	2	3	1	0	0	1303	7	1.5
0	0	2	3	4	0	0	1303	7	1.5
0	0	1	2	3	0	0	1303	7	1.5

5	3	3	4	2	0	2	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
3	1	0	1	4	2	0	1303	7	1.5
0	0	3	4	6	2	0	1303	7	1.5
0	1	3	4	2	0	0	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
3	0	3	4	1	0	0	1303	7	1.5
0	0	2	3	3	0	0	1303	7	1.5
3	0	2	3	5	0	0	1303	7	1.5
1	1	0	1	2	0	0	1303	7	1.5
8	1	2	3	2	0	0	1303	6.7	0.5
1	1	2	3	0	0	0	1303	7	1.5
1	1	3	4	1	0	0	1303	7	1.5
6	4	4	5	2	0	0	1303	7	1.5
0	1	2	3	2	0	0	1303	7	1.5
3	2	3	4	0	2	1	1303	7	1.5
0	0	1	2	1	2	1	1303	7	1.5
0	0	0	1	7	2	1	1303	7	3
32	0	2	3	7	2	1	1303	7	3
0	2	5	6	4	2	0	1303	7	3
9	3	3	4	4	0	0	1303	7	1.5
0	19	3	4	5	0	0	1303	7	1.5
0	0	3	4	4	0	0	1303	7	1.5
2	1	1	2	3	2	0	1303	7	1.5
1	1	1	2	3	2	0	1303	7	1.5
15	8	2	3	2	2	3	1303	7	1.5
0	1	3	4	3	0	0	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
0	1	2	3	3	0	0	1303	7	1.5
0	0	0	1	1	0	0	1303	7	1.5
41	18	2	3	2	0	0	1303	7	1.5
0	0	4	5	1	0	0	1303	7	1.5
6	0	2	3	2	2	2	1303	7	1.5
0	11	2	3	3	2	0	1303	7	1.5
0	0	2	3	4	2	3	1303	7	1.5
14	16	1	2	2	2	0	1303	7	1.5
0	0	2	3	2	0	0	1303	7	1.5
0	0	3	4	2	0	0	1303	7	1.5
0	0	2	3	4	0	0	1303	7	1.5
0	1	3	4	1	0	0	1303	7	1.5
8	2	2	3	1	0	0	1303	7	1.5
3	0	2	3	2	0	0	1303	7	1.5
9	0	2	3	4	0	0	1303	7	1.5
0	10	3	4	3	0	0	1303	7	1.5
37	9	0	1	4	0	0	1303	7	1.5
1	15	1	2	5	0	24	1303	7	3
0	0	3	4	4	2	1	1303	7	3
1	2	3	4	5	2	1	1303	7	3
0	0	3	4	2	0	0	557	7	1.5
0	0	3	4	3	0	0	557	7	1.5
1	5	2	3	3	0	0	557	7	1.5
3	0	4	5	2	0	0	557	7	1.5
0	0	0	1	3	0	0	557	7	1.5

1	1	4	5	1	2	2	557	7	1.5
0	0	1	2	2	0	0	557	7	1.5
4	4	2	3	4	0	0	557	7	1.5
0	0	5	6	5	0	0	557	7	1.5
4	1	2	4	3	0	0	557	7	1.5
0	0	2	3	2	0	0	557	7	1.5
0	2	2	3	2	0	0	557	7	1.5
1	2	1	2	2	0	0	557	7	1.5
0	12	2	3	1	0	0	557	7	1.5
0	1	3	4	2	0	0	557	7	1.5
0	1	3	4	1	0	0	557	7	1.5
0	1	5	6	5	0	0	557	7	1.5
7	1	2	3	3	0	0	557	7	1.5
9	6	0	0	0	0	0	557	7	1.5

C. number of accident per Km, predicted number of crash for base condition and Accident modification factors

Number of Accident	Nspr1	Nspr2	Nspr3	AMF HC	AMF Vc	AMF1 lane	AMF2 shoulder	AMF super elevation	AMF 1DD	AMF2DD	AMF3DD	AMF RHR
39	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
8	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
18	0.37	0.388	0.287	1.04304	1.12	1	1.01	1	1	1	1	1
21	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
28	0.37	0.388	0.287	1.019926	1.16	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.384286	1.16	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.2152	1.16	1.022575	1	1	1	1	1	1
17	0.37	0.388	0.287	1.082769	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.08	1.022575	1	1	1	1	1	1
6	0.37	0.388	0.287	1.011956	1.08	1	1	1	1	1	1	1
10	0.37	0.388	0.287	1.019926	1	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.005978	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.01076	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008277	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
17	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
4	0.37	0.388	0.287	1.019926	1	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.012659	1.04	1	1.01	1.012	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.12	1	1.01	1.012	1	1	1	1
0	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1.484336	0.862468	1.227925	1
0	0.37	0.388	0.287	1.044833	1.08	1	1.01	1	1	1	1	1
5	0.37	0.388	0.287	1.044833	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.005978	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.1076	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.153714	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.035867	1.12	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.012659	1.04	1	1.01	1.048	1	1	1	1
0	0.37	0.388	0.287	1.012659	1.04	1	1.01	1	1	1	1	1

3	0.37	0.388	0.287	1.005978	1.08	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1	1.022575	1	1	1	1	1	1
8	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.012659	1.08	1	1.01	1.048	1	1	1	1
1	0.37	0.388	0.287	1	1.04	1	1.01	1	1	1	1	1
6	0.37	0.388	0.287	1.005978	1.04	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.12	1.022575	1	1	1	1	1	1
3	0.37	0.388	0.287	1.044833	1.12	1.022575	1	1	1.458078	0.827763	1.493836	1
0	0.37	0.388	0.287	1	1.04	1	1	1	1.484336	0.827763	1.227925	1
0	0.37	0.388	0.287	1.044833	1	1	1	1	1	1	1	1
32	0.37	0.388	0.287	1.1076	1.12	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.126588	1.12	1.022575	1	1	1	1	1	1
9	0.37	0.388	0.287	1.1076	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.04304	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.1076	1.12	1	1	1	1	1	1	1
2	0.37	0.388	0.287	1.153714	1.12	1	1	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
15	0.37	0.388	0.287	1.044833	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1.01	1	1	1	1	1
41	0.37	0.388	0.287	1.012659	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008967	1.04	1	1.01	1	1	1	1	1
6	0.37	0.388	0.287	1.004138	1.04	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.059778	1.04	1	1	1	0.821219	1.521851	1.569811	1
0	0.37	0.388	0.287	1.048909	1.04	1	1	1	0.821219	0.827763	1.493836	1
14	0.37	0.388	0.287	1.059778	1.04	1.022575	1	1	0.821219	1.59126	1.645786	1
0	0.37	0.388	0.287	1.044833	1.08	1	1.01	1.042	1	1.001285	1	1
0	0.37	0.388	0.287	1.035867	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008967	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1	1	1	1	1	1
8	0.37	0.388	0.287	1.011956	1.04	1	1	1	1	1	1	1
3	0.37	0.388	0.287	1.011956	1.08	1	1	1	1	1	1	1
9	0.37	0.388	0.287	1.022417	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.022417	1.12	1	1	1	1	1	1	1
37	0.37	0.388	0.287	1.1076	1.08	1	1	1	1	1	1	1
1	0.37	0.388	0.287	1.04304	1.04	1	1	1	1	1	1	1
0	0.131	0.15	0.287	1.0538	1.04	1	1.01	1	1	1	1	1
1	0.131	0.15	0.166	1.0538	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.04304	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.022417	1.08	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.022417	1.04	1.013925	1	1	1	1	1	1
3	0.131	0.15	0.166	1.04304	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.022417	1.08	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.287	1.022417	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1.04	1	1	1	0.772182	1.044444	1.091789	1
4	0.131	0.15	0.166	1.022417	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.04304	1.04	1	1	1	1	1	1	1
2	0.131	0.15	0.166	1.04304	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.019926	1.04	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.011956	1.04	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.008277	1.04	1.013925	1	1.096	1	1	1	1
0	0.131	0.15	0.166	1.008277	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.044833	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1.04	1.013925	1	1	1	1	1	1
7	0.131	0.15	0.166	1.153714	1.12	1.013925	1	1	1	1	1	1
9	0.131	0.15	0.166	1.044833	1.12	1.013925	1	1	1	1	1	1
39	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
8	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
18	0.37	0.388	0.287	1.04304	1.12	1	1.01	1	1	1	1	1
21	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
28	0.37	0.388	0.287	1.019926	1.16	1	1.01	1	1	1	1	1

1	0.37	0.388	0.287	1.384286	1.16	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.2152	1.16	1.022575	1	1	1	1	1	1
17	0.37	0.388	0.287	1.082769	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.08	1.022575	1	1	1	1	1	1
6	0.37	0.388	0.287	1.011956	1.08	1	1	1	1	1	1	1
10	0.37	0.388	0.287	1.019926	1	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.005978	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.01076	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008277	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
17	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
4	0.37	0.388	0.287	1.019926	1	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.012659	1.04	1	1.01	1.012	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.12	1	1.01	1.012	1	1	1	1
0	0.37	0.388	0.287	1.019564	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1.484336	0.862468	1.227925	1
0	0.37	0.388	0.287	1.044833	1.08	1	1.01	1	1	1	1	1
5	0.37	0.388	0.287	1.044833	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.005978	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.1076	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.153714	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.035867	1.12	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.012659	1.04	1	1.01	1.048	1	1	1	1
0	0.37	0.388	0.287	1.012659	1.04	1	1.01	1	1	1	1	1
3	0.37	0.388	0.287	1.005978	1.08	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1	1.022575	1	1	1	1	1	1
8	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
1	0.37	0.388	0.287	1.012659	1.08	1	1.01	1.048	1	1	1	1
1	0.37	0.388	0.287	1	1.04	1	1.01	1	1	1	1	1
6	0.37	0.388	0.287	1.005978	1.04	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.12	1.022575	1	1	1	1	1	1
3	0.37	0.388	0.287	1.044833	1.12	1.022575	1	1	1.458078	0.827763	1.493836	1
0	0.37	0.388	0.287	1	1.04	1	1	1	1.484336	0.827763	1.227925	1
0	0.37	0.388	0.287	1.044833	1	1	1	1	1	1	1	1
32	0.37	0.388	0.287	1.1076	1.12	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.126588	1.12	1.022575	1	1	1	1	1	1
9	0.37	0.388	0.287	1.1076	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.04304	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.1076	1.12	1	1	1	1	1	1	1
2	0.37	0.388	0.287	1.153714	1.12	1	1	1	1	1	1	1
1	0.37	0.388	0.287	1.019926	1.04	1	1.01	1	1	1	1	1
15	0.37	0.388	0.287	1.044833	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.12	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.019926	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1.01	1	1	1	1	1
41	0.37	0.388	0.287	1.012659	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008967	1.04	1	1.01	1	1	1	1	1
6	0.37	0.388	0.287	1.004138	1.04	1.022575	1	1	1	1	1	1
0	0.37	0.388	0.287	1.059778	1.04	1	1	1	0.821219	1.521851	1.569811	1
0	0.37	0.388	0.287	1.048909	1.04	1	1	1	0.821219	0.827763	1.493836	1
14	0.37	0.388	0.287	1.059778	1.04	1.022575	1	1	0.821219	1.59126	1.645786	1
0	0.37	0.388	0.287	1.044833	1.08	1	1.01	1.042	1	1.001285	1	1
0	0.37	0.388	0.287	1.035867	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.008967	1.08	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.011956	1.04	1	1	1	1	1	1	1

8	0.37	0.388	0.287	1.011956	1.04	1	1	1	1	1	1	1
3	0.37	0.388	0.287	1.011956	1.08	1	1	1	1	1	1	1
9	0.37	0.388	0.287	1.022417	1.04	1	1.01	1	1	1	1	1
0	0.37	0.388	0.287	1.022417	1.12	1	1	1	1	1	1	1
37	0.37	0.388	0.287	1.1076	1.08	1	1	1	1	1	1	1
1	0.37	0.388	0.287	1.04304	1.04	1	1	1	1	1	1	1
0	0.131	0.15	0.287	1.0538	1.04	1	1.01	1	1	1	1	1
1	0.131	0.15	0.166	1.0538	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.04304	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.022417	1.08	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.022417	1.04	1.013925	1	1	1	1	1	1
3	0.131	0.15	0.166	1.04304	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.022417	1.08	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.287	1.022417	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1.04	1	1	1	0.772182	1.044444	1.091789	1
4	0.131	0.15	0.166	1.022417	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.04304	1.04	1	1	1	1	1	1	1
2	0.131	0.15	0.166	1.04304	1.08	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.019926	1.04	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.011956	1.04	1.013925	1	1	1	1	1	1
1	0.131	0.15	0.166	1.008277	1.04	1.013925	1	1.096	1	1	1	1
0	0.131	0.15	0.166	1.008277	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.044833	1.04	1.013925	1	1	1	1	1	1
0	0.131	0.15	0.166	1.004138	1.04	1.013925	1	1	1	1	1	1
7	0.131	0.15	0.166	1.153714	1.12	1.013925	1	1	1	1	1	1
9	0.131	0.15	0.166	1.044833	1.12	1.013925	1	1	1	1	1	1