Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Highway Engineering Stream

Effect of Geometric Design Parameters on Traffic Accident along Black Spot Section; A Case Study Sekoru Town to Gibe River Bridge

A Research submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Highway Engineering

By:

Feyissa Tesema

March 2020

Jimma, Ethiopia

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SCHOOL OF POST GRADUATE STUDIES

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As members of the examining board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by **Feyissa Tesema** entitled: "**Effect of Geometric Design Parameters on Traffic Accident along Black Spot Section; A Case Study Sekoru Town to Gibe River Bridge**" and recommended that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Highway Engineering.

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Declaration

I, the undersigned, declare that this final thesis entitled: **"Effect of Geometric Design Parameters on Traffic Accident along Black Spot Section; A Case Study Sekoru Town to Gibe River Bridge** "is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for this thesis have to be duly acknowledged.

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Signature Date

As Master's thesis Advisors, I hereby certify that I have read and evaluated this MSc Thesis prepared under my guidance by **Mr. Feyissa Tesema** entitled**: Effect of Geometric Design Parameters on Traffic Accident along Black Spot Section; A Case Study Sekoru Town to Gibe River Bridge."**

18//2020

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Abstract

A traffic accident is one of the series problems frequently occur in developing countries, leads to loss of life and property. In Ethiopia, various road segments are facing to effect of geometric design elements on traffic accidents; one of road section is along Sekoru town to Gibe River Bridge, which is located in Jimma Zone of Oromia Region. The main aim of this research study was to identify the main effects of road geometric design elements that cause road traffic accidents. Therefore, a mitigation of traffic accident is one of the prime concerns. Henceforth, scope of the study was limited to Sekoru town to Gibe River Bridge road segment with a total length of 70 kilometers. This research was conducted using both descriptive and analytical methods; simple random sampling was used for interview, and questionnaires of drivers, the pedestrian's likewise purposive sampling was used for obtaining of recorded accident data from traffic police office, as a built drawing and annual average daily traffic data from Ethiopian Road Authority. These data were analyzed using prioritization value (P) for the last three years (three or more) road traffic accidents have occurred was first selected, then for value of P≥15 selected as black spot section. Generally, the segment has 15 black spot sections from which 10 black spot sections were found in Sekoru Woreda; Qumbi Muzi tare has the highest 79 P-value and Doma have the smallest 15 p-value and the other 5 black spot section were founded in the Yem special woreda; Kosho has the highest 78 p-value and Saja town has the smallest 18 P-value. Also, analyzing the results based on multiple linear regressions for indicating variables using SPSS and excels tools; the value of R^2 *is always between 0 and1 because r is between -1 and +1. Normally, when correlating geometric design elements; lane width, shoulder width, radius of curves, vertical curve length, k-value, algebraic difference, stopping sight distance, passing sight distance with road traffic accident; they have* R^2*=0.999 which means strong positively correlate with TRTA and P= 0.035 which is significant because of P<0.05, as a shown in summary of multiple regression output. Therefore, the counter measures are needed because of there is the effects of geometric design parameters brings road traffic accidents as investigated in research.*

Keywords: Geometric parameters, Regression analysis, SPSS tool, Road traffic accident

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Acronyms

A	Algebraic Difference
AADT	Average Annual Daily Traffic
AASHTO	American Association State Highway and Transportation Officials
ADT	Average Daily Traffic
APW	Accident Point Weight Age
AP	Number of Access Points per Kilometer
AR	Accident Rate
CR	Curve Radius
DC6	Design class 6
ERA	Ethiopian Road Authority
GDP	Geometric Design Parameters
GP	Geometric Parameters
HTV	Hourly Traffic Volume
HCM	Highway Capacity Manual
LW	Lane Width
MLR	Multiple Linear Regression
PD	Property Damage
PDO	Property Damage Only
PSD	Passing Sight Distance
RTA	Road Traffic Accident
SLR	Single Linear Regression
SPSS	Statistical Package for the Social Sciences
SSD	Stopping Sight Distance
SW	Shoulder Width
TA	Traffic Accident
TRTA	Total Road Traffic Accidents
VCL	Vertical Curve Length

CHAPTER ONE
INTRODUCTION

1.1. Background

Every year, more than 1.25 million people die and as many as 50 million people are injured or disabled on the world's road [1]. Over 90% of death occurs in low and middle- income countries. The world report on road traffic injury prevention predicts more than 80% increase of road crash deaths in sub-Saharan Africa in the period 2000-2020[2]. Ethiopian currently loses almost 1700 lives each year; another 7500 are injured, and a further 7783 face property damage only due to road accidents [3]. In most African countries, urbanization is growing and road infrastructure is expanding, safety consideration in the land – use planning and road design are not adequate to serve the mixed traffic that exists in the county [4]. Therefore, geometric design parameters have a direct relationship with a road traffic accident. Key geometric design elements that influence traffic operations include number and width of lanes, the presence, and widths of shoulders and highway medians, and the horizontal and vertical alignment of the highway [5]. The major contributing factors to the occurrence of road traffic accidents (RTAs) are roadway geometry, driver error, vehicle factor, and environmental aspect [6]. Of all the systems that people have to deal with on a daily basis, road transport is the most complex and the most dangerous [7]. Road infrastructure should be designed taking account of the same injury tolerance criteria as this development for vehicle occupant protection and pedestrian impacts so that roads and vehicles together provide an effective safety system [8].

The road condition is a primary reason of traffic accidents; the lack of coordination between drivers and the road can lead to an increase in driver's reaction time and miscarriage of justice and increases the risk of traffic accidents [9]. The proper identification of the black spot is important in terms of efficient resource allocation. If the most hazardous site is identified and treated first, it becomes increasingly difficult to identify sites whose treatment will result in substantial social benefits [10]. The three broad approaches to identifying black spots are based on crash numbers, crash rates related to exposure to risk, and qualitative methods. Accident black spot on a national highway in Norway is defined as any place with a maximum length of 100 meters, where at least four injury accidents have been reported to the police during a four year period [11]. Although the main purpose of this study is to determine the effect of geometric parameters on driving behavior along with the black spot by using regression analysis. Geometric design consistency can be demarcated as how a driver's expectation and the road's performance match up (i.e., when a road with good consistency level matches a driver's expectations, the road user is not amazed while driving along with it) [12].

The values of geometric parameters were obtained from as-built road design outputs and a regression analysis was made between the variables [13]. Explanatory data analyses were conducted to investigate relationships underlying the use of correlations and regression analysis techniques. Correlations were established in the form of an equation of accident rate as a function of geometric parameters by considering the effect of individual elements on accident.

1.2. Problem of Statement

A number of countries have seen success in reducing road traffic deaths over the last few years, but progress varies significantly between the different regions and countries of the world. With an average rate of 27.5 deaths per 100,000 populations, the risk of a road traffic death is more than three times higher in low-income countries than in high-income countries where the average rate is 8.3 deaths per 100,000 populations [14]. Road traffic collision is reported as the first leading cause of death for the age 15-29 years followed by HIV/AIDS and TB, the second leading cause of death for age 5 to 14years next to lower respiratory infections, and it is the third leading cause of death following HIV/AIDS and TB among the people whose age is 30 to 44 years worldwide [1].

Every year, road crashes are estimated to claim over 300,000 lives in Africa. The correct number is unknown due to the very poor accident data recording and management system in the region. In Ethiopia, the rate of road traffic accidents (RTAs) is very high; because of road transport are the major transport mechanisms along with poor road infrastructure, poor enforcement of traffic laws and other factors [4].

The severity of road collision in Ethiopia varies from region to region; more than one-third of the fatal injuries (36%) occurred in Oromia regional state. Oromia region has the largest number of road traffic collision fatalities as vehicles from every corner of the country to the capital city (Addis Ababa) passes through the region. Therefore, Ethiopia traffic control system archives data on various aspects of the traffic system, such as traffic volume, concentration, and vehicle accidents [16].

The problem of a traffic accident is commonly observed on the Jimma zone, in Oromia region, on the Sekoru town to Gibe River Bridge road segment. Therefore, aims of this research will be encounter problem along black spot locations with respect to the road geometric design parameters on traffic accident to correlate between geometric parameters and road traffic accident rates that would be create an understanding on the basic root causes of traffic accidents, and can be very important for further consideration and quantification of the remedial measures. Therefore, identifications of black spot locations based on prioritization the hazardous location with the aid of the regression analysis model set a possible solution to the worst road traffic accidents [17].

Sekoru town to Gibe River Bridge road segment is at present has the worst condition of a traffic accident with respect to individual road geometric parameters such as horizontal alignment, vertical alignment, and road cross-sectional. Therefore, accident analysis is necessary to carry out in order to determine the effects of geometric design parameters on traffic accident along the black spot section.

1.3. Research Question

1) Where a black spot road section is commonly occurs, based on Road Traffic Accidents data of Sekoru Town to Gibe River Bridge?
2) What are the geometric design elements that causing traffic accident along the study road section?
3) What is the correlation between the geometric design elements and road traffic accidents?
4) What are the possible solutions and the way to reduce the effect of geometric parameters using regression analysis?

1.4. Objectives of the Study

1.4.1. General Objectives

The general objective of the study was to investigate the effect of geometric design parameters on Traffic Accident along the black spot section from Sekoru Town to Gibe River Bridge road segment

1.4.2. Specific Objectives

- ✓ To identify the black spot sections along the study road section from Road Traffic Accident's data.

- ✓ To identify the geometric design elements causing Traffic Accident along the study road section.
- ✓ To correlate the geometric design elements and the Road Traffic Accident
- ✓ To recommend countermeasures based on the result obtained from the regression analysis.

1.5. Significance of the Study

This study is important on how to decrease the occurrence of a road traffic accident by identifying black spot location and the defects of geometric design elements along the road study area. Therefore, using the regression analysis and principle based on the measurement of existing geometric element and traffic data collected from existing design values and traffic accident data from the police station recorded as a data-based system.

- ✓ Helps for identifying the causes of accidents along with the hazardous locations
- ✓ Minimizing the occurrence of road traffic accidents that comes from the variables of geometric design parameters.
- ✓ Give solution to research question or recommend values of geometric design parameters problem along the black spot section.

1.6. Scope of the Study

The scope of this research were limited to investigate the effect of road geometric parameters on traffic accident along black spot section through collecting road traffic accident data and road geometric design data of Sekoru Town to Gibe River Bridge. Field measurements of road geometric elements at black spot locations was compiled and recorded together with the traffic accident data reported by traffic police officials.

1.7. Limitation of the Study

The main problem faced during conducting this research was availability of well-organized and well recorded data. The traffic accident data obtained from Sekoru town to Gibe River Bridge traffic police commission office had no full information and awareness of recording using technology such as computer based system; they record manually on paper only; fatality, injuries, accident frequency property damage and, also road safety audit from ERA was not available. The other limitation that face me during preparation of this research was some of organizational stake holders were not willing to give information concerning to my research.

CHAPTER TWO

REVIEW OF RELATED LITERATURES

2.1. Introduction

This chapter presents a comprehensive review of varies literature related to the topic under consideration in order to find critical facts and findings which have already been identified by previous researchers and numerous studies on the effects of geometric design parameters along with black spot locations. This chapter explores the conceptual frameworks of the effects of geometric design parameters such as horizontal alignment, SSD, super elevation, and accident black spot identification methods by using regression analysis.

2.2. Black Spot Method

2.2.1. Definition of Black Spot

There is no universally accepted definition of black spot. To be classified as black spots, sites are generally assessed in terms of their degree of hazard or probability of being associated with a crash. The risk of a crash is not uniform throughout the road network. At certain locations, the level of risk will be higher than the general level of risk in surrounding areas. Crashes will tend to be concentrated at these relatively high-risk locations. Locations which have an abnormally high number of crashes are described by terms such as high hazard, hazardous or black spot sites [10].

2.2.2. Calculating of Accident Frequency

According to the priority, criteria developed by the Flemish government, road sections which have greater than or equal to 15 of priority value considered for further black spot investigation. The existing value of cross section elements for the audit road have been measured and compared with ERA geometric design manual as shown in the table below. In order to check the design standard of the cross section of the road of the study area, the researcher should have to know the standard design of the road [22].

Table 2.1: Comparison of road cross section of existing road with ERA standards [22]

SNo.	Roadway Element	ERA Standard Values	Observed Values
1.	Design speed	30-85km/hr depending on the terrain roads	Mostly 80km/hr and above
2.	Lane width	6.7-7m	5-6.5m
3.	Shoulder width	0.5-1.5m	0-1m
4.	Number of lanes	Two lane	One and two-lane

5.	Bridge width	At least full approach traveled width or plus 0.6m way width on each side	Less than travel way width
6.	Pedestrian	Controlled	Uncontrolled

In addition to the above listed geometric related factors, some of elements were discussed under road safety audit checklist prepared for evaluations of identified black spot locations. A total of 19 hazardous locations fulfilled the first criteria which have 3 or more accidents within the last 3 year of study period of 2012-2015 of those 12 dangerous areas were identified as black spot location in Sululta town. Also in table below shows the calculated values of priority value based on fatalities and injuries for each black pot locations [22].

2.2.3. The Priority Value of Hazardous Location

According to the priority, criteria developed by the Flemish government, road sections which have greater than or equal to 15 of priority value considered for further black spot investigation [23].

2.2.4. The Accident Rate

The accident rate is defined as the ratio between the number of accidents which happened in a given year and the number of vehicles with kilometers of travels length during the same year. It is generally expressed in crashes per million vehicle-kilometers of travel [22].

$$AR = \frac{Cx1{,}000{,}000}{Vx\ 365\ xNxL}$$ …..…………………….……………….………..……..…… Equation (2.1)

The variable in the equation is:

AR = Accident rate expressed as crashes per 100 million vehicles of travel (100mvkm)

C = Total number of crashes in the study period

V = Traffic volumes using Annual Average Daily Traffic (AADT)

N = Number of years of data L = length of the roadway in km

2.2.5. Earlier Models Survey

Developed the following accident prediction model for the 1991 FHWA study cost-effective [17]

A=[(1.552)(L)(V)+(0.014(D)(V)(0.012)(S)(V)](0.978)W……………….....Equation (2.2)

Where, A = Number of total accidents on the curve in 3years period

L = Length of curves

V = Volume of vehicles in million vehicles passing through (both direction) in a 5 year time

D = degree of curve

S = presence of spiral

W = width of roadway (twice the lane plus shoulder width) on the curve

i) Black spot study and accident prediction model using multiple regression, linear models. The study area was the federal route (FT50) Batu Pahat – Ayer Hitam (31).

In (APW) 0.5 = 0.0212 (AP) +0.0007(HTV 0.75+ GAP 1.25) + 0.0210(85th PS) …………………………………………………………………………....Equation (2.3)

Where APW = accident point weight age

AP = number of access points per kilometer

HTV = hourly traffic volume

Gap = amount of time, between the end of one vehicle and the beginning of the next in second.

85th PS = PS =85th percentile speed

The model has R-square of 0.9987

The result of the paper has shown that the existence of a larger major junction density, an increase in traffic volume and vehicle speed in federal route 50 is the contributor's to a traffic accident. Reduction of vehicle speed, access point, traffic volume, and gap are likely to have an influential effect on road traffic accidents.

2.3. Statistical Models

To investigate the influence of each of effective parameters on a number of accidents or accident rates, sensitivity analysis is performed on the models to determine the share of each of the effective parameters on dependent parameters. To develop a better relationship between them, it is better to use a regression method to determine the better relationship among variables. The factors influencing such accidents are to be analyzed for remedies. Using regression models, factors influencing road accidents have analyzed using SPSS model [30].

Regression models display the relationship between the dependent and independent variables using the statistical and mathematic method so that dependent variables have the most correlation with independent variables and can describe it best [31].

Linear regression analysis is a statistical method for modeling the relationship between two or more variables using simple and multiple linear equations [32].

In this research work, an attempt is made to apply single linear regression models to characterize the influence of road geometric parameters on the rate of traffic accidents using a statistical approach. Simple linear regressions refer to a regression on more than two variables.

2.3.1. Multiple Linear Regression Analysis

During the multiple linear regression analysis, after a combination of predictors, the following results were obtained for the selected variables and significant relationships are presented here under [33].

A statistical software program (SPSS) has been used in regression analysis to find the effect of road attributes on the accident rate. The general equations of probabilistic single and multiple linear regression models are presented in the following forms [32].

$Y = \beta o + \beta 1X + \varepsilon$ ……………………………………..………..………..…Equation (2.4)

$Y = \alpha 1X1 + \alpha 2X2 \ldots + \alpha nxn + \varepsilon$ ……………………..…………………Equation (2.5)

Where, the slope (β1) and intercept (βo) of the single linear regression model are called regression coefficients. Similarly, coefficients $\alpha o, \alpha 1, \alpha 2 \ldots \alpha n$termed as multiple regression coefficients which are not applied in this study. The standard error term (ε) is a dispersion of prediction error when it is needed to predict dependent values from the independent variables in a regression analysis. The basic assumption to estimate the regression coefficient of the single regression model is based on the least square method. The correlation coefficient R2only gives a guide to the “goodness of fit” or how closely variables X and Y are related. It does not indicate whether an association between variables is statistically significant. A number of techniques can be used to judge the adequacy of a regression model, some of which area standard error (ε), R-square value (R2), R adjusted and the p-value. The value R2 is always between 0 and1 because r is between -1 and +1, whereby a negative value of R indicates inversely relationship. Confidence of the result indicates in terms of significant value (P). The correlation was considered significant if (P) is zero or 5% different from zero [33].

2.4. Road Design Elements Affecting Traffic Accidents

The following traffic, roadway, and geometric features that influence safety horizontal curve sections have been identified [17]. Traffic volume on the curve and traffic mix (such as percentage of trucks), Vertical alignment on horizontal curve distance to adjacent curves, Curve features (such as degree of curve, curve length, super elevation, presence of transition curves), Curve section roadside hazard features (such as clear slope, rigidity, and types of obstacles), Cross-sectional curve elements (such as lane width, shoulder width, shoulder type, shoulder slope), Stopping sight distance on curve (at curve approach), Distance of curve to nearest intersection, driveway, Pavement friction and Presence and type of traffic control devices (signs and delineation)

2.5. Factors Responsible for Road Accidents and Geometric Design Parameters

These can be grouped into the following [29].

1. Vehicle-related factors: this may due to inherent design limitations or defects to lack of maintenance, failure of components like brakes, tires, and lighting. Visibility, speed, and vehicle lighting are also important.
2. Road user-related factors: psychological factors of the users, alertness and intelligence, the patience of the driver, drivers experience and shoulder width, vertical curves.
3. Road related factors: this includes pavement design and condition, horizontal curves, insufficient lane and shoulder width, vertical curves.
4. Environmental related factors: rain, reduced visibility, bad weather and heavy fog and mist and heavy rain also plays an import role.

2.5.1. Horizontal Alignment

The horizontal alignment of a road comprises straight lines, circular curves (with a constant radius), and transition curves, whose radius changes regularly to allow for a gradual transfer between adjacent road segments with different curve radii, the main objective of horizontal alignment should be to ensure consistency and uniform along the alignment, in order to avoid the creation of sections demanding an important adjustment of travel speed [8].

There are several elements of horizontal alignments which are associated with horizontal curve safety. It states that the safety of a horizontal curve, its accidents frequency and severity is determined by: Internal features: radius or degree of the curve; super elevation. External features: density of curves upstream; length of the connecting tangent section, sight distance, etc. that influence driver expectation and curve approach speed. Road geometric improvements or remedial measures used to ensure safety at deficient horizontal curves include the following points: Lengthen the radius of a curve to reduce accidents in sharp horizontal curves, Improving warning and guidance provided for drivers, better sight distance, curve conspicuity, Signing and marking, delineations. Minor geometric improvements; modification to the shoulder and roadside conditions [18]

Curve straightening. Roadway widening at curve sections and Super elevation improvements, the degree of curvature and radius are significant variables influencing crash rate on horizontal curves. When curves became sharper the model predicts an increase in track crashes on horizontal curves. The radius and degree of curvature significantly influence motorcycle crashes on horizontal curves [18].

2.5.2. Vertical Alignment

The vertical alignment of the road consists of straight segments (level or inclined) connected by sag or crest vertical curves. Combinations of these elements create various shapes of road profiles [8].

i) Vertical Curve

There are three main effects of vertical road alignments, which are closely associated with the occurrences of traffic accidents. These are excessive speeds and out of control vehicles on downgrades, differential speed between vehicles created on both down and upgrades, and low range of visibility that often occurs in the immediate vicinity of steep grades at the crest of vertical curves [21].

ii) Crest Vertical Curves

Minimum lengths of crest vertical curves based on sight distance criteria generally are satisfactory from the standpoint of safety, comfort, and appearance. An exception may be at decision areas, such as sight distance to ramp exit gores, where longer lengths are needed; for further information, refer to the section of this chapter concerning decision sight distance. Values now in use range from about 30 to 100 m [100 to 325 ft]. To recognize the distinction in design speed and to approximate the range of current practice, minimum lengths of vertical curves are expressed as about 0.6 times the design speed in km/h, L min = 0.6V, where V is in kilometers per hour and L is in meters, Design controls stopping sight distance, when the height of eye and the height of object are 1,080 mm and 600 mm [3.5 ft. and 2.0 ft.], respectively, as used for stopping sight distance, the equations become [25]. For a particular design speed, the minimum radius crest vertical curve is usually governed by sight distance requirements. However, for small changes of grade, the appearance criterion may suggest larger values of radius to provide satisfactory appearance of the curve. Riding comfort is generally not considered on crests as the sight distance requirements almost always require the use of large radius vertical curves, Although vertical crest curves as large as possible are generally used, there are cases where the provision of a sharper crest vertical curve with a longer vertical straight will lead to longer and safer overtaking opportunities. This issue becomes important on high speed roads with limited overtaking opportunities caused by tight alignments or traffic density [41].

A= G2-G1 in percent it must be positive

Where g1 and g2 are gradient,

L=KA where L is length of vertical curve, A – is algebraic difference

For stopping sight distance

L= (AS^2)/658 for s<L OR L=2S-658/A for s>L

S= (658L/A) $^{1/2}$ for S<L

For passing sight distance

L= AS^2/864 when S is less than L OR L=2S-864/A when S is greater than L

S= (864L/A) $^{1/2}$ for S<L

iii) Sag Vertical Curves

At least four different criteria for establishing lengths of sag vertical curves are recognized to some extent. These are (1) headlight sight distance, (2) passenger comfort, (3) drainage control, and (4) general appearance flexibility, and other factors. A headlight height of 600 mm [2 ft] and a 1-degree upward divergence of the light beam from the longitudinal axis of the vehicle is commonly assumed. The upward spread of the light beam above the 1-degree divergence angle provides some additional visible length of roadway, but is not generally considered in design. The following equations show the relationships between S, L, and A, using S as the distance between the vehicle and point where the 1-degree upward angle of the light beam intersects the surface of the roadway [27].

For overall safety on highways, a sag vertical curve should be long enough that the light beam distance is nearly the same as the stopping sight distance. Accordingly, it is appropriate to use stopping sight distances for different design speeds as the value of S in the above equations. The effect on passenger comfort of the change in vertical direction is greater on sag than on crest vertical curves because gravitational and centripetal forces are in opposite directions, rather than in the same direction. Comfort due to change in vertical direction is not readily measured because it is affected appreciably by vehicle body suspension, vehicle body weight and tire [25].

L= (AS^2)/ (120+3.5S) for S<L or L=2S-(120+3.5S)/A for S>L…Equation (2.6)

Where, L = length of sag vertical curve

A = algebraic difference in percent

The existing value of cross section elements for the audit road have been measured and compared with the ERA geometric design manual as shown in the table below. In order to check the design standard of the cross-section of the road of the study area, the researcher should have to know the standard design of the rod [24].

iv) Gradient

The gradient is the rate of rising or falls with respect to the horizontal along the length of expressed as a percentage or as 5 a ratio or in degrees. Vertical curves to effect gradual changes between gradients with any one of the crest or sag types and result is safe and comfortable in operation, pleasing in appearance, and adequate for drainage [22].

2.5.3. Road Cross-Sectional Elements

This study was conducted to minimize the known relationships between accident experience and cross-sectional roadway elements, along with accident reductions expected because of related roadway safety improvements. Such elements include lane width, shoulder width, shoulder type, roadside features, bridge width, median design, and others. Lane widening can reduce these related crashes by up to 40%, whereas shoulder widening can reduce related accidents by up to 49% [for the addition of 8ft (24m) paved shoulders]. Improving roadsides can also contribute to the reduction of as much as 44% [for a 20ft (6.1m) increase in the clear zone], whereas side slope flattening can reduce single-vehicle crashes up to 27% (for flattening a 2:1 side slope to 7:1 or flatter). Bridge widening can reduce total bridge crashes by as much as 80%, depending on the width before and after widening. On multilane roads, wider and flatter medians are associated with a reduced rate of total crashes [23].

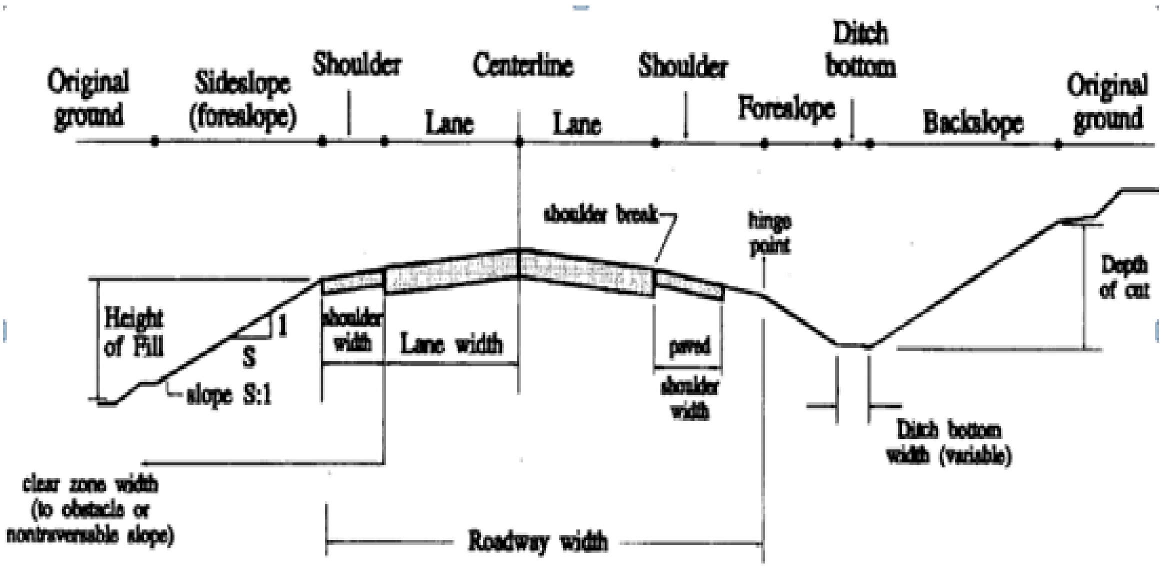


Figure 2.1: Elements of Rural Two-Lane Highway Cross Section [23]

2.6. Super elevation

A number of studies have attempted to link supper elevation to accident causation. The available super elevation at flat accident sites was typically deficient. Curves with too little supper elevation had worse accident rates than curves with proper super elevation. Thus, curves with super elevation below the AASHTO guideline, as specified in the policy on geometric design of highway and streets have significantly worse accident rates than those with super elevation above the minimum guideline(8). Super elevation values ranging from 5% to 8% are recommended in design and improving the super elevation reduces the number of accidents by 5% to 10% [8].

2.7. Sight Distance

This is the ability to see ahead in order to stop safely or overtake a vehicle or review approach intersection. Sight obstructions on the road, generally occur due to the presence of deep cuts, embankments, vegetation, walls on the inside of the horizontal curves and intersection quadrants, and sharp crest vertical curves themselves [13]. Types of sight distance are: stopping sight distance, passing sight distances, intersection sight distance, and decision sight distance. Inadequate sight may be a factor in 20 to 25 percent of accidents resulting from overtaking maneuvers. The actual percentage of crashes in which sight distance has a role would clearly be related to the extent of overtaking maneuvers, which is related to traffic flow [28].

$d= (0.278)\,(t)\,(v) + v^2/254f$ ……………………………………………………..…..Equation (2.6)

Where, d= distance (meter)

t= driver reaction time, generally taken to be 2.5 seconds, v= initial speed (km/hrs.)

f= coefficient of friction between tires and roadway

2.8. Speed and Design

Current freeway designs have nearly reached the goal of allowing drivers to operate at high speeds in comfort and safety. Control of access to the traveled way reduces the potential for conflicts by giving drivers a clear path. Clear roadsides have been provided by eliminating obstructions or designing them to be forgiving. The modern freeway provides alignment and profile that, together with other factors, encourages high operating speeds [25].

Speed has a strong correlation with pedestrian crashes and is a key risk factor in pedestrian injury crashes [26]. Researchers have frequently used posted speed (as indicated by advisory speed signs erected on roads) to model crashes; however, the majority of drivers navigate with an actual speed which often deviates substantially positively or negatively from the posted speed. This could easily be done by taking some observations of vehicle speed to capture the operating speed of drivers at various sites. It is well documented that vehicle speed affects a driver’s stopping distance. If the vehicle travels with a higher speed the vehicle will require a longer distance before coming to stop. For instance, the Ethiopia geometric design guide provides both recommended stopping and recommended passing sight distances with the change in designated traffic speed for the design of new or upgrading road project see in the table below.

Table 2.2: Geometric Parameters for DC6 Paved (AADT 1,000-3,000)

Design Element		Unit	Flat	Rolling	Mountain	Escarp’t	Urban Peri-Urban
Design Speed		Km/hrs.	100	85	70	60(3)	50
Width of running surface		M	7.0				7.0+
Width of shoulders		M	Table 2.2 and Table 2.5				
Minimum. Stopping Sight Distance	g = 0%	M	210	155	110	85	65
	g = 5%	M	240	175	120	90	70
	g = 10%	M	285	205	140	105	75
Min. Passing Sight		M	375	330	270	230	180
% Passing Opportunity		%	50	33	25	0	20
Minimum Horizontal Curve Radius(4)	SE = 4%	M	515	350	215	145(3)	95
	SE = 6%	M	455	310	195	135(3)	85
	SE = 8%	M	410	280	175	120(3)	-
Transition Curves Required			Yes	Yes	Yes	No	No
Max. Gradient (desirable)		%	3	5	7	7	6
Max. Gradient (absolute)		%	5	7	9	9	8
Minimum Gradient		%	0.5	0.5	0.5	0.5	0.5
Maximum Super-elevation		%	8	8	8	8	4
Min. Crest Vertical Curve (1)		K	100	55	30	17	10
Min. Sag Vertical Curve		K	25	18	12	9	7
Normal Cross-fall		%	2.5	2.5	2.5	2.5	2.5
Shoulder Cross-fall		%	4	4	4	4	4
Right of Way		M	50	50	50	50	50

Source: ERA 2013

2.9. Traffic Volume Characteristic

i. Average Daily Traffic

The average daily traffic (ADT) is the total number of vehicles in a time period (more than one day and less than a year) divided by the number of days in the period. It is a figure that may be used for a specific time for purposes relating to that time period. The annual average daily traffic (AADT) is the total volume of traffic for the whole year divided by a number of days in the year. These parameters can be readily established when continuous counts are available. When only periodic counts are undertaken, the ADT and AADT can be estimated by applying relevant factors to account for the season, month and day of the week.

ii. Hour Traffic

Hourly volumes provide a much better measure of the operating condition to be met by the design of the road. All roads exhibit a propensity to have a brief period of intense activity repeated regularly. This is particularly obvious in urban conditions but it is also the case that rural roads have a significant variation in hourly volume since the facility provide would be underused for most of the time. A balance between the inadequacy of the average traffic volume and the wastefulness of the maximum volume must be struck.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Description of the Study Area

This study were conducted along asphalt road from Sekoru Town to Gibe River Bridge that covers 70 kilometers, the collection of data were accompanied in two woreda Sekoru woreda and Yem Special woreda and GPS coordinates of Sekoru Town to Gibe River Bridge is between Latitudinal 80

Sekoru is Part of the Jimma Zone is bordered on the south by Omo Nada, on the west by Tiro Afeta, and on the north and east by the Southern Nations, Nationalities and Peoples Region; the Gibe River defines the northern boundary. Other towns in this woreda include Deneba, Kumbi and Natri. The altitude of this woreda ranges from 1160 to 2940 meters above sea level; the highest points include Ali Shashema, Ali Derar and Kumbi. Perennial rivers include the Gilgel Gibe a tributary of the Gibe, and the Kawar; seasonal streams include the Melka Luku. The 2007 national census reported a total population for this woreda of 136,320, of whom 68,469 were men and 67,851 were women; 12,724 or 9.33% of its population were urban dwellers. The Gibe River is one of the largest rivers in Ethiopia. This river connects the central government with the West – South of the country along Wolkite - Jimma route and its found 185 km away from Addis Ababa [42].

Yem is one of the woreda in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) of Ethiopia. Because Yem is not part of any Zone in the SNNPR, it is considered a Special woreda, an administrative subdivision which is similar to an autonomous area. Yem is named for the Yem, people whose homeland lies in this special woreda (see Kingdom of Janjero). Yem is bordered on the west and north by the Oromia Region, and separated from Gurage on the northeast and Hadiya on the east by the Omo River. High points in Yem include Mount Bor Ama, Mount Azulu and Mount Toba. The administrative center of Yem is Fofa. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this woreda has a total population of 80,687, of whom 40,566 are men and 40,121 women; with an area of 647.90 square kilometers, Yem has a population density of 124.54. While 7,952 or 9.86% are urban inhabitants, a further 106 or 0.13% are pastoralists. A total of 17,632 households were counted in this woreda, which results in an average of 4.58 persons to a household, and 17,204 housing units [41].

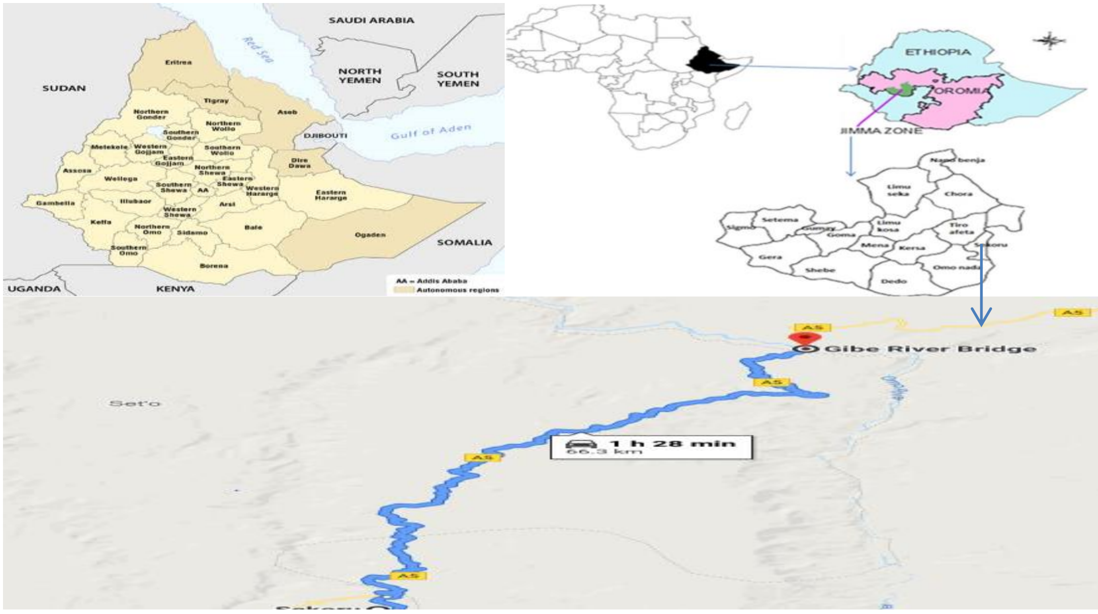


Figure 3.1: Satellite Image of Sekoru- Gibe River Bridge Road (Google Map 2019)

3.2. Research Design

A descriptive research method and analytical design approach were used in this study. The descriptive type of research would considered to be an appropriate method to investigate the status; causes and countermeasures of road traffic were analyzed for different traffic accident along with black spot locations along the study area.

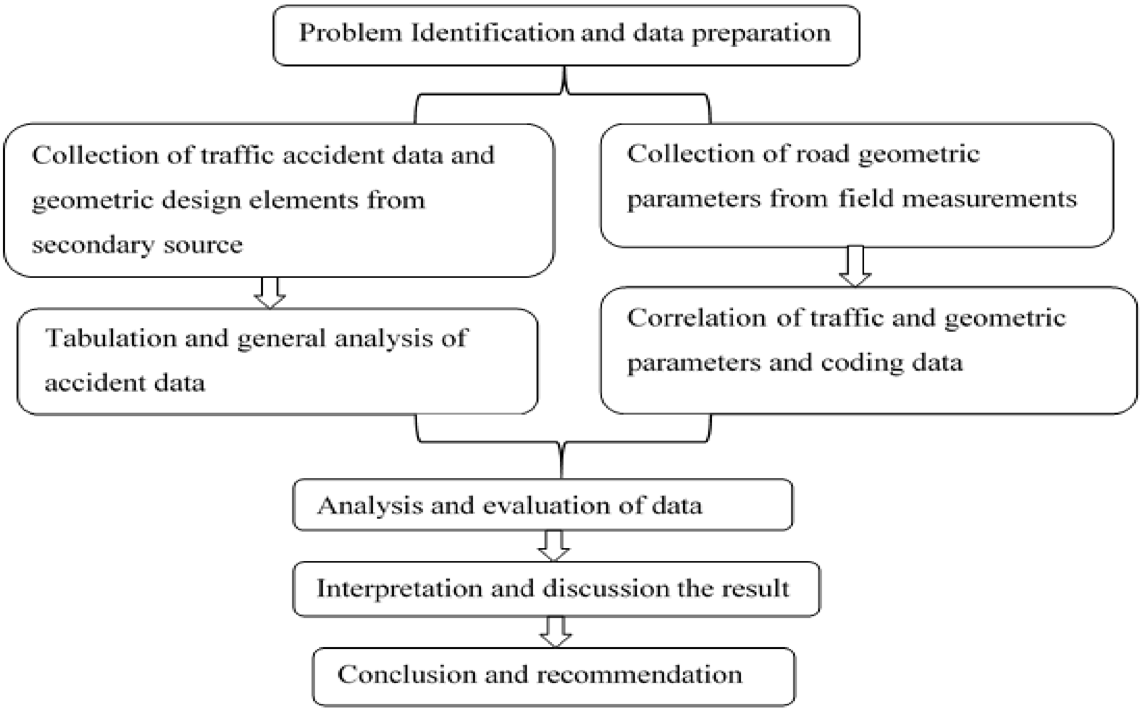


Figure 3.2: Flow Chart for Research Design

3.3. Population

The population of the study was considered as road geometric features, pedestrians, drivers, traffic police, transport office and woreda towns' administrative bodies between Sekoru towns to Gibe River Bridge.

3.3.1. Sample Size

The sample size was determined based on population size using a sample size formula. The sample size was calculated using the equation of infinite population (where the population is greater than 50,000) since the population

The sample size was calculated by

$S= ((z)^2 \times p \times (1-p))/C^2$……………………………………………..……Equation (3.1)

Where: - Ss=sample size

Z=z-value (e.g., 1.96 for a 95 percent confidence level)

P= percentage of population picking a choice expressed as a decimal

C= confidence interval, expressed as decimal (e.g., 0.05 = +/- 5 percentage points,).

Percentage points $SS = (1.96)^2*0.5*(1-0.5) / (0.07)^2 = 196$

Taking 5% non-response rate = 7% of 196 becomes 10.

Adding to the previous one it becomes 206 (pertinent sample size).

3.3.2. Sampling Technique

The study was adapted to probability sampling (simple random sampling technique and stratified sampling) was used for a sample size of pedestrians and drivers; but non probability (purposive sampling) was used for traffic police office, transport office, Ethiopian Road Authority, administrative body and any other stakeholder for the road segment from Sekoru to Gibe River Bridge. The sample was picked accordingly based on their importance and as behave of target body for purposive sampling.

3.4. Study Variables

There were two types of variables that were taken into consideration:

Independent variable:

The independent variables are; Lane width, Gradient, Shoulder width, Radius of the horizontal curve, Super elevation (e), Annual Average Daily Traffic (AADT), Vertical curve length, Algebraic difference, passing sight distance and stopping sight distance.

Dependent variables: Road Traffic Accidents, Accident Rate

3.5. Data Collection Process

Both descriptive and analytical research methods were used for conducting of this research; in descriptive method describing the available (existing) data by graphical analysis for Sekoru town to Gibe River Bridge road segment but in analytical method in depth study or evaluation were commenced using SPSS and Excel tools. The first step of analysis was determining the most accident sites; as Flemish government analyses the accident data that are obtained from the Belgian Analysis form for Traffic Accidents, this form should be filled up by a police officer for each traffic accident that occurs with injured or deadly wounded casualties on a public road. Based on these data, the following criterion was used. For site where in the last three years three or more accidents have occurred was selected. Then, a site was considered to be hazardous when its priority value (P), calculated using the following formula, equals 15 or more [10].

$P = X + 3*Y + 5*Z$……………………………….…………….………..Equation (3.2)

Where, X = total number of light injuries

Y = total number of serious injuries

Z = total number of deadly injuries

And identification of the black spot locations using the prepared checklist and also by stating the comment for each the black spot locations.

The checklist included the following road safety audit criteria's such as road widening (wider road decreases occurrence of accident) so that the width was checked, the provision of Lane width, because a longer and steeper road was more useful for provision of climbing lane, the provision of Roadside Delineator because it helps vehicles not to leave the road, both the center and edge road marking was checked because it reduces rate of occurrence of accidents, the presence of Speed limit post because lower speed limits decrease the rate of occurrence of accidents, ridge width along black spot location because shortened than the road or check whether pedestrian walking was provided or not, road Side improvements because flat slopes were best to decrease the severity of accidents, provision of guard rails was checked both along carriage way and shoulders, because it helps vehicles from leaving the road way, Provision of Median Barriers was checked, the longitudinal slope of the road was visually checked, the horizontal curve of the road was visually checked, whether the curve was sharp or not, the adequacy of lane width of shoulder were checked. Finally, detailed road safety audit undertaken for each black spot locations was described in *Appendix A.*

3.6. Primary Data Collection

Primary research data was obtained through site observations of black spot sections, from questionnaires' of drivers; town administrative body, traffic police, transport bureau, pedestrians and direct measurements of geometric components at accident locations.

3.7. Secondary Data Collection

Secondary data was collected through reviewing the existing relevant documents such as built drawing from ERA, reports, literature, Sekoru woreda and Yem special woreda traffic police commission office traffic accident data or any other relevant documents.

3.8. Data Processing and Analysis

The quantitative data processing and analysis was an attempt to make to apply correlation and multiple regression models to collect the influence of road geometric elements along black spot section on the traffic accidents.

The first step was the preparation of the accident data format that helps for collection compiled data in the police commission office and transport bureau.

The second step was the collection of accident data from secondary sources (such as police records, transport bureau record documents, notebooks or any compiled documents) and the collection of existing road geometric parameters and traffic data from a secondary source.

The third step was the collection of as a built drawing and AADT from Ethiopian Road Authority

The fourth step was tabulation and general analysis of accident data obtained from the police report and Consolidation of traffic and geometric parameters & coding the data.

The fifth step was analysis of data by using multiple linear regressions, and correlation between Accident Rate (AR) or Total Road Traffic Accident (TRTA) with geometric design elements; radius of horizontal curve, super elevation (e), gradient (G), Annual Average Daily Traffic (AADT), vertical curve length (VCL), Lane width, Algebraic difference (A), passing sight distance (PSD) and stopping sight distance (SSD) based on the significant standard error (p-value) and coefficient of determination (R^2).

The sixth step was interpretation of results; conducting statistical correlation and regression analysis between the various road geometric elements and Total Road Traffic Accident.

The seventh step was Conclusion and recommendation

3.9. Computation of A, SSD and PSD

According to AASHTO, the minimum lengths of crest vertical curves based on sight distance criteria generally are satisfactory from the standpoint of safety, comfort, and appearance.

Design controls stopping sight distance**,** the minimum lengths of vertical curves for different values of A to provide the minimum stopping sight distances

A= G2-G1 in percent it must be positive

Where g1 and g2 are gradient

$L= (AS^2)/658$ for s<L OR $L=2S-658/A$ for s>L

$S= (658L/A)^{1/2}$ for S<L

Design controls—passing sight distance, design values of crest vertical curves for passing sight distance differ from those for stopping sight distance because of the different sight distance

and object height criteria

$L= AS^2/864$ when S is less than L OR $L=2S-864/A$ when S is greater than L

$S= (864L/A)^{1/2}$ for S<L

Design controls stopping sight distance, design values of Sag vertical curves for stopping sight distance and A headlight height of 600 mm [2 ft.] and a 1-degree upward divergence of the light beam from the longitudinal axis of the vehicle is

commonly assumed object height criteria

$L= (AS^2)/ (120+3.5S)$ for S<L or $L=2S-(120+3.5S)/A$ for S>L

3.10. Computation of curve elevation

Vertex (V) the point of intersection of the grade line (PVI) point of V. Curvature (PVC)- The pt of tangency where the parabolic V. curve leaves initial grade.

Point of Vertical tangency (PVT)- The pt of tangency where the parabolic V. curve meets the forward grade.

Length of vertical curve (L) - the horizontal distance b/n PVC to PVT.

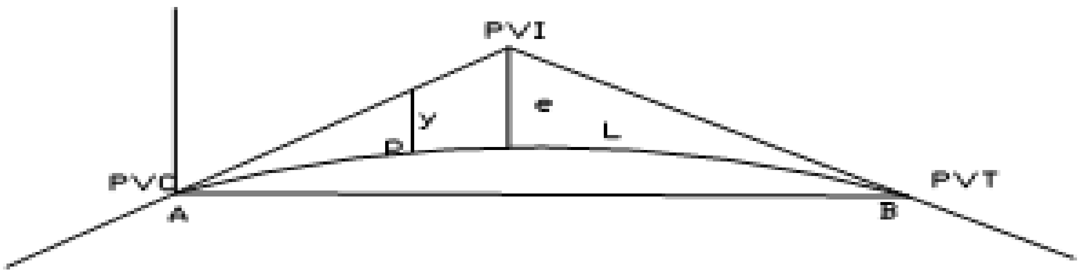


Figure 3.3: Equations of symmetrical parabolic Vertical curve

Let X and Y be the coordinates of pt p on the curve wrt point A.

X= the vertical offset (m) from the vertex (PVI) to the middle of the curve.

Y= the vertical offset (m) from the tangent to any point on the curve.

Based on the rule of offsets [26]

The entire curve may be established by offsets from the initial tangent or the first half may be referred to the first & the second half to the second tangent

$y = 4e\left(\frac{x}{L}\right)^2$ ………………………………………………………..………...Equation (3.1)

Where e is y offset from the tangent to the curve

Elevation on tangent (EPT) = EPVC +g1x

Elevation on Curve (EPC) + EPT + y

EPC = EPVC + g1x + y

EPC = EPVC + g1x + 4e $\left(\frac{x}{L}\right)^2$

Where x = the distance of a point on curve from PVC

L= the length of curve

g1 =the initial grade per station

EPC= elevation of points on curve

EPT= elevation of points tangent.

EPVC= elevation of PVC

e = the offset from PVI to curve

3.11. Multiple Linear Regression Model

The collected data were statistically analyzed to evaluate the effect of the selected parameters on accidents. The relationship between accidents and various factors was also obtained [34]. The data were analyzed using Excel Data Analysis tool and SPSS (Statistical Package for Social Sciences) tool. Here the number of accidents was taken as the dependent variable and width of the Lane, shoulder width, Gradient; Super elevation, Gradient, AADT, Radius Horizontal Curves, K-value, and Algebraic Difference, passing sight distance and stopping sight distance was taken as independent variables

The statistical technique which will be most frequently encountered by a traffic engineer and traffic planner is the multiple linear regression analysis. The problem concerns with the establishment of a relationship between a variable which is known to respond to changes in two or more other variables. The variable which is known to respond, Y variable, is commonly called the independent variable, and the other variable influencing it is called the independent variables i.e. X variable [34].

$Y=a_0+a1x+a2x2+a3x3+\ldots +am\ xm$……………………….………..…….Equation (3.3)

Where Y=true estimate of the dependent variable, x1, x2, x3……xm = m independent variables, a_0=regression constant a1, a2, a3….am=regression coefficients of the respective m independent variables [34].

3.12. Ethical Consideration

The data was collected after ethical permission given from Jimma University before continuing the study acceptance was given from local authorities. Then if there were ethical problems it can be resolved; to keep secret and feel confidence, the name and address of respondent not taken. The purpose of the study were clearly described to the organization and to the concerning local communities.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Characteristics of Accident Data of Sekoru Town to Gibe River Bridge

The road traffic accident data was collected from the two woreda; Yem special woreda and Sekoru woreda along this road segment road traffic accident data between year 2015 and 2019 had the characteristics shown in the figure below.

Figure 4.1: Road Traffic Accident Occurred in Sekoru Woreda in 2015 and 2016

Figure 4.2: Road Traffic Accident Occurred in Yem special Woreda in 2015 and 2016

Table 4.1 indicates the total number of traffic accidents and estimated loss of property along Sekoru town to Gibe River Bridge from 2015 to 2019.

Table 4.1: The TRTA Data of the Two Woreda Based on RTA and PD

Year	**Yemi Special Woreda**		**Sekoru Woreda**	
	Total RTA	PD in ETB	Total RTA	PD in ETB
2015	29	117,500.00	51	2,860,850.00
2016	21	247,625.00	38	1,230,385.00
2017	47	433,400.00	66	178,900.00
2018	60	935,450.00	71	1,387,400.00
2019	19	120,000.00	42	1,498,530.00
Total	176	1,853,975.00	268	7,156,065.00

The number of road traffic accidents in Yem Special Woreda had increased from 2016 to 2018 , but decrease in 2019 also had increasing in Sekoru Woreda from 2008 to 2019 because of awareness was given to the drivers and the pedestrians. .However, the total property damage was 1,853,975.00 Birr from Yem special woreda and 7,156,065.00 Birr from Sekoru Woreda. The total number of accidents and the property damage were very high; the figure below show that in each year convince that the country had lost a huge amount of the economy every year along this road

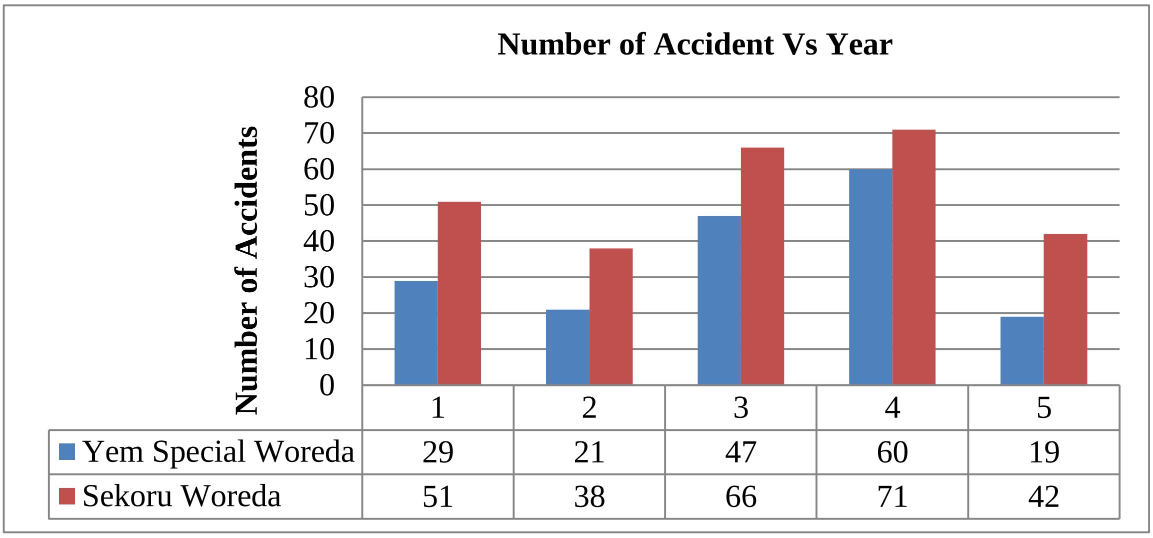


Figure 4.3: The Relationship between Number of Accidents and Year

As shown on Figure.4.3, Yem special Woreda had 60 total road traffic accident in 2018, but Sekoru Woreda had highest traffic accident which is 71 when we compare with Yem special Woreda.

The table below indicates, degree of severity and Accident frequency in both woreda, Sekoru woreda has the highest degree of severity and Accident frequency; fatal 55, serious injury 27, Slight injury 31, Property damage only 155 and Accident frequency 244 and Yem special woreda has also; fatal 18, serious injury 45, Slight injury 78, Property damage only 35 and Accident frequency 91

Table 4.2: Degree of Severity in Sekoru and Yem Special Woreda

Degree of Severity										
	Sekoru Woreda					**Yem Special Woreda**				
Year	AF	F (Z)	SI (Y)	LI (X)	PDO	AF	F (Z)	SI (Y)	LI (X)	PDO
2015	40	6	10	3	32	14	0	10	13	6
2016	40	8	0	0	30	17	1	2	10	8
2017	50	13	7	12	34	23	1	11	29	6
2018	71	17	9	15	30	26	15	21	14	10
2019	43	11	1	1	29	11	1	1	12	5
Total	244	55	27	31	155	91	18	45	78	35

AF- Accident Frequency F –Fatality SI- Series Injury LI- Light Injury PDO- property damage only

From figure below the accident frequency was higher in 2018; 71 in Sekoru woreda and 26 in Yem special woreda which shows, higher accident record than the previous years.

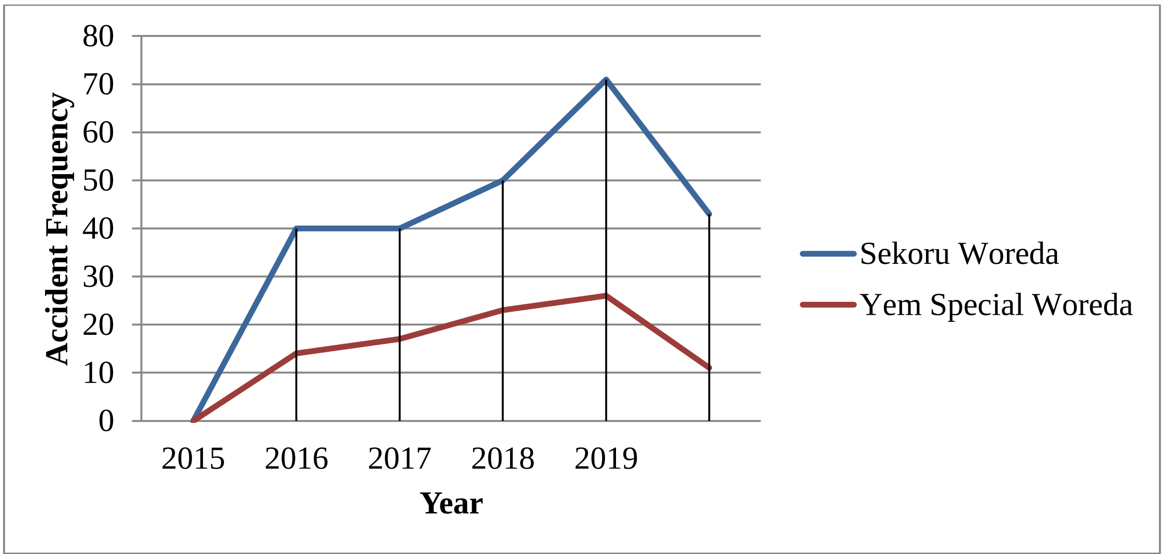


Figure 4.4: Accident Frequency vs. Years

4.2. Identification of Black spot Locations in each Woreda

The traffic accident data had different characteristics in each Woreda. The identification of black spot location was done by the method of Prioritization and ranking for both Keble of Yem special Woreda and Sekoru Woreda separately.

4.2.1. Black Spot Locations in Yem special woreda

A total of 10 hazardous locations that fulfilled the first criteria which have 3 or more accidents within the last 3 years of the study period of 2017-2019 of those ten hazardous locations were identified as black spot location in the Yem special woreda as on Appendix B-1.The calculated values of priority value were based on fatalities and injuries for each black spot location.

Generally, there was 10 hazardous traffic accident locations from those 5 locations were fulfilling the prioritization rule for P-value which is greater than or equal to 15. Kosho in Yem Special woreda had the 78 p-value of the highest value and there are four stations listed from by number 1-5 which did not fulfill the criteria of prioritization shown on appendix B-1

4.2.2. Black Spot Locations in Sekoru Woreda

A total of 15 hazardous locations that fulfilled the first criteria which have 3 or more accidents within the last 3 years of black spot location in Sekoru Woreda as shown in Appendix B-2. The calculated values of priority value were based on fatalities and injuries for each black spot location. Generally, there were 15 hazardous traffic accident locations from those 10 locations were fulfilling the prioritization rule for P-value which is greater than or equal to 15. Qumbi muzi tera had the highest 79 P-value and Doma in Sekoru woreda had 15 p-value had least value, there was other areas that not fulfilling the criteria of prioritization.

Generally, as a shown in the table below, there are a total of 15 black spot locations identified from Sekoru town to Gibe River Bridge which fulfilling the condition using the priority value formula

Table 4.3: Sekoru Town to Gibe River Bridge Black Spot Sections

No.	Black Spot Location	F(Z)	Injuries S (Y)	Injuries L(X)	PDO	TRTA	P	AF	%	Rank.
1	Saja Town	1	3	4	2	10	18	7	4.17	9
2	Kosho (Yem)	13	2	7	3	25	78	11	10.42	2
3	Muku (Saja town)	1	7	9	4	21	35	9	8.75	3
4	Ashe Doma (Saja)	1	6	8	3	18	31	8	7.5	4
5	Cher bridge(Saja)	1	4	5	2	12	22	6	5	5
6	Badessa	2	2	1	6	11	17	14	4.58	10
7	Simini bridge	3	1	1	4	9	19	15	3.75	8
8	Qumbi muzi tera	13	4	2	20	39	79	18	16.25	1
9	Doma	2	1	2	6	11	15	10	4.58	11
10	Shen Debitu 4th	2	1	4	5	12	17	16	5	10
11	Bakare bridge	3	1	2	6	12	20	13	5	7
12	Dimiz (Bruk Frafire tera)	3	1	3	8	15	21	11	6.25	6
13	Dobi Qumbi	2	1	4	11	18	17	9	7.5	10
14	Simini curves	3	1	2	9	15	20	12	6.25	7
15	Simini No. 2	3	1	2	6	12	20	17	5	7
Total		53	36	56	95	240		176	100	

From fifteen black spot identified location in figure 4.6 below Qumbi muzi tera in Sekoru woreda has 79 p-values the first ranking and Doma has p-values of 15 which is the smallest eleventh ranking. Hence, the locations have 3 or more traffic accidents within the last 3 years of the study period, and the locations priority value were more significant and equal to15.

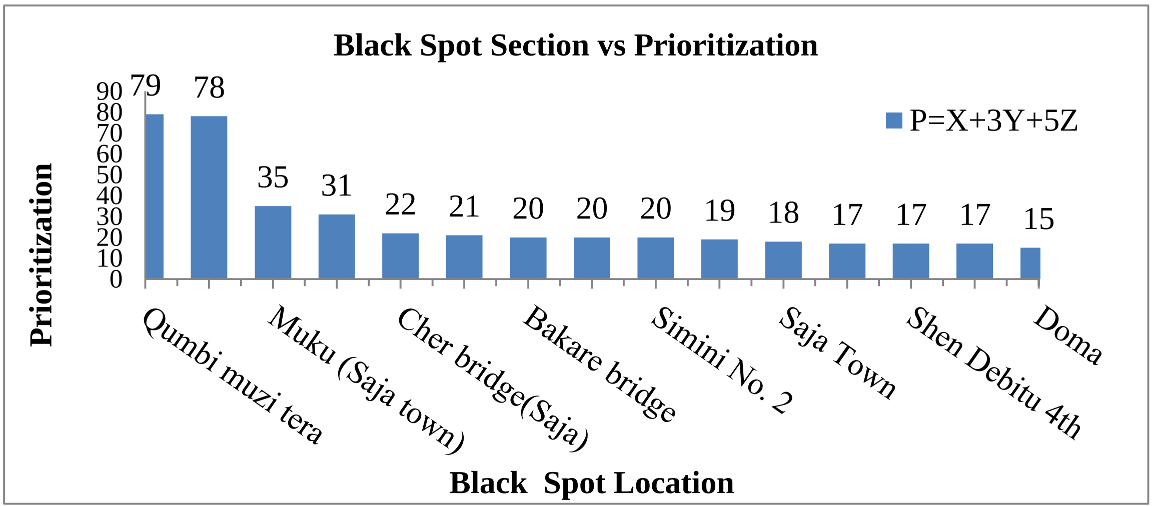


Figure 4.5: Prioritization of Black Spot Location for the Study Road section

As shown on figure 4.7 below the study area has Fatalities, Series injuries, slight injuries, and PDO along 15 black spot section among these section; Qumbi muz tera has the highest degree of severity which is 39 total road traffic accidents due to steepness grade of land scape and sharpness of curve, so the oppositly coming vehicles are suddenly crashing each other, but Doma from Sekoru woreda has the lowest Degree of Severity which is 9 total road traffic accidents.

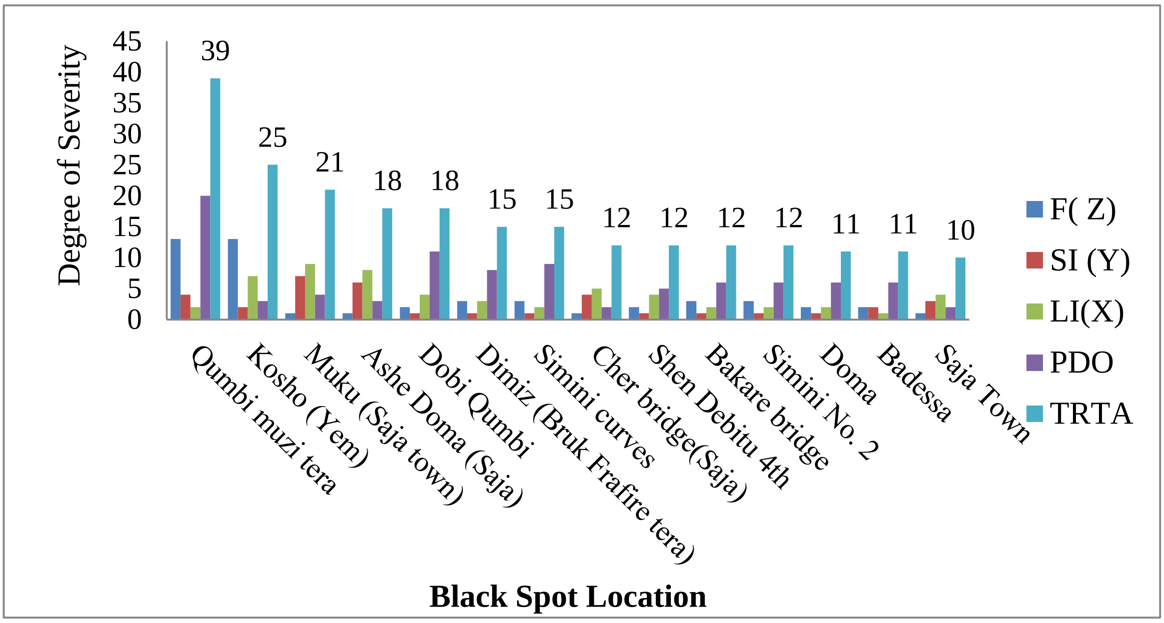


Figure 4.6: Degree of Severity along Black Spot Section.

4.3. Identifying the Geometric Design Parameters Causing the Traffic Accident

The identification was made after the prioritization of selected Black spot locations started from site investigation using tape, GPS, Camera, and comparison was made with as a built data. Geometric design parameters such as Lane width, Shoulder width, Average elevation, easting and northing were measurements on site along the black spot section

4.3.1. Field Work Activities

During the field observation, it was necessary to begin by conducting visual inspection and site inventory of the whole stretch of the Sekoru town to Gibe River Bridge road segment in order to get more information and for investigating effect of the road structure and its existing condition. All relevant information and data concerning to the road and its geometric condition; presence of traffic signs, road side delineators, road markings, lane width, shoulder width, and other traffic safety works of the area were collected through the initial field visit activities of the study. Some data were also collected by informal interviewing of road users, drivers, Sekoru and Yem special woreda traffic police officers and site engineers. According to the information from the people the selected case study area, the road structure could be one of the factors that trigger frequent accident events at different times. This information from the people assisted to put emphasis on the road geometric elements in comparison to design values of an as built road to understand the impact of design elements on traffic safety, as it could be one of the major causative factors for traffic accident problems encountered. Furthermore, a visual site visit was made to know the performance of the road, and hazardous road sections were identified depending on the degree of their traffic accidents indicated in the traffic police records and photographs were also taken to show the existing geometric condition.

Table 4.4: Data Taken with GPS and Tape at Black Spot Section

Beginning			**Ending**			**Existing length**	
Northing	Easting	Elevation	Northing	Easting	Elevation	SW (m)	LW (m)
48336.02	292595.03	1497.02	48370.92	292543.85	1510.32	0.7	2.75
48819.25	294150.28	1678.96	48895.97	293956.34	1685.03	0.85	3.25
4873.06	300054.91	1834.18	48792.44	300148.77	1839.94	0.6	3.2
48916.08	301945.29	1885.12	48942.97	301970.83	1889.02	1.2	2.75
48751.22	301840.11	1847.15	49034.05	302178.33	1851.85	0.3	3.15
60060.45	319011.07	1857.73	60169.08	319159.06	1861.44	1	3.5
60055.23	318581.24	1903.37	60233.12	319025.42	1909.22	0.4	2.75
60067.35	318690.27	1856.30	60167.55	319100.85	1863.41	0.25	3.25
60734.62	319390.22	1767.66	60773.04	319471.26	1764.98	0	3
60605.94	321231.83	1737.81	60870.36	321112.29	1743.63	0.8	3
62103.91	320870.11	1770.88	62132.13	320973.95	1774.54	0	3.5
62431.66	321240.77	1746.71	62481.22	321392.24	1753.61	0	3.5
61917.45	321664.97	1801.07	61954.75	321678.04	1805.29	0.3	3
62113.95	321612.08	1823.04	62253.81	321556.38	1827.42	0.7	3.75
59998.91	318756.06	1926.32	60194.25	318971.33	1911.34	1	3.25

As a shown on the table above, the existing shoulder width (SW) and lane width (LW) is out of the standard specification; 1m SW and 3.5m LW is specified on as a built drawing. Therefore, this may one of the contributing factor for road traffic accident

4.3.2. Problem Observed During Site Observation

The roadway has snagged geometric alignment, mainly with respect to sharp horizontal curves and steep grades to the vehicle's maneuvering position

- Retaining wall or Abatement constructed along Bridge length couldn't reconstructed after deteriorate
- Faded wearing surface
- The types of regulatory, warning traffic signs and provisions placed along the roadway would not as per the road alignment.
- The Road edge marking and center line are worn out and barely visible throughout the roadway length.

4.3.3. Computation of A, SSD and PSD for Shen Debitu 4th

A=5.77-2.799=2.971

Since, the curve is crest curve with S<L, stopping sight distance is $S=\sqrt{(L*658/A)}$

$S= \sqrt{(50*658/2.971)} = 105.23$, but for passing sight distance $S=\sqrt{(L*864/A)}$

$S = \sqrt{(50*864/2.971)} = 120.584$

Table 4.5: Computation of A, SSD and PSD for each black spot section

No.	Black Spot Location	G min	G max	VCL	K	A	SSD	PSD
1	Shen Debitu 4th	2.799	5.77	50	16.83	2.971	105.23	120.584
2	Doma	0.42	0.73	60	193.55	0.31	356.87	408.93
3	Badessa	2.454	6.857	70	15.90	4.403	102.28	117.201
4	Qumbi muzi tera	2.214	3.974	60	34.09	0.946	252.17	252.17
5	Dobi	4.09	6.322	80	35.84	2.232	153.57	175.977
6	Muku (Saja town)	1.07	7.074	120	19.99	5.488	119.95	485.67
7	Ashe Doma	2.174	5.655	120	34.47	3.213	156.76	179.636
8	Cher bridge(Yem)	1.07	7.074	45	7.50	6.004	45.85	45.85
9	Kosho (Yem)	1.114	1.556	20	7.49	2.67	45.83	567.25
10	Dimiz (Bruk Frafire tera)	5.258	7.211	80	40.96	1.953	164.17	375.63
11	Bakare bridge	0.283	6.953	10	14.99	6.67	31.41	35.991
12	Simini bridge	1.67	6.102	40	5.15	7.772	35.44	35.44
13	Simini No. 2	5.439	5.832	50	127.23	0.393	448.7	446.5
14	Simini curve	5.979	7.816	60	32.66	1.837	141.93	140.93
15	Saja Town	5.174	5.655	60	124.74	0.481	286.49	328.292

According to ERA 2013 geometric standard specification the study road is classified as trunk road DC6 for flat, rolling, mountainous and Escarpment terrain type, but almost all this study coverage is mountainous. Therefore, the minimum Crest Vertical Curve (K) for mountainous is 30, minimum Sag Vertical Curve (K) is 12. As a shown from table 4.5; the black spot locations under number 1 up to 6 were crest vertical curve; but K- value for Shen Debitu 4th (K=16.83) and Badessa (K=15.90); had less than the minimum requirements k-value because of their Algebraic Difference (larger) and length vertical curve is not proportionate. From sag vertical curve under black spot section number 6 up to 12; Black spot section 8, 9 and 12 had less than the minimum requirements k-value because this shows the difference between gradient is very large and not proportionate with vertical curve length. The minimum stopping sight distance for g=0% is 110m, g=5% is 120m and g=10% is 140m according to ERA standard specification; from the computed stopping sight distance all are fulfilling the standard specification but the black spot section under the number 1, 8, 9 11, and 12 were had SSD less than the minimum requirement because of steep gradient and short curve length. Minimum Passing Sight Distance for mountainous is 270m, as a shown on table 8 black spot sections had not fulfill the standard specification because of the obstruction trees along the road way, gradient and algebraic difference and curve radius.

4.3.4. Analysis of the Effects Geometric Parameters on road traffic accident

For the analysis of effect of geometric parameters the following activities were carried out; computation of Algebraic difference, K-value, Stopping Sight Distance, Passing Sight Distance from as a built drawing (Super elevation, Gradient, length of vertical curve, radius of horizontal curve, and chain ages) and shoulder Width, Lane Width, and, average, elevation were measured on the site. For further analysis the following computation had been carried out;

4.3.5. Computing of Compound Curve Length for Simini River Bridge

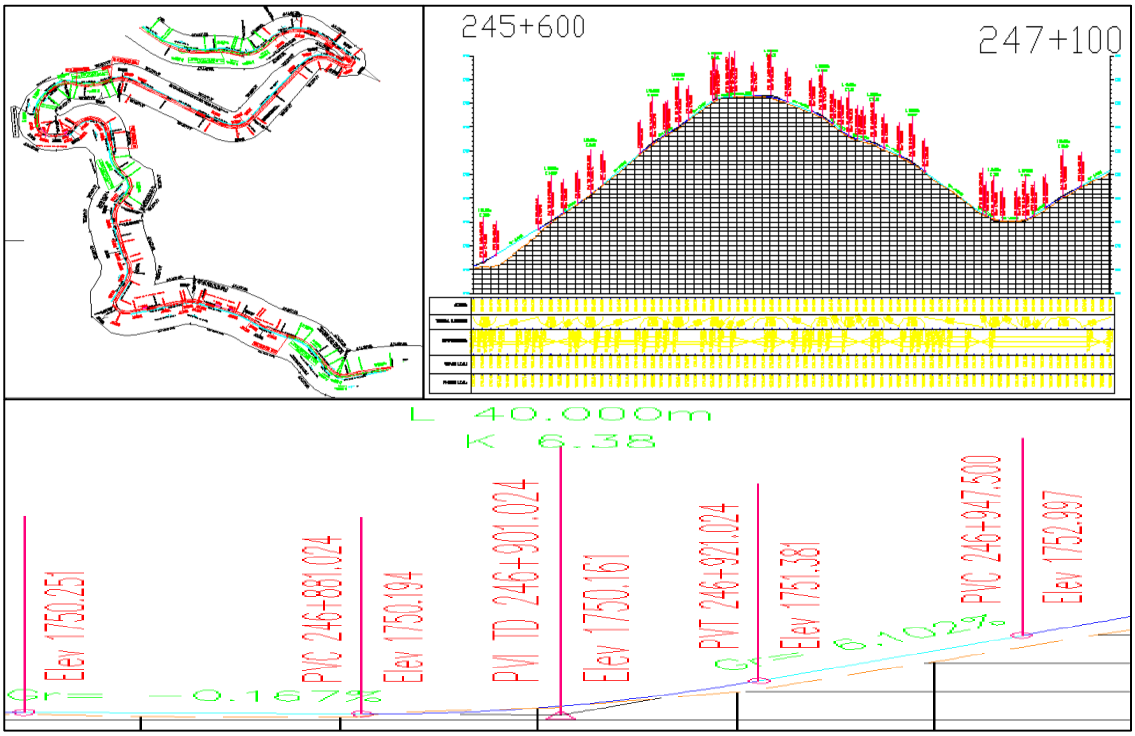
The following necessary data at the station were taken from as a built drawing for computation of deflection angle and curve length of compound curve.

PVC =246+881.024 EPVC = 1750.194

PVI = 246+901.024 EPVI = 1750.161

PVT = 246+921.024 EPVT = 1751.381

G1 = -0.167% G2 = 6.102% L=40m L1=20m L2=20m K=6.38



Source: ERA as a built drawing

Figure 4.7: Plan and Cross Sectional Drawing Road along Simini Bridge

Solution

Station of PVI = 246+901.024

-L/2 = -0+020

PVC = 246+881.024

+ L = 0+ 040

PVT = 246+921.024

Elevation of PVC = EPVI +g1 L/2

$$=1750.194 + \frac{4}{100} * \frac{40}{2}$$

= 1750.194 +0.8

= 1750.994m

Elevation on tangent

EPT = EPVC + g1x

EPT0 = 1750.194

EPT20= 1750.194 – (0.167/100*(20)) = 1750.161m

EPT40= 1750.194 – (6.102/100*(40)) = 1750.127m

Elevation on curve = Elevation on tangent + y

EPC = EPT +y

$$= EPVC + g1\ x + 4e\left(\frac{x}{L}\right)^2$$

At x= 20m, (at full station = 246+ 901)

EPC0 = 1750.994m

$$\mathbf{e} = \frac{(g2-g1)*L}{8} = \frac{\left(\frac{6.102}{100} - (-0.167\ /100)\right)*40}{8} = 0.297$$

$$\text{EPC20} = 1750.994 + (-\frac{0.167}{100})(20) + 4\text{e}\left(\frac{20}{40}\right)^2 = 1751.258\text{m}$$

$$\text{EPC40} = 1750.994 + (-\frac{0.167}{100})(40) + 4e\left(\frac{40}{40}\right)^2 = 1752.115m$$

As a shown on figure 4.6, chain ages and radius of curves were taken from as a built drawing for computation of deflection angles and length of compound curves for further analysis of line of sight and for comparing the computed one with the measured line of sight at the study area.

Table 4.6: Summery of Deflection Angle & Curve Length at Simini Bridge

Chain age		Radius of curve	Deflection angle	Tangent length	Length of curve
PC	246+881.024		Δ1=15.124°		
PI	246+901.024	R1=74m	Δ2=15.124°	T1=20m	
PT	246+921.024		Δc1=30.248°	T2=20m	Lc1=39.027m
PC	246+806.916		Δ3=36.027°	T3=20m	
PI	246+826.916	R2=27.5m	Δ4=36.027°	T4=20m	
PT	246+846.916		Δc2=72.054°		Lc2=34.57m
Sum			Δ=102.302°		L=73.6m

From the table 4.6 above calculated curve length at Simini River Bridge has length L= 73.6m and Length of sight line (S) = 2R sin (Δ/2) = 2*101.5 *sin (102.302°/2) = 158.097m when we compare with curve length, S>L, it is good as shown on as a built drawing and the calculation carried out, but currently measured sight line at site is only 121m, this makes traffic accidents because of obstruction of the curves by trees.

Checking for the radius of the curves with the minimum requirement, which are smooth driving characteristics require that the larger radius be more than 1 times larger than the smaller radius. Accordingly, the larger radius is 74m and the smaller one is 27.5m.R2 ≤ R1. From all the above analysis, the smaller radius of curve has used is 27.5m for the compound curve even if the requirement between the larger and the smaller radius for a smooth driving of the curve had met and there is still a limited site distance to vehicles would be happen because of obstruction of trees and intervening of ground surface

Table 4.7: Calculated Curve Elevation at Simini River Bridge

Station	**X in m**	**EPT** (EPVC+g1x)	**EPC** (EPT +y)	**Remark**
246+881.024	0	1750.194	1750.994	PVC
246+901.024	20	1750.161	1751.115	PVI
246+921.024	40	1750.127	152.115	PVT

EPT- elevation of point on tangent EPC- elevation of point on curve

As shown on table above elevation on sag vertical curve abruptly change between the curve elevation 1750.994 to 1751.115, and also change from 1751.115 to 1752.115 because of the grade steepness high at PVT.

K-value of Vertical Curve (K)

The K-value or equivalent radius of vertical curve defines the sharpness or flatness of the vertical curve.

$$K = \frac{VCL}{\Delta g}$$

Where, VCL = Vertical curve length and ¨g = Change of grade

K= 40m/(6.102-(-1.67)) = 5.147

When we compare with as built drawing, the K –value given on drawing is 6.38, therefore, there is the gap of 1.233 between calculated and as built drawing

4.3.6. Analysis of the Effects Geometric Parameters on TA at Simini No.2

The figure below shows sharp curve with radius of 13.75m and steep graded curve at Simini No. 2 Keble in Sekoru woreda. Consequently, overturning vehicles on sharp curve areas is to cause; traffic accident, out of control and maneuvering problems at the road section, also can leads to severe crashes and property damages. The main criterion considered during the selection of sections within the trunk-road segment to be evaluated was the condition of hazardous road geometrical setups and common occurrence of traffic accidents pertinent to the statistical correlation analysis. Simini curve have the following characteristics as a shown on photo; is a sharp curve with steep grade, has no traffic sign, sight distance and spot speed installation.

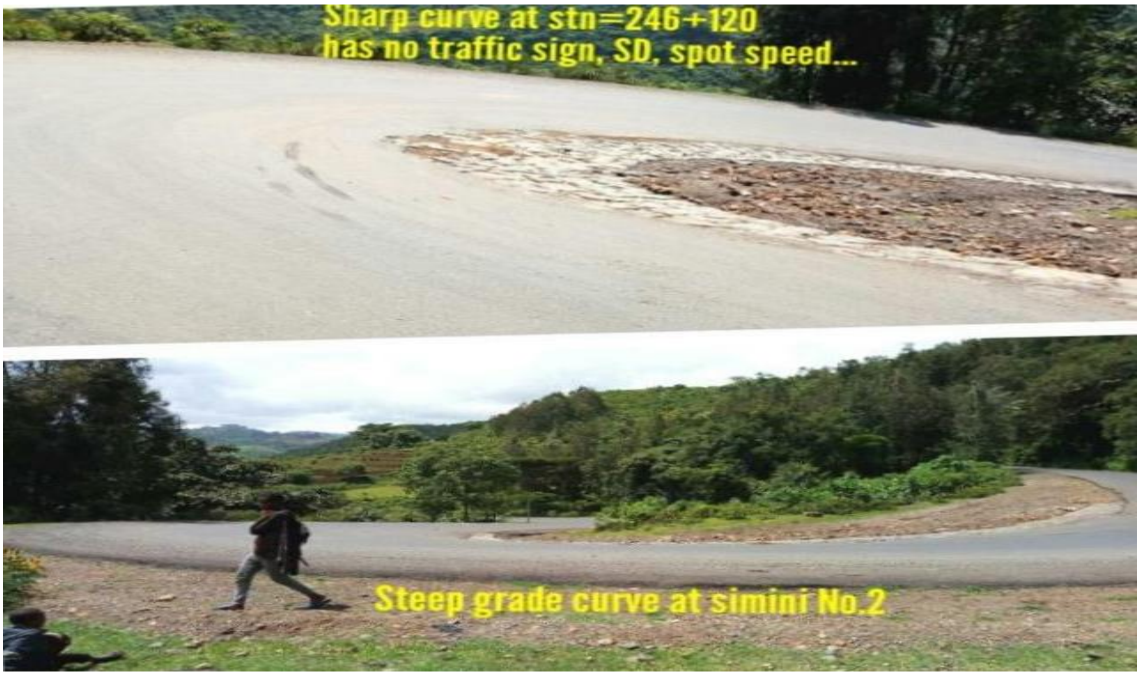
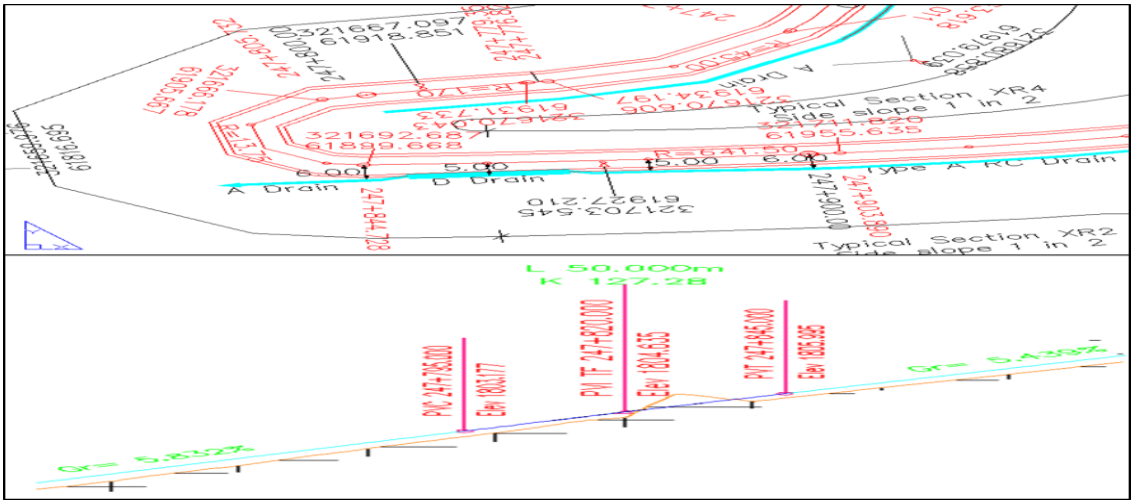


Figure 4.8: Curve with a Problem of Grade, Sharpness (Aug. 02/2011 by Dereje)

4.3.7. Simple Circular Curve Length Computation for Simini No. 2

The following necessary data were taken from as a built drawing for computation of deflection angle and curve length of Simple circular curve as shown on figure and table below.



Source: ERA as a built drawing

Figure 4.9: Sharp Curve at Simini No. 2

As shown on table 4.7 below, radius of horizontal curve R=13.75m, computed curve length 35.79m, and sight line (S) =2RsinΔ/2 =2*13.75*sin149.25/2=26.5m are very small. Therefore, both small curve length and small radius leads to traffic accident when over turning on sharp curve especially for large vehicle such as trunk trailer on steeped grade.

Table 4.8: Simple Circular Curve Length Computation of Simini No. 2

Chain age		**Radius of curve**	**Deflection angle**	**Tangent length**	**Curve length**
PC	247+795			T1=25m	Lc= ΠΔR/180^0
PI	247+820	R1=13.75m	Δ=149.20	T2=25m	
PT	247+830.79			T=50m	Lc=35.79m

Source: Compute from

4.3.8. Analysis of the Effects Geometric Parameters on Shen Debitu 4th

Calculation of Deflection angle for the compound curves, treating the curves as separate simple curve. The compound curve was divided as curve 1 and curve 2 to make computation easy. For the first curve with the following data between 194+061.687 and 194+097.407

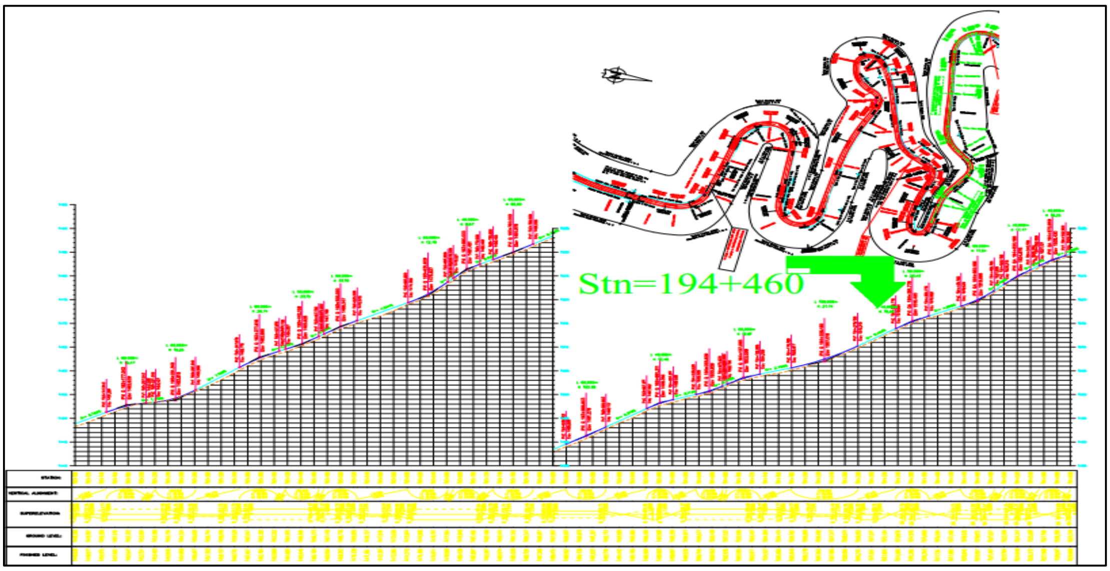


Figure 4.10: Plan and Cross Sectional Road at Shen Debitu 4th

Computed Deflection Angle and Curve Length of Shen Debitu 4th

- PC=194+435.186
- PI= 194+460.186

- PT=194+485.186
- R1=13.75m
- T1=PI-PC =**25m**
- T2=PT-PI =**25m**

For simple horizontal curve with different tangents the following equation can be used

T1 = $R1$ tan Δ1/2 = 13.75tan Δ1 Δ1=tan-1(25/13.75) = **61.189°**

T2= $R2$ tan Δ2/2 Δ2= 2tan-1(25/55) = **24.44°**

Δc1= Δ1 + Δ2 = 61.189° + 24.44° **= 85.63°**

Similarly, for the second curve the following data from as a built drawing

- PC=194+485.186
- PI= 194+496.186
- PT=194+510.627
- R2=55m

- T3=PI-PC = **11m**
- T4=PT-PI = **14.441m**

For simple curve, with different tangents we have the following equation

$T3$ = Rtan Δ3 11m = 13.75tan Δ3 → Δ3 $= \tan^{-1}(11/13.75) =$ **38.66°**

T4 = R tan Δ4 14.441m = 55tanΔ3 →Δ4 $= \tan^{-1}(14.441/55) =$ **14.71°**

Δc2 = Δ3 + Δ4 = 38.66°+ 14.71° **=53.37°**

Δ =Δc1+ Δc2 = 85.630 + 53.37° **= 139°**

The Length of the curve can be the calculated as:

Lc1= $\frac{\Pi \text{ Rc1 } \Delta\text{c1}}{180}$= 3.14*13.75*85.63°/1800 = **20.54m**

Lc2= $\frac{\Pi \text{ Rc2 } \Delta\text{c2}}{180}$= 3.14*55*53.37°/1800 = **51.20m**

L=20.54m+51.20m **=71.74m**

Table 4.9: Summery of deflection angle and curve length of Shen Debitu 4th

Check for the radius of the curves with the minimum requirement, which is smooth driving

Chain age		Radius of curve	Deflection angle	Tangent length	Length of curve
PC	194+435.186		Δ1=61.189°		
PI	194+460.186		Δ2=24.44°	T1=25m	
PT	194+485.186	R1=13.75m	Δc1=85.63°	T2=25m	Lc1=20.54m
PC	194+485.186		Δ3=38.66°	T3=11m	
PI	194+496.186		Δ4=14.71°	T4=14.4m	
PT	194+510.627	R2=55m	Δc2=53.37°		Lc2=51.20m
Sum			Δ=139°		L=71.74m

characteristics require that the larger radius be more than 1 times larger than the smaller radius. Accordingly, the larger radius is 55m and the smaller one is 13.75m, thus R1 ≤ R2. From all the above analysis, it can be said that a smaller radius of curve has been used which is 13.75m for the compound curve even if the requirement between the larger and the smaller radius for a smooth driving of the curve has been met. Therefore, there is still a limited site distance for drivers of vehicles, Length of sight line (S) = 2R sin (Δ/2) = 2*68.75 *sin (139°/2) = 128.79m. When we compare with curve length L= 71.74m, S>L, it is good as shown on drawing and the calculation carried out but currently as measured on site, sight line is only 87m this cause traffic accident because of the obstruction of trees along the curve length.

4.4.Traffic Data (AADT)

As a shown from table 4.10, A five year currently data of AADT could be considered under geometric parameters for DC6 Paved (AADT 1,000-3,000) according to ERA standard specification which is collected by Ethiopian road authority ERA for different vehicle types. These AADT data are used to predict the traffic trend and in the calculation of traffic accident rates and to determining funding for the maintenance and improvement of highways, VKT is obtained through multiplying 70 km by AADT of each year from 2015 to 2018.

Table 4.10: Accident Rate and AADT of Sekoru Town to Gibe River Bridge

Year	AADT	KM	VKT	Total Accident	Accident Rate
2014	1,453	70	101,710	81	0.4364
2015	1,536	70	107,520	80	0.4077
2016	1,797	70	125,790	59	0.2570
2017	1,674	70	117,180	113	0.5284
2018	1,920	70	134,400	131	0.5341

Source: ERA

As shown on the table above AADT is increasing from 1453 to 1797 in the year 2014 to 2016 but decreasing to 1674 in the year 2017, also greatly increasing to 1920 in the year 2018, in figure 4.12 the accident rate is decreasing in the year 2016 but greatly increasing in the year 2019.

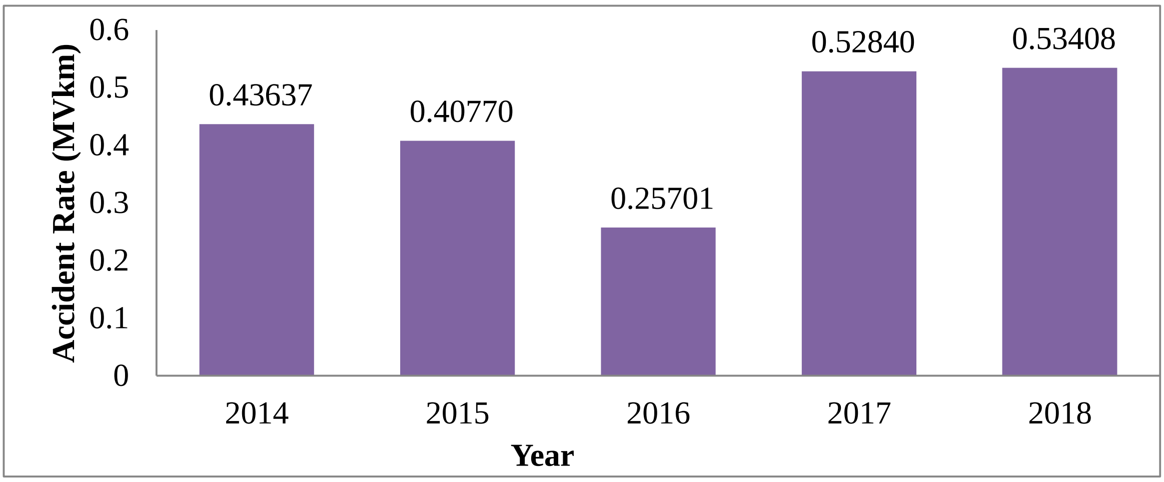


Figure 4.11: Accident Rate Distribution through Analysis Period

The total road traffic accident in the year 2016 and 2018 is very high when comparing the previous year; this show that high traffic volume as a shown on figure 4.11.

From the figure 4.12, as annual average daily traffic increase the total road traffic accident is not increasing because of it depends on capability of traffic management system, the awareness given to the societies and the drivers is different at different years.

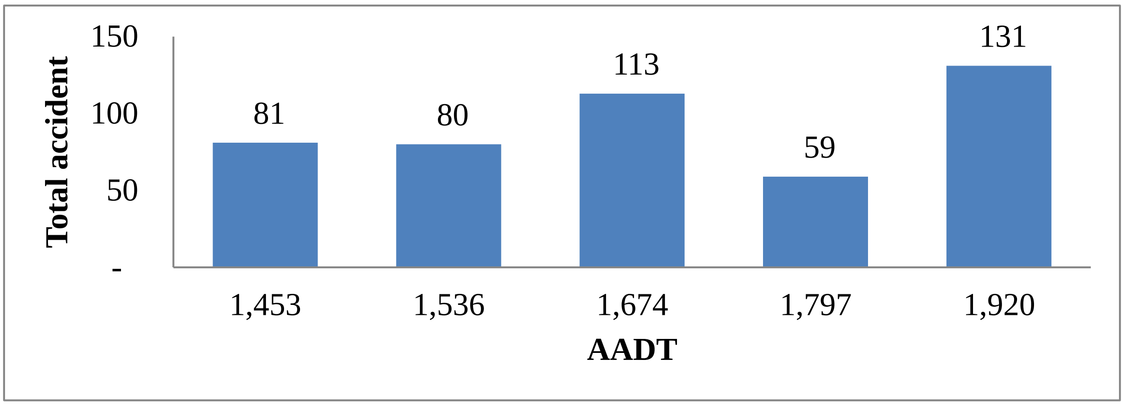


Figure 4.12: AADT versus Total Road Traffic Accident

4.5.The Correlation between GDP and RTA Using Regression Analysis

As black spot location identified the following geometric design elements were collected; curve radius, Algebraic difference, k-value, vertical curve length (checked and also calculated), shoulder width, lane width and Average elevation were measured on field, minimum super elevation, maximum super elevation, minimum gradient, maximum gradient were taken from as a built drawing, Stopping Sight Distance and Passing Sight Distance were calculated from as a built drawing. The following table 4.10 shows, geometric parameters that causes traffic accidents and the relationship between them and with total road traffic accident.

Table 4.11: The summary of Geometric Design Parameters and RTA

Black Spot Location	CR (m)	SW (m)	LW (m)	e min	e max	G min	G max	VCL	K	Ave. Elen.	A	SSD	PSD	TRTA
Shen Debitu 4th	33.00	0.70	2.75	2.50	7.00	2.80	5.77	50	16.83	1504.30	2.97	105.23	120.58	12
Doma	135.00	0.85	3.00	2.50	7.00	0.42	0.73	60	193.55	1682.00	0.31	356.87	408.93	11
Badessa	85.00	0.60	3.00	6.00	6.50	2.45	6.86	70	15.90	1837.06	4.40	102.28	117.20	11
Qumbi muzi tera	52.50	1.20	2.75	2.50	6.50	2.21	3.97	60	34.09	1887.07	0.95	252.17	252.17	39
Dobi	160.00	0.30	3.00	2.50	2.50	4.09	6.32	80	35.84	1849.50	2.23	153.57	175.98	18
Muku (Saja town)	20.00	1.00	3.00	7.00	7.00	1.07	7.07	120	19.99	1859.59	5.49	119.95	485.67	21
Ashe Doma	19.50	0.40	2.75	2.50	6.50	2.17	5.66	120	34.47	1906.30	3.21	156.76	179.64	18
Cher bridge(Yem)	38.00	0.25	3.25	7.00	7.00	1.07	7.07	45	7.50	1859.86	6.00	45.85	45.85	12
Kosho (Yem)	22.00	0.00	2.96	2.50	7.00	1.11	1.56	20	7.49	1766.32	2.67	45.83	567.25	25
Dimiz (Bruk Frafire tera)	57.50	0.80	2.95	2.50	6.50	5.26	7.21	80	40.96	1743.60	1.95	164.17	375.63	15
Bakare bridge	26.00	0.00	3.00	2.50	7.00	0.28	6.95	10	14.99	1772.71	6.67	31.41	35.99	12
Simini bridge	47.00	0.00	3.00	7.00	7.00	1.67	6.10	40	5.15	1750.16	7.77	35.44	35.44	9
Simini No. 2	13.75	0.30	3.00	5.50	7.00	5.44	5.83	50	127.23	1803.18	0.39	448.70	446.50	15
Simini curves	59.00	0.70	3.00	7.00	7.00	5.98	7.82	60	32.66	1825.23	1.84	141.93	140.93	12
Saja Town	167.0	1.00	3.00	2.50	7.00	5.17	5.66	60	124.74	1918.83	0.48	286.49	328.29	10

4.5.1. The correlation between RTA and Geometric Parameters

Table 4.11 shows that the geometric design elements that causes the traffic accident in the roadway. Therefore, the multiple linear regression analysis is very important in correlating road traffic accidents with geometric design elements like, curve radius, Super elevation, lane width, shoulder width, Stopping sight distance and passing sight distance. Consequently, as output obtained on the figure below the geometric elements has very significant role in causing road traffic accident in flat, rolling, mountainous & steep terrain highway; K-value is very significant in flat and rolling terrain highway and vertical gradient is very significant in mountainous and steep terrain highway to cause accident. Generally, all the above mentioned geometric parameters have positive strong correlation with total road traffic accident because of the value of R^2=0.999 which means effect geometric parameters on traffic accidents and the value of P=0.35, it significant because of P<0.05.

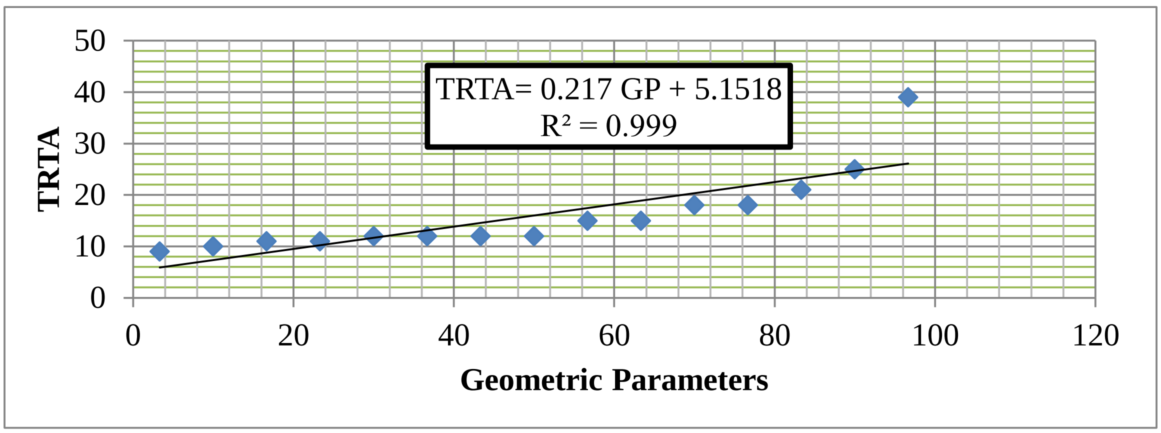


Figure 4.13: Scatter Plot and Best Fit of TRTA versus Geometric Parameters

4.5.2. The Correlation between Geometric Parameters and TRTA

From the table 4.12 below the correlation between variables; geometric design parameters such as shoulder width, lane width, super elevation (e min, e max), gradient (G min, G max), average elevation and road traffic accident (RTA). These variables are correlated under bivariate correlation coefficient of Pearson test significant with two tailed, Pearson correlation is a measure of linear association between two variables the value of correlation coefficient range from -1 to 1 the sign of the coefficient indicate the direction of relationship and absolute value indicate the strength, with larger absolute values indicting stronger relationship. The Sig. (2-tailed) is the probability of obtaining results as extreme as the one observed and in either direction when the null hypothesis is true. A two - tailed significant level test a null hypothesis in which the direction of an effect is not specified in advance. Sum of squares and cross – products is the cross – product deviation is equal to the sum of products of mean corrected variables. Covariance is also an unstandardized measure of association between two variables, equal to the cross product deviation divided by N-1. N is number of cases or observation or records.

Table 4.12: The Correlation among Geometric Parameters and RTA

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	CR (m)	1													
2	SW (m)	0.295	1												
3	LW (m)	-0.297	-0.04	1											
4	e min	-0.31	-0.05	0.493	1										
5	e max	-0.485	0.192	0.288	0.295	1									
6	G min	0.244	0.226	-0.11	0.08	-0.21	1								
7	G max	-0.195	0.009	0.407	0.484	-0.07	0.439	1							
8	VCL	0.085	0.303	-0.09	0.077	-0.32	0.168	0.231	1						
9	K	0.507	0.247	-0.33	-0.23	0.121	0.144	-0.471	0.045	1					
10	AE	0.158	-0.16	0.025	0.2	-0.23	0.114	0.233	0.358	-0.034	1				
11	A	-0.449	-0.41	.603*	0.417	0.166	-0.5	0.383	-0.211	-.713**	-0.06	1			
12	SSD	0.102	0.118	-0.35	-0.04	-0.07	.628*	0.073	0.21	0.502	0.301	-.702**	1		
13	PSD	0.143	0.257	-0.28	-0.24	0.159	-0.09	-.686**	0.156	.643**	-0.08	-.592*	0.259	1	
14	TRTA	-0.228	0.053	-0.2	-0.29	-0.21	-0.15	-0.35	0.145	-0.198	0.295	-0.237	0.216	0.240	1

CR=Curve Radius SW=Shoulder Width LW = Lane Width VCL=Vertical Curve Length A= Algebraic difference k-value SSD= Stopping Sight Distance PSD= Passing Sight Distance AE= Average Elevation

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Algebraic difference is 0.603 significant at $p>0.01$ and 0.713 is significant at $p>0.05$

Stopping sight distance 0.628 significant at $p>0.01$ and 0.702 is significant at $p>0.05$

Passing sight distance 0.686 significant at $p>0.01$ and 0.643 is significant at $p>0.05$

Table 4.13: Summary output of correlation and SLR

TRTA	R^2	Sig. order based on R^2& P
-0.4679G+19.743	0.0726	>0.05
-1.0036emax+22.59	0.022	<0.05

-1.0525emin+20.35	0.0817	>0.05
-11.761LW+53.685	0.222	>0.05
-0.0341RC+18.124	0.0499	<0.05
8.23SW+12.253	0.1636	>0.05
-0.0277K+17.314	0.0393	<0.05
0.0219AE-23.303	0.0869	>0.05
0.0042AADT+36.301	0.0449	<0.05
0.0149SSD+13.846	0.0463	<0.05
-0.8536A+18.694	0.0698	>0.05
0.009PSD+13.603	0.0583	>0.05

The R^2 value is b/n 0 and 1; $R^2=0$ means no correlation b/n variable, but for $R^2>0.05$ is strong correlation, for $R^2<0.05$ weak correlation; .the correlation between TRTA and emax, RC, k-value, AADT and SSD is significant because of R^2 value is less than 0.05, for further reading on Appendix F1-F11.

4.5.3. Summary of Multiple Linear Regression Analysis

The result of multiple linear regression Analysis on table below, variance (ANOVA) shows that after correlating Total Traffic Accident with Geometric elements; Radius of curve, Shoulder width, Lane width, Super elevation, Gradient, Vertical curve length, K-value, Average elevation, Algebraic difference, Stopping sight distance and passing sight distance is expressed by the following multiple regression equation with its corresponding correlation coefficients, the correlation is strong correlation $R^2=0.99$ and significant (P=0.036) with all independent variables appear to contribute to predicting road traffic Accident because of $P\leq0.05$. Therefore, the model developed is the best model; that shows the relationship between variables as a shown below.

TRTA =2.524 -0.167CR+21.94SW+0.172LW-6.077emax-0.543emin+1.558Gmin-3.754Gmax-0.124VCL-0.016K+0.04AE+1.874A+0.003SSD-0.001PSD

R = 0.99990476 R^2 = 0.9973 Adjusted Standard error = 0.401 P = 0.039

Table 4.14: Summary Output of Multiple Regression Analysis

Regression Statistics								
Multiple R	0.9999							
R Square	0.9998							
Adjusted R Square	0.9978							
Standard Error	0.3634							
Observations	15							
ANOVA								
	Df	SS	MS	F	Sign. F			
Regression	13	843.868	64.913	491.503	0.035			
Residual	1	0.132	0.132					
Total	14	844						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.635	2.303	1.144	0.457	-26.623	31.893	-26.623	31.893
CR (m)	-0.166	0.007	-22.463	0.028	-0.259	-0.072	-0.259	-0.072
SW (m)	21.724	0.813	26.706	0.024	11.388	32.059	11.388	32.059
LW (m)	0.403	0.853	0.472	0.719	-10.434	11.239	-10.434	11.239
e min	-0.555	0.080	-6.918	0.091	-1.575	0.464	-1.575	0.464
e max	-6.027	0.249	-24.192	0.026	-9.192	-2.861	-9.192	-2.861
G min	1.496	0.243	6.168	0.102	-1.586	4.578	-1.586	4.578
G max	-3.752	0.173	-21.630	0.029	-5.957	-1.548	-5.957	-1.548
VCL	-0.121	0.008	-15.013	0.042	-0.224	-0.019	-0.224	-0.019
K	-0.018	0.008	-2.236	0.268	-0.122	0.085	-0.122	0.085
Ave. Eln.	0.040	0.002	20.350	0.031	0.015	0.065	0.015	0.065
A	1.820	0.231	7.882	0.080	-1.114	4.755	-1.114	4.755
SSD	0.004	0.003	1.278	0.423	-0.040	0.049	-0.040	0.049
PSD	-0.001	0.001	-0.880	0.541	-0.014	0.012	-0.014	0.012

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1.Conclusion

From the identification of Black spot locations that existed on the road from Sekoru to Gibe River Bridge, the following locations are found to be Black spots Locations. Total of 15 black spot locations were identified. 10 locations were from Sekoru woreda, 5 were from Yem special woreda. Road safety audit and traffic data analysis from 2017-2019 were undertaken for the road corridor. Based on the existing traffic and as a built data, priority value and accident frequency were used in order to rank the black spot locations. According to the result of the study Shen Debitu 4th, Doma Badessa, Qumbi muzi tera, Dobi, Muku (Saja town), Ashe Doma, Cher bridge(Yem), Kosho (Yem), Dimiz (Bruk Frafire tera), Bakare bridge, Simini bridge, Simini No. 2, Simini curves, and Saja Town were the identified black spot locations on the road from Sekoru to Gibe River Bridge.

There were identified the effects of geometric parameters; Curve radius, shoulder width, lane width, super elevation, gradient, Stopping Sight Distance, K-value, Algebraic Difference, AADT, Stopping Sight Distance and Passing Sight distance that causes the Road traffic accident. Based on correlation the effects of geometric design parameters such as shoulder width, lane width, super elevation, gradient, algebraic difference, k-value, stopping sight distance, passing sight distance, average elevation were correlated with total road traffic accident; have strong positive correlation among variables R^2= 0.99 this show that; most of the locations have problems of inadequate shoulder width, lane width, curve radius, max super elevation, and min super elevation, improper gradient and k-value, lack of traffic sign and spot speed installation, absence of road side delineator, fading of pavement marking.

Based on multiple regression analysis the model was developed with respect to both dependent and independent variables (TRTA =2.524 -0.167CR+21.94SW+0.172LW-6.077emax-0.543emin +1.558Gmin-3.754Gmax-0.124VCL 0.016K +0.04AE+1.874A + 0.003SSD-0.001PSD), the value of F= 0.035 (significant because $F<0.05$)

Generally, road traffic accident decreases as increase; radius horizontal curve, lane width, but as super elevation, vertical grade and AADT as increase road traffic accident increases.

5.1.Recommendation

Based on the analysis of the black spot locations; the major countermeasures that should be applied in order to decrease the incidence of accidents along this road. It is recommended that the shoulder width will be increased, the provision of lane width, the installation of traffic signals, spot speed and road side delineator, the provision of roadside improvements, and painting of pavement markings.

Finally, the Ethiopian Roads Authority should take the remedial measures as input and undertake Road Safety Audit regularly for all road sections under their responsibility area in order to mitigate the effects geometric parameters and also traffic police office should have to record, capture, store and manipulate accident data as data base by using computer based system or Geographical Information System.

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APPENDIX

A-1: Black Spot Identification and the Possible Countermeasures

Date: ____________			
Name of black spot location:_________________________station(km):30km fom_________			
Checklist of site inspection for the identified black spot locations			
No.	Type of measure	Comment	
1	The provision of adequate width of right shoulder		
2	The provision of adequate width of left shoulder		
3	Provision of road side delineators		
4	Provision of road marking		
5	The provision of speed limit post		
6	The provision of Signing in Horizontal Curves		
7	The provision of signing in Vertical curves		
8	The provision of Median Barriers		
9	The provision of adequate horizontal curve radius.		
10	The requirement of clear (flat slopes) road side improvement		
11	The provision of widening		
12	The requirement of climbing lane		
13	The provision of adequate and visible pavement marking		
14	The provision of Effective road markings at night and in wet weather.		
15	Provision of pedestrian walking on town section		
16	The provision of efficient signals installed		

B-1: Ten Identified Dangerous Spot Locations in Yem Special Woreda

No.	Black Spot Location	F (Z)	Injuries		PDO	TA	P=X+3Y +5Z	AF
			S (Y)	S (X)				
1	235+238 to 235+338	0	1	6	1	8	9	3
2	235+945 to 236+045	0	2	2	2	6	8	2
3	237+400 to 237+500	0	3	5	1	9	14	4
4	238+300 to 238+400	0	2	5	2	9	11	5
5	239+510 to 239+610	0	3	4	1	8	13	5
6	Saja Town	1	3	4	2	10	18	7
7	Kosho (Yem)	13	2	7	3	25	78	11
8	Muku (Saja town)	1	7	9	4	21	35	9
9	Ashe Doma (Yem)	1	6	8	3	18	31	8
10	Cher bridge(Yem)	1	4	5	2	12	22	6
Total		17	33	55	21	126		60

B-2: Fifteen Dangerous Locations in Sekoru Woreda

No.	Black Spot Location	F (Z)	Injuries		PDO	TA	P=X+3Y +5Z	AF
			S (Y)	L (X)				
1	243+800 to 243+900	1	1	0	3	5	8	6
2	243+500 to 243+600	1	0	1	2	4	6	3
3	213+605 to 213+705	1	1	1	2	5	9	8
4	197+800 to 197+900	1	0	2	1	4	7	5
5	Sekoru Town	1	1	1	4	7	9	7
6	Badessa	2	2	1	6	11	17	14
7	Simini bridge	3	1	1	4	9	19	15
8	Qumbi muzi tera	13	4	2	20	39	79	18
9	Doma	2	1	2	6	11	15	10
10	Shen Debitu 4th	2	1	4	5	12	17	16
11	Bakare bridge	3	1	2	6	12	20	13
12	Dimiz (Bruk Frafire tera)	3	1	3	8	15	21	11
13	Dobi Qumbi	2	1	4	11	18	17	9
14	Simini curves	3	1	2	9	15	20	12
15	Simini No. 2	3	1	2	6	12	20	17
Total		41	17	28	93	179		164

AF = Accident Frequency

C-1: Design Controls Stopping Sight Distance

When the height of eye and the height of object are 1,080 mm and 600 mm [3.5 ft and 2.0 ft], respectively, as used for stopping sight distance, the equations become:

Metric	US Customary	
When S is less than L, $L = \frac{AS^2}{658}$	When S is less than L, $L = \frac{AS^2}{2158}$	(3-45)
When S is greater than L, $L = 2S - \frac{658}{A}$	When S is greater than L, $L = 2S - \frac{2158}{A}$	(3-46)

Source: AASHTO a Policy on Geometric Design of Highways And Streets 2001

D-1: Design Standard of DC6

According to ERA road functional classification Addis Ababa to Jimma road is classified as trunk, design standard of DC6 have the following design specification

Table 4.4: Design Standard of DC6 (Source: ERA 2013)

Design Standard	Rural Terrain/Shoulder Width (m)			
	Flat	Rolling	Mountainous	Escarpment
DC6	1.5 - 3.0++	1.5 - 3.0	0.5 - 1.5	0.5 - 1.5

F-1: Total road traffic accident verses gradient

According to ERA 2013, the maximum gradient (desirable) is different based on types of terrain, for flat terrain g max=3, for rolling terrain g max=5, but for mountainous and escarpment terrain have g max=7. The minimum gradient for all types of terrain is 0.5, as a shown on table 4.11 from as a built drawing, g min at Doma 0.42 and Bakare Bridge 0.283 which is below the standard of 0.5, and Muku (Saja town) g max 7.074, Dimiz (Bruk Frafire tera) has gmax 7.211 and Simini curve has g max 7.816 . Therefore, the figure 1.1, total road traffic accident verses grade is weak correlation as show on scatter plot because of the grade on as a built drawing is out of standard, summary output of regression analysis

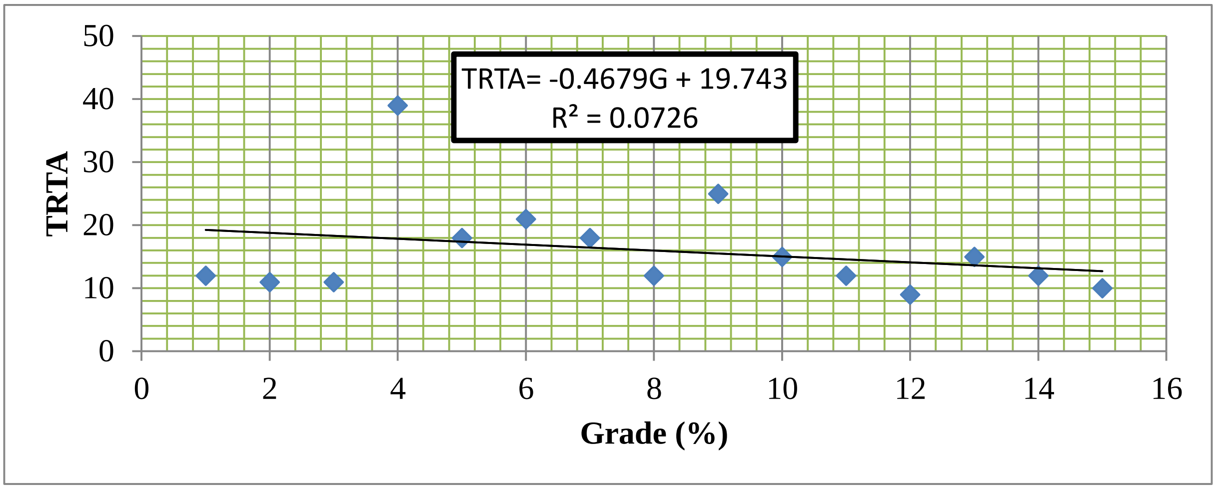


Figure 1.1: Scatter plot and best fit curve of road traffic accident vs gradient accidents

F-2: Total road traffic accident verses Super elevation

According to AASHTO 2001, the maximum rates of super elevation used on highways are controlled by four factors: climate conditions (i.e., frequency and amount of snow and ice); terrain conditions (i.e., flat, rolling, or mountainous); type of area (i.e., rural or urban); and frequency of very slow-moving vehicles whose operation might be affected by high super elevation rates. Consideration of these factors together leads to the conclusion that no single maximum super elevation rate is universally applicable and that a range of values should be used. Design elements that are not uniform for similar types of roadways may be counter to a driver's expectancy and result in an increase in driver workload. Generally, from as a built drawing e max 7% and e max 2.5% was taken for design because of terrain conditions; when we compare with AASHTO and ERA standard, 8 percent is recognized as a reasonable maximum value for super elevation rate. Therefore, as shown on fig.1.2 below the correlation is weak correlation because of R^2 value is 0.022 which less than 0.05

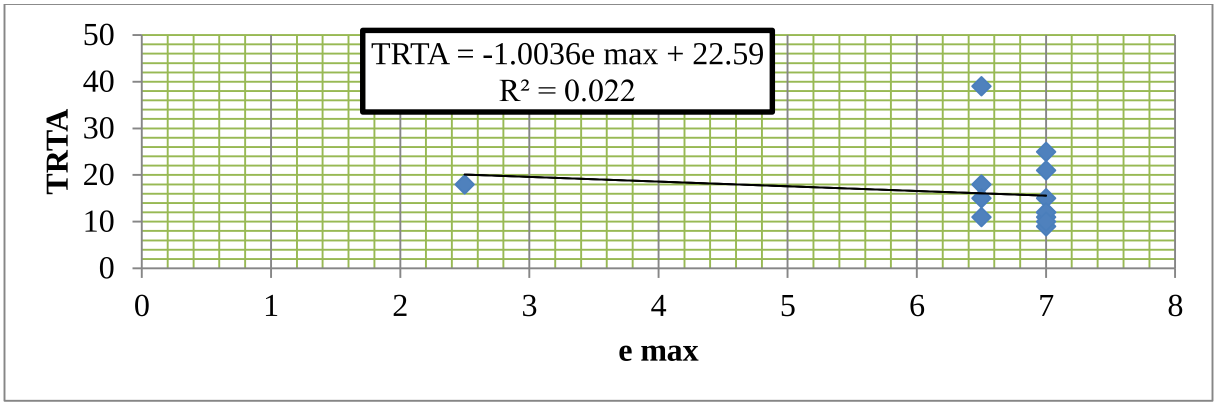


Figure 1.2: Scatter plot and best fit of road traffic accident vs e max

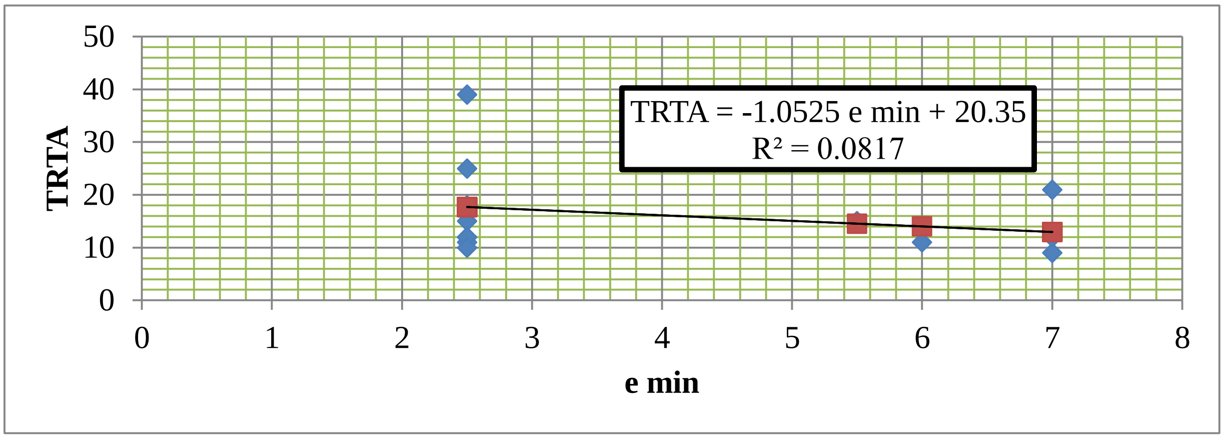


Figure 1:3: Scatter plot and best fit of road traffic accident vs. e min

F-3: Total road traffic accident verses Lane width

Width of running surface recommended according to ERA manual and as a built drawing is 7m, as a shown on table 4.11 above the lane width is not exactly 3.5m but in some black spot section 2.75m and less than 3.5 meters are measured on the field. Therefore, lane width and road traffic accident has the strong negative correlation because of R2 value is greater than 0.05 which is 0.22

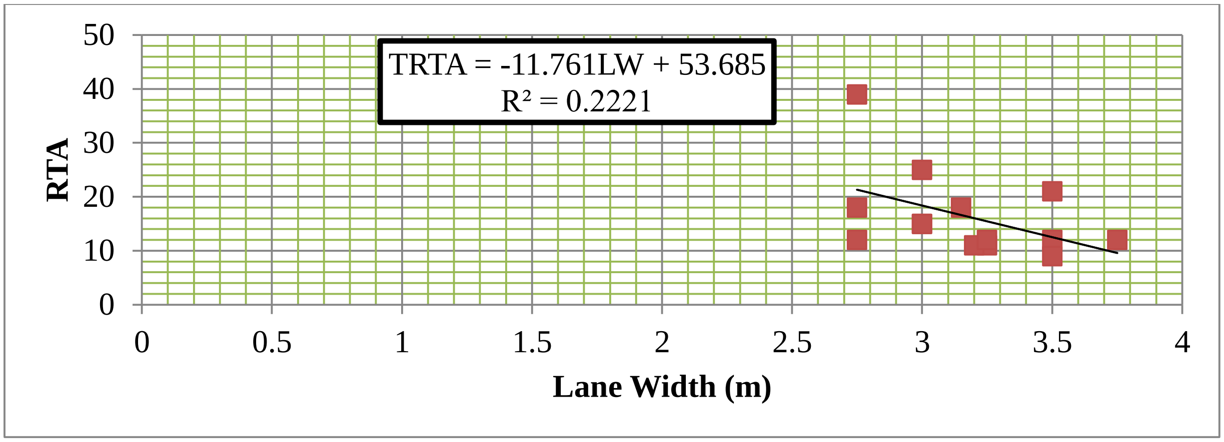


Figure 1.3: scatter plot and best fit of road traffic accident vs Lane Width

F-4: Total road traffic accident verses Radius of curve

The minimum radius is a limiting value of curvature for a given design speeds and is Determined from the maximum rate of super elevation and the maximum side friction factor selected for design (limiting value of f) [25]. The minimum radius taken on as a built drawing is 13.75m and the maximum radius is 167m, taking small radius makes sharp curvature of curve this leads to traffic accidents especially for large vehicles when overturning. Therefore, as shown on figure below the correlation is weak correlation because of R2=0.0499 because of significant ($P<0.05$)

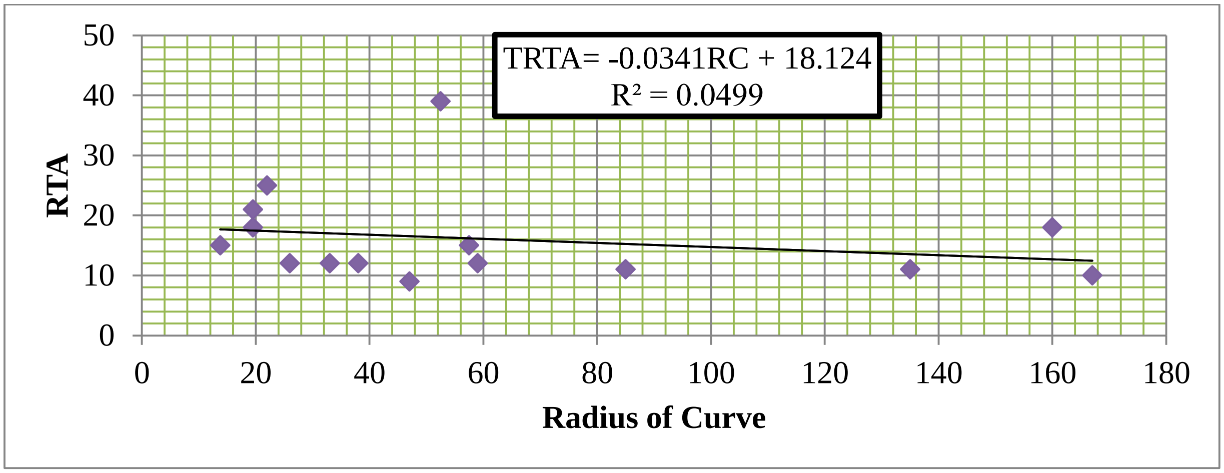


Figure1.4: scatter plot and best fit of road traffic accident vs. Radius of horizontal curve

F-5: Total road traffic accident verses Shoulder Width

According to ERA 2013, design standard DC6 rural terrain type for (flat 1.5m-3m, Rolling1.5m-3m, Mountainous 0.5m-1.5m, Escarpment 0.5m-1.5m). From table 4.11, the shoulder width measured on field along bridge is zero and in some place is 0.3m, therefore the correlation is weak positive correlation because of R2=0.1636

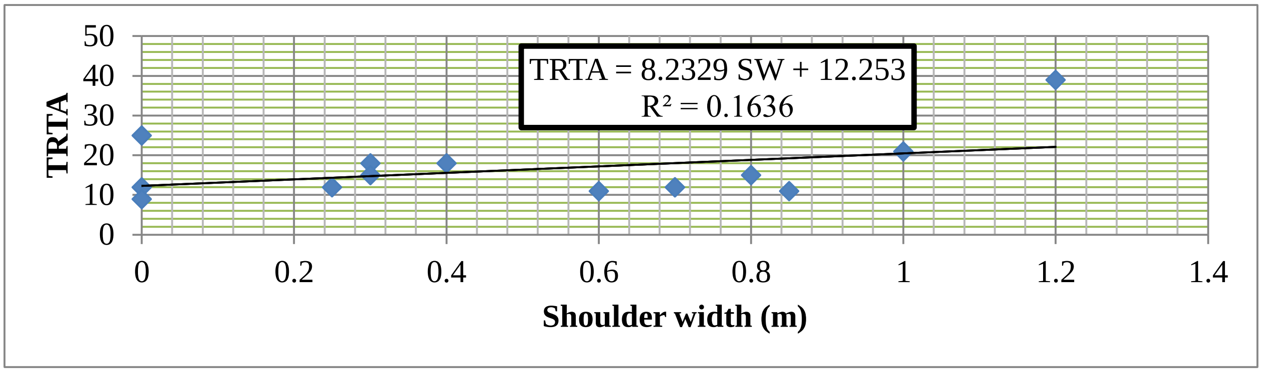


Figure 1.5: Scatter plot and best fit of road traffic accident vs shoulder width

F-6: Total road traffic accident verses K- value

The K-value or equivalent radius of vertical curve defines the sharpness or flatness of the vertical curve. This is a ratio of parabolic curve length and change of vertical grade. Also, this is horizontal $K = \frac{VCL}{\Delta g}$ distance required to effect a one percent change in gradient. This is expressed as:

Where, VCL = Vertical curve length and Δg = Change of grade

Therefore, the correlation of road traffic accident with respect to K- value is also weak because of $R^2 < 0.05$

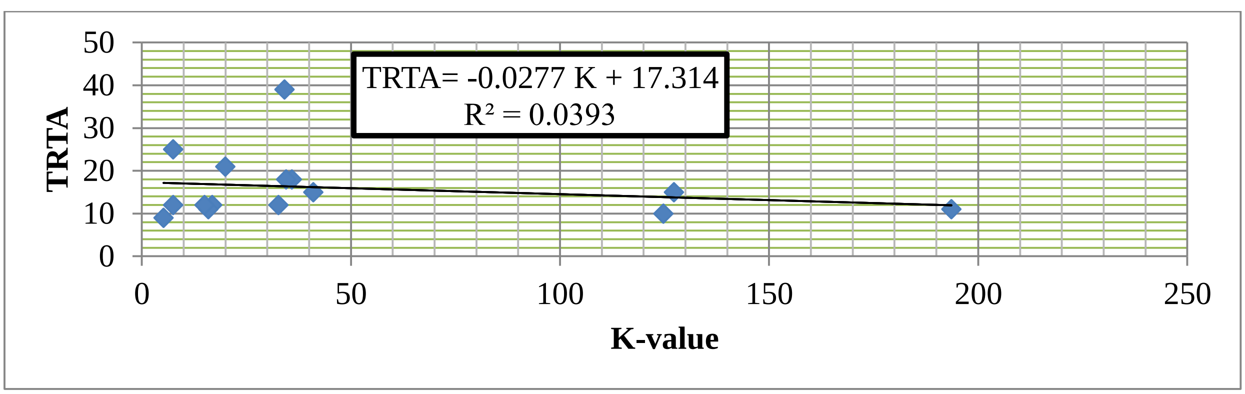


Figure 1.6: scatter plot and best fit of road traffic accident vs K-value

F-7: Total road traffic accident verses Average Elevation

The average elevation along the study section is taken by GPS especially for black spot section. This elevation with gradient could affect driving behavior, road at low elevation have different characteristics than at high elevation on driving behavior. This elevation difference is called gradient in some cases cause traffic accident, as shown on figure 1.7, have weak positive correlation R2=0.0869

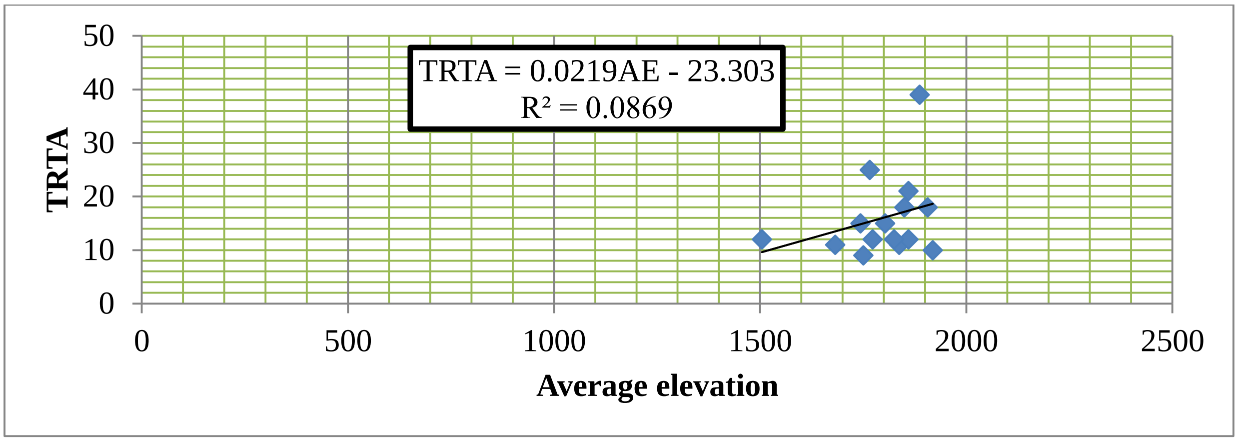


Figure 1.7: scatter plot and best fit of road traffic accident vs. Average Elevation

F-8: Total road traffic accident verses AADT

The correlation between AADT and Accident Rate is weakly correlated as shown on figure 1.8 below have R^2=0.0449 which is weak correlation but significant.

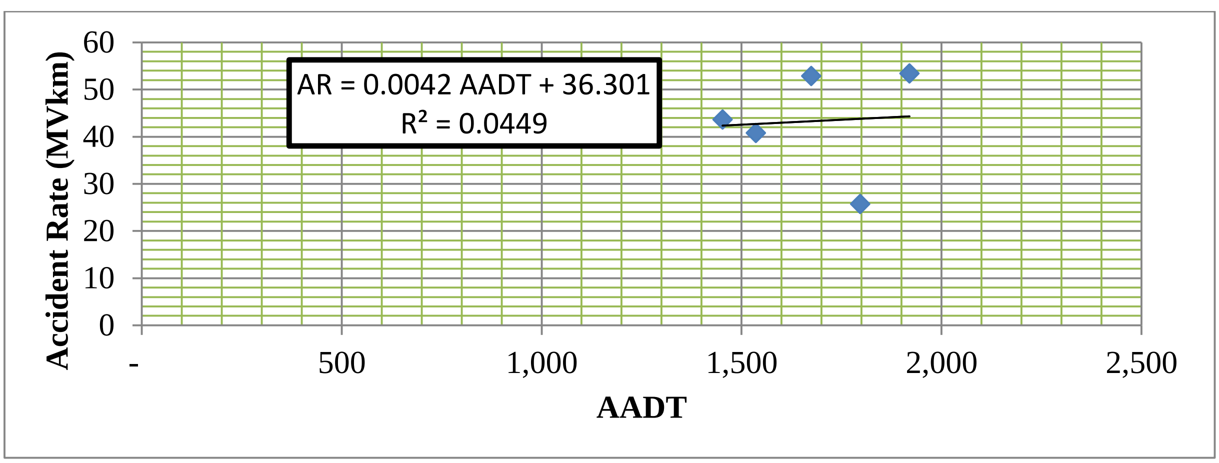


Figure 1.8: scatter plot and best fit of Accident Rate vs. Annual Average Daily Traffic

F-9: Total road traffic accident verses Algebraic Difference

The difference between forward gradient (g2) and backward gradient (g1) makes absolute value of algebraic difference (A) in percentage, this has also effect on traffic accident because as larger algebraic difference smaller K-value this leads to variation on vertical curve length. Therefore, as shown on figure below 1.9, the correlation is weak negative correlation because of R^2=0.069811.

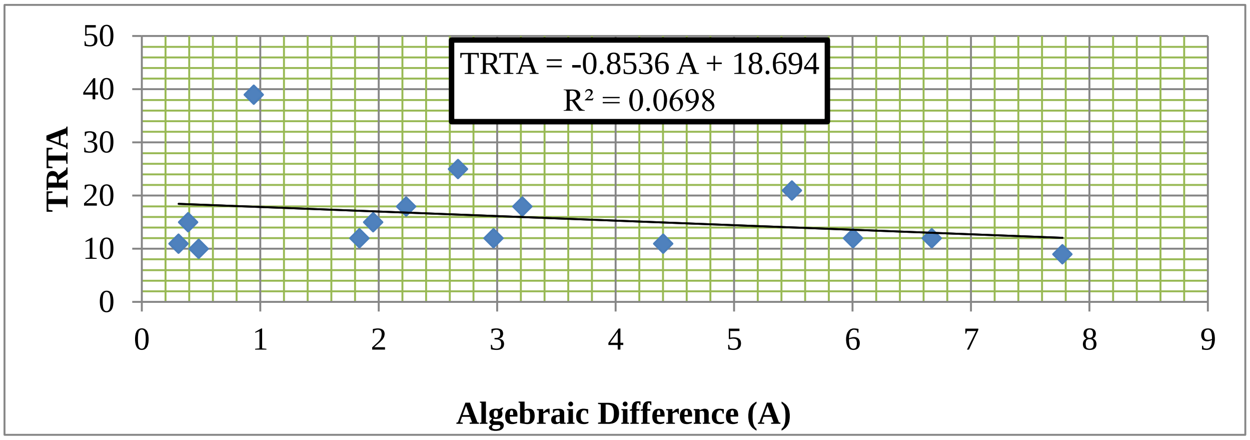


Figure1.9: Scatter plot and best fit of Total Road Traffic Accident vs. Algebraic

F-10: Total road traffic accident verses Stopping Sight Distance

For the height of eye and the height of object are 1080 mm and 600 mm the stopping sight distance is S= √(658L/A) when S < L and S=L/2+658/2A when S>L figure 1.10, below show that the correlation is weak strong because R^2=0.0463

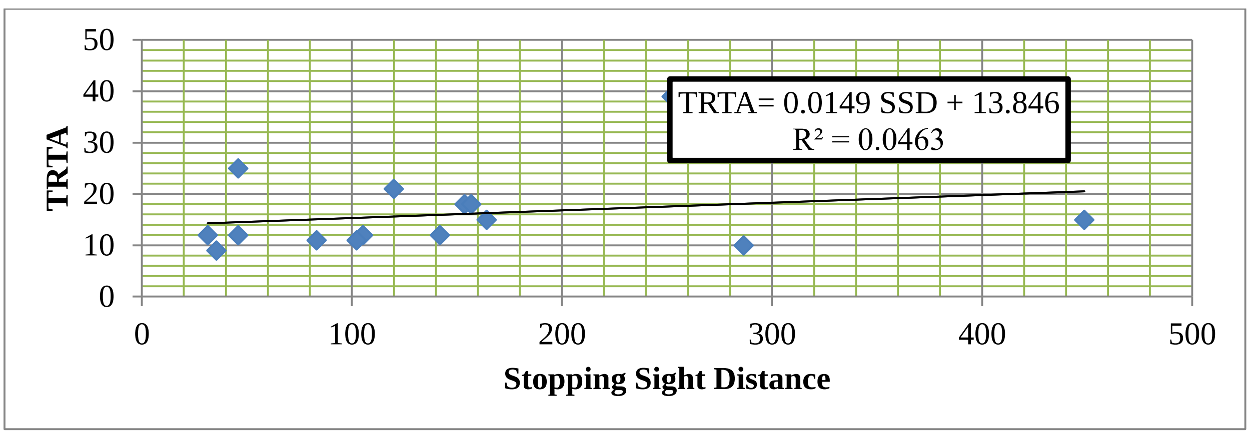


Figure 1.10: scatter plot and best fit of Total Road Traffic Accident vs Stopping Sight Distance

F-11: Total road traffic accident verses Passing Sight Distance

For the height of eye and the height of object are 1080 mm and 600 mm the stopping sight distance is S= √(864L/A) when S < L and S=L/2+864/2A when S>L figure 1.11, below show that the correlation is weak strong because R^2=0.0583

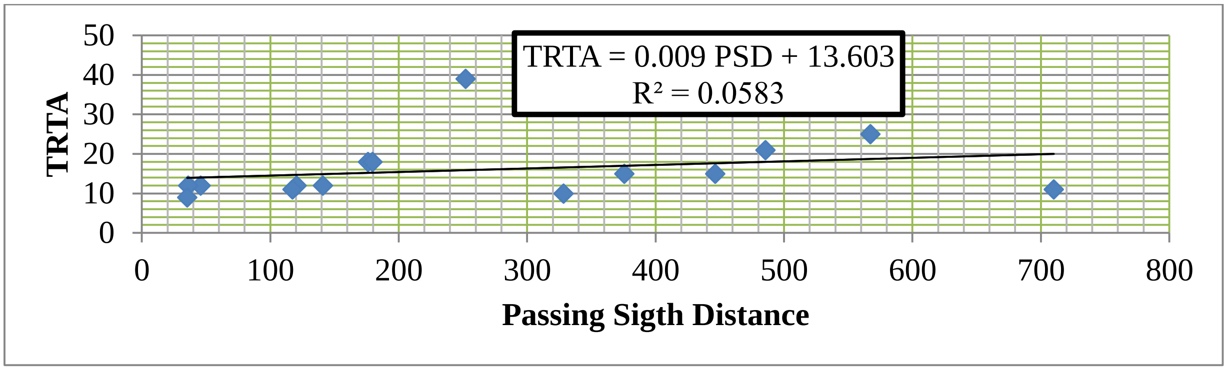


Figure 1.11: Scatter plot and best fit of Total Road Traffic Accident vs Passing Sight Distance

E-1: Traffic Accident Data

Unka Gabaasa Balaa Tiraafikaa kan Kurmaanaa 4 ffaa itti dhiyaatuu

Lakk	Godinaa fi Magaalaa	Balaa Du'a				Balaa Qaama Cimaa				Balaa Qaama Salphaa				Balaa Qabeenya		Wal-galaa		Tilmaama Qabeenya Barbadaa'ee qarshiidhan		Baayina Namoota miidhaan irra ga'e: Namoota Du'an		Namoota Miidhaan ciimaan		Namoota miidhaa salphaan	
		2010		2011		2010		2011		2010		2011													
		Dhi	Du	Dhi	Du	Dhi	Du	Dhi	Du	Dhi	Du	Dhi	Du	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
1	Sokorru	10	7	8	3	5	4	1	-	20	10	-	-	21	29	15	29	1,387,400	1498,530	17	11	9	1	20	-

Hubachiisa

- Miidhaan du'aa ykn namootni du'an saala dhiiraa fi dhalaan adda bahee gabaafamuu qaba.

Cuunfaan gabaasaa balaa tiraafikaa chaappaa mana hojii lamaan (kan geejjibaa fi poolisii)kan mirkanaa'e dhiyaate ta'aa.

[Type text] Page 24

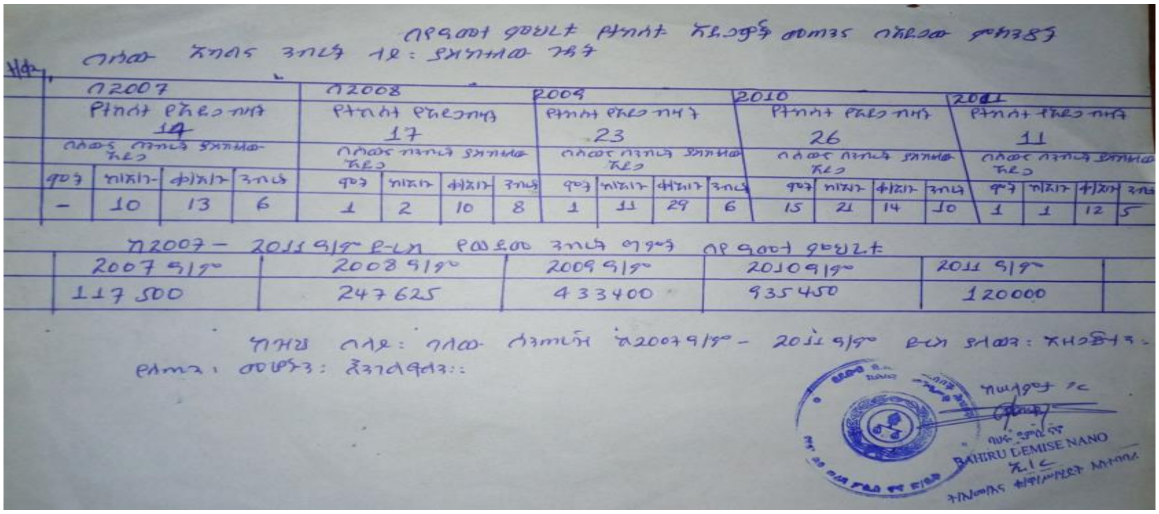
2. **Balaa Tirafikii Qaqqabee**

lakk	Aanaafi magalaa	Balaa du'a		Balaa qaama cimaa		Balaa qaama salhpa		Balaa qabeenya irra ga'e		Waliti qabaa		Tilmaama qabeenya barbadaa'			Namota midhaanirra ga'ee: Kan Du'an		Mi/Cimaa		Mi/Salphaa	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	Garagarumaa	2010	2011	2010	2011	2010	2011	2010	2011
1		17	8	9	1	15	-	30	29	71	43	28	1387400	1498530	17	11	9	6	10	4-
2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ida'ama		17	8	9	1	15	-	30	29	71	43	28	1387400	1498530	17	11	9	6	10	4-

Balaan qaqabee ____38_ qofa

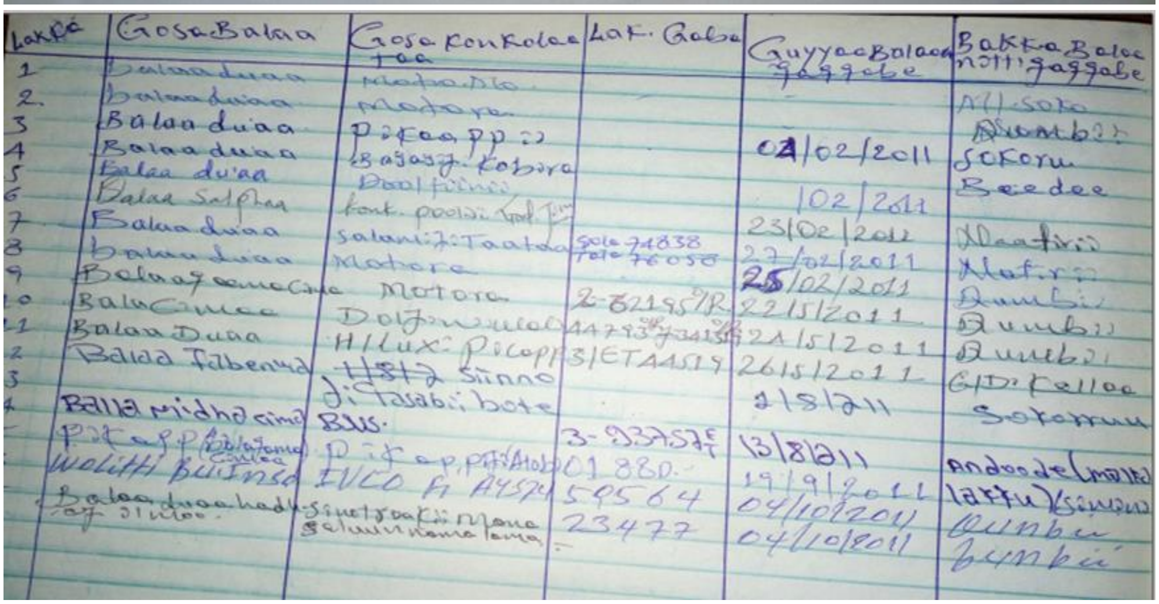
Midhaan qabeenyaa fi namaa irraa ga'ee ____43__dha. Tiilmammaa Qar 1498530_

Lakk	Gosa Balaa	Gosa Konkolaataa	Lak. Gabatee	Guyyaa Balaan qaqqabe	Bakka Balaan itti qaqqabe
1	Balaa duaa	Motor. [illegible]			
2.	Balaa duaa	Motora		-	A/l soko
3	Balaa duaa	Pikaapp [illegible]			Dumbi
4	Balaa duaa	Bajaaj. Kobira		02/02/2011	Sokoru
5	Balaa du'aa	Dool [illegible]			Beedee
6	Balaa Salphaa	Konk. poolisii [illegible]		/02/2011	
7	Balaa duaa	Salaan[illegible]: Taataa	Sole 74838 Tele 76050	23/02/2011	[illegible]
8	Balaa duaa	Motora		27/02/2011	[illegible]
9	Balaa qaama Cimaa	Motora		25/02/2011	[illegible]
10	Balaa Cimaa	Dolfin [illegible]	2-82195	22/5/2011	Dumbi
11	Balaa Duaa	Hilux Picopp	44793 [illegible]	24/5/2011	Dumbi
12	Balaa Tabenyaa	[illegible] Siino	3/ETA4519	26/5/2011	Gidi Kelloo
13		ji Tasabi bote		1/8/2011	
14	Balaa midhaa cimaa	Bus.			Sokorruu
	Pikapp Balaa qaama Cimaa	Pikap, pikap Aiolo	3-93757	13/8/2011	
	Waliti Buusa	IVCO fi AY524	01 880	19/9/2011	Andoode (maraa lafa) / Siinaa
	Balaa duaa hadu [illegible]	Sinotraak in Mona Galumma [illegible]	59564	04/10/2011	Dumbi
			23477	04/10/2011	Dumbi



	2007				2008				2009				2010				2011			
	14				17				23				26				11			
	–	10	13	6	1	2	10	8	1	11	29	6	15	21	14	10	1	1	12	5

2007	2008	2009	2010	2011
117 500	247 625	433400	935450	120000



Lakk'a	Gosa Balaa	Gosa Konkolaataa	Lak. Gabatee	Guyyaa Balaa Gaggabe	Bakka Balaa Gaggabe
1	Balaa duuaa	Motor Dls			
2.	Balaa duuaa	Motora			All Soko
3	Balaa duuaa	Pikap pp			Dumbi
4	Balaa duuaa	Bajaaj Kobira		02/02/2011	Sokoru
5	Balaa du'aa				
6	Balaa Saphaa			02/2011	Beedee
7	Balaa duuaa			23/02/2011	
8	Balaa duuaa	Salon Taataa	Sole 74838 Tele 76058	27/02/2011	
9	Balaa	Motora		25/02/2011	
10	Bala	Motora	2-B2195	22/5/2011	Dumbi
11	Balaa Duuaa			24/5/2011	Dumbi
12	Balaa	Hilux: Picopp	3/ET44579	26/5/2011	Dumbi
13					
14	Balla	BUS		2/8/2011	Sokoru
			3-93757	13/8/2011	
		IVCO	59564	19/9/2011	
	Balaa duuaa		23477	04/10/2011	Dumbi
				04/10/2011	Dumbi

E-2: Road Safety Audit photos (Aug. 02/2011 by me)

Photo No. 1: road safety audit such as measurements lane width, shoulders width

Photo No. 2 and 3: cracking of retaining wall along the bridge side

Photo No. 4: checking road side delineators such as traffic sign, spot speed and likewise others