

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING



*Identification and Countermeasures of Accident
Black Spot Locations Using Statistical Modeling*
(A Case Study of Addis Ababa)

A Thesis in Road and Transport Engineering

By Mitiku Dinsamo

June, 2018

Addis Ababa

A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science



ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

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A Thesis Submitted School of Graduate Studies in Partial Fulfillment of the
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(Road and Transport Engineering)

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UNDERTAKING

I certify that research work titled “*Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)*” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

Mitiku Dinsamo

ABSTRACT

Nowadays the issue of traffic safety has become the most considerable concern throughout the world, though it challenges more of developing countries, of which Ethiopia is one with its growingly urbanized capital city, Addis Ababa. With regard to traffic safety, the six-year summarized statistical data of Addis Ababa Police Commission (AAPC) revealed that 2,632 fatal, 9,133 severe injuries, 6,957 slight injuries and 85,316 property damage only (PDO) type of accidents were recorded in Addis Ababa city i.e. from July 6, 2009 – July 6, 2016. These figures pinpoint a fact how much the safety aspects of the entire road networks are becoming a pressing challenge in Addis Ababa city, and thus looking for policy attention and inquiry. The very objective of this research was therefore to investigate and develop accident prediction model using the prevalent geometric and traffic parameters. To this end, three principal arterial streets of Addis Ababa city were selected based on the premise of their susceptibility for the occurrence of frequent number of accidents and the availability of better accident data. Moreover, accident blackspot locations were distinguished through point weightage approach by employing three years of accident data from the police stations and AAPC database. Accordingly, primary data analysis was executed on the traffic and spot speed studies by employing the data gathered from site investigation survey. An accident prediction model was also derived from Generalized Linear Model (GLM), specifically from Negative binomial regression analysis using SPSS software packages, version 20. Accordingly, as per the yield of the investigations four logical factors such as traffic volume (APHV), the 85th percentile speed, availability of U-turn and number of access points, were discovered significant, and thus incorporated in the final accident prediction model. Based on this finding, the coefficients of all variables except number of access point carry the expected signs, where they have shown positive relation with the natural log count of accident frequency. However, number of access point was found significant with negative coefficient.

Key words: - Traffic Safety, Accident Frequency, Black Spot, Modeling, Geometric variables, Traffic variables, GLM, Negative Binomial.

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TABLE OF CONTENTS

ABSTRACT.....	i
AKNOWLEDGMENT	ii
TABLE OF CONTENTS.....	iii
LIST OF FIGURE.....	vii
LIST OF TABLES.....	viii
ABBREVIATION AND ACRONYMS	x
CHAPTER 1 - INTRODUCTION.....	1
1.1. Background	1
1.2. Statement of The Problem.....	2
1.3. Objectives of The Study.....	3
1.3.1. General Objective	3
1.3.2. Specific Objectives	3
1.4. Scope and limitation of The Study.....	3
1.5. Organizational Structure of the Report	4
CHAPTER 2 - LITERATURE REVIEW.....	5
2.1. Introduction	5
2.2. Road Traffic Accident.....	5
2.3. Contributing Factors of Road Accident	5
2.3.1. Human factors.....	6
2.3.2. Vehicle factors	6
2.3.3. Road and Environmental Factors.....	7
2.4. Road Safety Management Approaches	7
2.4.1. Proactive Approach.....	7
2.4.2. Reactive Approach.....	8
2.5. Road Accident Black Spot Definition Reviews	10
2.5.1. Introduction.....	10
2.5.2. Commonly Used Black Spot Definitions.....	10
2.5.3. Definition of Road Accident Black Spots in European Countries.....	12
2.6. Accident Prediction Model.....	15
2.6.1. Definition	15
2.6.2. Uses of Accident Prediction Model	15

2.7.	Modelling Techniques for Analyzing Crash Data.....	16
2.7.1.	Poisson regression model.....	16
2.7.2.	Negative Binomial (Poisson-Gamma) Regression Model.....	17
2.7.3.	Poisson-Lognormal Model.....	17
2.7.4.	Zero-inflated Poisson and Negative Binomial.....	18
2.7.5.	Generalized Estimating Equation Model.....	18
2.7.6.	Negative Multinomial Models.....	19
2.7.7.	Bivariate/Multivariate Models.....	19
2.8.	Explanatory Variables Used in Recently Developed Models.....	20
2.9.	A Review of Previously Developed Statistical Models.....	24
2.10.	Model Goodness-of-Fit Assessment Techniques.....	26
2.10.1.	Goodness-of-Fit Test.....	26
2.10.2.	Omnibus Test.....	27
2.10.3.	Residuals.....	27
2.10.4.	Outliers.....	27
CHAPTER 3 - MATERIAL AND METHODOLOGY.....		28
3.1.	Introduction.....	28
3.2.	Study Area.....	30
3.2.1.	Sampling Method and Procedure.....	30
3.2.2.	Selection Criteria.....	30
3.2.3.	Sample Size.....	30
3.2.4.	Selected Road Networks.....	30
3.3.	Road Network Classification.....	37
3.3.1.	Accident Data.....	42
3.3.2.	Traffic Data.....	43
3.3.3.	Geometric Design Data.....	56
CHAPTER 4 - ANALYSIS AND RESULT.....		58
4.1.	Introduction.....	58
4.2.	Analysis of Collected Data.....	58
4.2.1.	Analysis of Secondary Data.....	59
4.2.2.	Analysis of Primary data.....	72
4.3.	Adopted Black Spot Definition and Identification.....	80
4.3.1.	Black Spot Definition.....	80
4.3.2.	Blackspot Identification Strategy.....	81

4.4.	Choices of Model Explanatory Variables	83
4.4.1.	Principle of Parsimony of the Model	84
4.5.	Selection of Modelling Method.....	90
4.6.	Parameter Estimation	92
4.7.	Model Development.....	94
4.7.1.	Model form	95
4.8.	Discussions.....	98
4.9.	Assessment of Model Goodness of Fit.....	100
4.9.1.	Goodness-of-fit test.....	100
4.9.2.	Omnibus test	103
4.9.3.	Residuals	103
4.9.4.	Outliers.....	104
CHAPTER 5 - CONCLUSION AND RECOMMENDATIONS		105
5.1.	CONCLUSIONS.....	105
5.2.	RECOMMENDATION	106
CHAPTER 6 - DEVELOPMENT OF COUNTERMEASURES		107
CHAPTER 7 - DIRECTION OF FUTURE RESEARCH.....		108
REFERENCES		109
APPENDIXES		114
Appendix A: - Adopted Formats of the Research.....		116
A.1.	Manual Accident Recording Format with Sample Data.	116
A.2.	Encoded Accident Recording Format with Sample Data.....	117
A.3.	Traffic Volume Counting Format with Sample Data.....	118
A.4.	Six-Hour Traffic Volume Counts Summary Format.....	119
A.5.	Spot Speed Recording Format with Sample Data.	120
A.6.	Road Geometry Inspection Checklist with Sample Data.	121
Appendix B: - Accident Analysis Summary Along Mexico – German Square.		122
B.1.	Accident Number Vs Temporal Variation.....	122
B.2.	Accident Number Vs Causes of accident.	123
B.3.	Accident Number Vs Collision Type.	123
B.4.	Accident Number Vs Vehicle Involved in Accident.	124
B.5.	Accident Number Vs Their Location.	125
Appendix C: - Accident Analysis Summary Along <i>Sarbet – Sost Kutir Mazoria</i>		126
C.1.	Number of Accidents with Temporal Variation.....	126

C.2. Number of Accidents with Nature of Accident cause.	127
C.3. Number of Accidents according to Collision Type.	127
C.4. Number of Accidents according to Type of Vehicle Involved in Accident.	128
C.5. Number of Accidents according to Accident Location.	128
Appendix D: - Summarized Traffic Volume Analysis of <i>Bole – Meskel</i> Square.	129
D.1. Summarized traffic volume Analysis @ Friendship Business center.	129
D.2. Summarized Traffic Volume Analysis @ <i>Bole</i> Printing Press.	130
D.3. Summarized Traffic Volume Analysis @ Sunshine Laundry.	131
Appendix E: - Summarized Traffic Volume Analysis of Mexico square – German Square.....	132
E.1. Summarized Traffic Volume Analysis @ Ethiopian Tobacco Enterprise.	132
E.2. Summarized Traffic Volume Analysis @ International Evangelical Church.	133
E.3. Summarized Traffic Volume Analysis @ Vatican Embassy.....	134
E.4. Summarized Traffic Volume Analysis @ Mekane Eyesus Management School.	135
Appendix F: - Summarized Traffic Volume Analysis of <i>Sarbet – Sost kutir mazoria</i>	136
F.1. Summarized Traffic Volume Analysis @ Tomocca Coffee.	136
F.2. Summarized Traffic Volume Analysis @ Austria Embassy.....	137
F.3. Summarized Traffic Volume Analysis @ Dimma Cultural Restaurant.	138
Appendix G: - Sample Spot Speed Computation	139
G.1. Sample Spot Speed Analysis along <i>Bole – Meskel</i> Square.	139
G.2. Sample Spot Speed Analysis along Mexico Square – German Square.....	140
G.3. Sample Spot Speed Analysis along <i>Sarbet – Sost kutir mazoria</i>	141
Appendix H: - Output of Negative Binomial Analysis using SPSS.	142
Appendix I: - Pictorial Illustration of Black Spot Locations along the study road networks.	145
I.1. Black Spot Locations along <i>Bole to Meskel</i> square	145
I.2. Black Spot Locations along Mexico to German square.....	147
I.3. Black Spot Locations along <i>Sarbet to Sost Kutir Mazoria</i>	150
Appendix J: - Observed Problems and Countermeasures of the Respective Blackspot Locations.	152

LIST OF FIGURE

Figure 2-1. Processes of Blackspot Management.	9
Figure 3-1. Methodology of the Research.	29
Figure 3-2. <i>Bole - Meskel</i> square road network. (Source: Google Earth).....	33
Figure 3-3. Mexico square to German square road network. (Source: Google Earth).	34
Figure 3-4. <i>Sarbet to Sost Kutir Mazoria</i> road network. (Source: Google Earth).....	35
Figure 3-5. Influence Zone of an Intersection.	36
Figure 3-6. Traffic Counting Station 1 Infront of Friendship Business Center.	47
Figure 3-7. Traffic Counting station 2 @ Bole Printing Press.....	47
Figure 3-8. Traffic Counting station 3 @ Sunshine Laundry.	48
Figure 3-9. Traffic Counting station 1 @ National Tobacco and Matches Corporation.	50
Figure 3-10. Traffic Volume Counting station 2: Infront of International Evangelical Church...	51
Figure 3-11. Traffic Volume Counting station 3: Infront of Vatican Embassy.....	51
Figure 3-12. Traffic Volume Counting Station 4: Infront of Mekane Eyesus Management School.	52
Figure 3-13. Traffic Volume Counting Station 1 @ Tomoca Coffee house.....	53
Figure 3-14. Traffic Volume Counting Station 2 @ Embassy of Austria.	53
Figure 3-15. Traffic Volume Counting Station 3 @ Dimma Cultural Restaurant.....	54
Figure 3-16; Stopwatch Spot Speed Study Layout.	55
Figure 4-1. Severity of Accident Number Vs Temporal Variation.	61
Figure 4-2. Accident number and its cause.....	62
Figure 4-3. Accident number by Vehicle type.....	64
Figure 4-4. Spot speed Vs Cumulative percentage chart at BM 13.....	79
Figure 4-5. Residual chart.....	103

LIST OF TABLES

Table 2-1. limiting values for identification of black spots in Germany.	13
Table 2-2. Road type and location with threshold values in Switzerland.....	14
Table 2-3. Review of crash contributing factors by Greibe, 2003 and AASHTO, 2010.....	23
Table 3-1. The study Road Networks.	32
Table 3-2. Selected road networks along with their coding.....	38
Table 3-3. Classified road segments of <i>Bole</i> - Meskel square Road network.	39
Table 3-4. Classified road segments of Mexico Square - German Square Road network.....	40
Table 3-5. Classified road segments of Sarbet – Sost kutir mazoria Road network.....	41
Table 3-6. Vehicle Classification.....	45
Table 3-7. Summarized Directional Volume Counts at Friendship Business Center (Day 1).	49
Table 3-8. Recommended spot speed study length.....	55
Table 3-9. Summarized Geometric Data of the Entire Black Spot Locations.	57
Table 4-1. Accident number Vs Temporal variation (Bole-Meskel square).	60
Table 4-2. Accident number Vs its cause.	62
Table 4-3. Accident Classified According to Type of Collision.	63
Table 4-4. Accident Classified According to Type of Vehicle Involved in Accident.....	64
Table 4-5. Accident number by locations.	65
Table 4-6. Overall accidents and black spot locations according to classified station.	70
Table 4-7. Overall accidents and black spot locations according to classified station Con'd.	71
Table 4-8. Overall accidents and black spot locations according to classified station Con'd.	72
Table 4-9. Suggested Passenger Car unit (PCU) equivalent.....	73
Table 4-10. Peak Hour Volume Analysis at Bole Printing Press.	75
Table 4-11. Traffic Volume studies along Bole – Meskel square.	76
Table 4-12. Summarized Average peak hour volume of the entire study areas.	76
Table 4-13. Sample Spot Speed Analysis of Station BM 13.	78
Table 4-14. Summarized Spot Speed of Blackspot Locations Along the Entire Road Networks.	80
Table 4-15. Frequency Statistics of the Accident Data.....	82
Table 4-16. Top twenty Black spot locations along the study area.	83
Table 4-17. The Hypothesized Geometric and Traffic Explanatory Variables.	85

Table 4-18. Standard Correlation table.....	86
Table 4-19. Contingency Table of the Selected Explanatory Variables.....	87
Table 4-20. Correlation Matrix Results of Continuous Explanatory Variables.....	88
Table 4-21. Correlation Matrix Result of Categorical Explanatory Variables.....	89
Table 4-22. Frequency Statistics of the Black spot locations.....	91
Table 4-23. Goodness of Fit of the given data in Poisson model.....	92
Table 4-24. Goodness of Fit of the given data in Negative Binomial model.....	93
Table 4-25. Comparative analysis of Poisson and NB model.....	94
Table 4-26. Coefficients of Variable estimates.....	97
Table 4-27. The significant explanatory parameters along with their respective effects.....	100
Table 4-28. Results of Goodness of fit test.....	101
Table 4-29: Comparative Analysis of Poisson and NB Model.....	102
Table 4-30. Results of Omnibus test.....	103
Table 4-31. Output of standardize Pearson residual.....	104

ABBREVIATION AND ACRONYMS

AACRA – Addis Ababa City Roads Authority.

AAPC – Addis Ababa Police Commission.

AADT – Average Annual Daily Traffic.

AAiT – Addis Ababa Institute of Technology.

APHV – Average Peak Hour Volume.

AU – Africa Union.

BM – Bole to Meskel Square

DHL – Dalsey Hillblom Lynn.

EB – Empirical Bayes.

EEPCO – Ethiopian Electric Power Corporation.

EIC – Ethiopian Investment Commission.

EPHARM – Ethiopia Pharmaceuticals Manufacturing Factory.

ERA – Ethiopian Road Authority.

ERC – Ethiopian Railway Corporation.

HV - Hourly Volume.

IEC – International Evangelical Church.

INSA – Information Network Security Agency.

IZ – Influence Zone.

MG – Mexico to German Square.

MLE – Maximum Likelihood Estimate.

NBR – Negative Binomial Regression.

NIB – Nib International Bank.

NOC – National Oil Company

PR – Poisson Regression.

PS – Percentile Speed.

RIPCORDER - Road Infrastructure Safety Protection Core Research and Development for Road Safety.

AARTMA – Addis Ababa Road Traffic Management Agency.

SPSS – Statistical Package for the Social Science.

SS – Sarbet to Sost Kutir Mazoria.

AATPMO – Addis Ababa Transport Programs Management Office.

TRACECA - Transport Corridor Europe-Caucasus-Asia.

UAE – United Arab Emirates.

UNECA–United Nations for Economic Commission for Africa.

VB – Vehicle to Bicycle.

VM – Vehicle to Motorcycle.

VO – Vehicle to Object.

VP – Vehicle to Pedestrian.

VPa – Vehicle to Passenger.

Vs – Versus.

VV – Vehicle to Vehicle.

VVO – Vehicle to Vehicle to Object.

VVP – Vehicle to Vehicle to Pedestrian.

VVPa – Vehicle to Vehicle to Passenger.

VVV – Vehicle to Vehicle to Vehicle.

ZINB – Zero Inflated Negative Binomial.

CHAPTER 1 - INTRODUCTION

1.1. Background

Nowadays the questions of traffic safety have become the most considerable issue of the world, in particular it is the prominent concern of developing countries. The rapidly increasing traffic on the undeveloped road infrastructure coupled with the unsafe behaviour of road users results in a highly conflicting traffic that consequently leads to the occurrence of many road traffic accidents in the city. The total population of Addis Ababa is more than 4 million and is expected to grow to 6 million and 10 million in the year 2025 and 2040 respectively. The high economic growth and growth of residential, business, sub-centres and settlements is leading to overcrowding, traffic jam, traffic accidents and air pollutions (on going Traffic Flow Improvement Study by Gauff, PB consulting and Alert engineering PLC, 2017).

Besides, a study by Berhanu (2000) disclosed that Addis Ababa accounts for approximately more than 21% of fatal accidents, 42% of injury accidents, and 65% of total accidents reported in the whole country. Additionally, with regard to traffic safety, the six-year summarized statistical data of the Addis Ababa Police Commission (AAPC) revealed that 2,632 fatal, 9,133 severe injuries, 6,957 slight injuries and 85,316 property damage only (PDO) type of accidents were recorded in Addis Ababa city i.e from July 6, 2009 – July 6, 2016. These figures pinpoint a fact how much the safety aspects of the entire road networks are becoming a pressing challenge in Addis Ababa city, and thus looking for policy attention and inquiry.

Consequently, these research was done in order to give insight towards the safety aspects of the road network through developing relevant accident prediction model that integrates the prevalent geometric and traffic related explanatory variables. In addition, it was also aimed at suggesting possible low-cost countermeasures for the context and respective situation of the selected blackspot locations, which in turn are used to reduce the occurrence of traffic accidents due to the significant factors among traffic volume (APHV), 85th percentile spot speed, number lanes, median width, walkway width, median availability, number of access points and availability of U-turns. Moreover, the study incorporated three principal arterial streets of Addis Ababa which runs from *Bole - Meskel Square*, *Mexico Square – German Square* and *Sarbet – Sost Kutir Matoria*.

And the road sections were selected owing to the following reasons i) they have been experiencing tremendous and frequent number of traffic accidents as compared to other road sections of the city; ii) they fall under a functional classification of principal arterial streets (Updated Road Network of AACRA, 2010); iii) availability of better accident database and finally iv) availability of various geometric features along the road sections.

1.2. Statement of The Problem

The major concern which brought the attention of this research towards developing an accident prediction model for identifying the relevant black spot locations goes to the dynamic growth of traffic accident on the urban road networks of the country, Ethiopia particularly in Addis Ababa; which consequently results in different level of severity on human beings (minor, serious and fatal), and related losses of properties.

In addition, the number of traffic accident victims due to lack of proper law enforcement issues, traffic characteristics and improper geometric road designs have become enlarged from time to time. Even some road networks can be regarded as non-functional from the perspective view of their provisional concept. Generally, the road environment, road users and the engineering setting of the road sections are among the main accident causing aspects.

Moreover, the traffic management system in the city is inadequate to cope with the rapidly increasing motor and pedestrian traffic. Traffic controls, signs, and markings as well as pedestrian facilities are not in place. The rapidly increasing traffic on the undeveloped road infrastructure coupled with the unsafe behaviour of road users results in a highly conflicting traffic that consequently leads to the occurrence of many road accidents in the city. Addis Ababa accounts for approximately more than 21% of the fatal accidents, 42% of the injury accidents, and 65% of the total accidents reported in the whole country (Berhanu,2000). On the other hand, the concerned road network safety management agencies of the city such as police stations, transport authorities, insurance companies and hospitals etc. in Addis Ababa have been experiencing a seriously insufficient road traffic accident database system and under-reporting of road accidents. Hence, it adds another strain on the selection and implementation process of possible safety intervention measures.

Therefore, identification of black spot locations based on accident prediction model sets the ground and paves the way for creating insight towards adopting a habit of proper data storage and application of database system. To sum up, the above stated explanations and inquiries evoke the attention of this research towards making study on black spot modelling and selection of relevant road safety intervention measures that can counterbalance and reduce the occurrences of traffic accidents due to the prevalent geometric and traffic parameters of the road networks.

1.3. Objectives of The Study

1.3.1. General Objective

The general objective of the research was to develop statistically significant accident prediction model for mid-block sections of the principal arterial streets using the prevalent geometric and traffic explanatory variables.

1.3.2. Specific Objectives

The specific objectives of the research were: -

- To test /learn theories about how the world work;
- Identifying the relevant black spot locations within the study road networks;
- Identifying the prevalent traffic and geometric related variables which are presumed to cause frequent number of accidents;
- Developing statistically significant accident prediction model using the identified prevailing traffic and geometric explanatory variables;
- Forecasting the three years' accident frequency of the specific segment; and
- Suggesting possible low-cost engineering counter measures.

1.4. Scope and limitation of The Study

The scopes of the research are: -

- ✓ The study was limited to the accident database obtained from the respective police stations, and the Addis Ababa Police Commission;
- ✓ The road types that were under the consideration of the study was midblock sections of three principal arterial streets of Addis Ababa;

- ✓ The study is limited to the effects of road geometry and traffic characteristics on the occurrences of frequent number of road traffic accidents. Specifically, it only incorporates the presumed traffic and geometric characteristics of the road section for developing the accident prediction model such as the 85th % spot speed, average peak hour (APHV), lane number, lane width, median width, walkway width, and number of access point. Hence, other factors that might be taken as the causative factors for the occurrences of accident are not discovered.
- ✓ In addition, the study was executed on three principal arterial streets of Addis Ababa which runs from *Bole* to *Meskel* square, *Mexico Square* to *German Square* and finally *Sarbet* to *Sost Kutir Mazoria*.

1.5. Organizational Structure of the Report

The structure of the report is systematized in to six chapters and an appendix part.

Chapter 1 – Introduction: deals with the background, rationale, objective and the limitation of the research.

Chapter 2 – Literature Review: illustrates the review of previous literatures which were executed on similar research area.

Chapter 3 – Materials and Methodology: described the methodology which was adopted to accomplish the objective of the research.

Chapter 4 – Analysis and Result: presented with the overall results of the study along with the relevant figures, tables and brief descriptions.

Chapter 5 – Conclusion and Recommendation: presents the conclusion of the entire study along with the respective suggested recommendations.

Chapter 6 – Direction of future research: this chapter depicted the possible directions that will be helpful in executing further research regarding the subject matter.

While the next section is the appendix part and it consist of the formats, checklists, sample data, summarized accident analysis tables. Additionally, it also comprises analyzed sample spot speed, traffic volume and geometric design data. The output of Negative Binomial regression analysis of SPSS software package and the pictorial representation of the black spot locations are also incorporated under this section.

CHAPTER 2 - LITERATURE REVIEW

2.1. Introduction

Thesedays, the dramatic growth of motorization, population expansion and urbanization become the most critical hindrances of the safety aspects of road networks of the whole globe. Hence, this situation distracts the attention of transportation agencies, transport planners, engineers and the relevant stakeholders on doing their part for improving the safety issue in appropriate manner. Consequently, many researchers have been performed their research concerning the provision of safety improvements on the problematic road networks by preparing various models which integrates different accident causative explanatory independent variables or factors. Henceforth, the reviews of the previous scholar's work are reviewed and presented under eight key topics namely I) definition of road traffic accident reviews, II) road accident contributing factors, III) road safety management approaches, IV) road accident black spot definition reviews, V) accident prediction models, VII) a review of several modeling techniques, VIII) explanatory variables used in recently developed models and finally IX) a review of previously developed models.

2.2. Road Traffic Accident

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

2.3. Contributing Factors of Road Accident

The causes of traffic accidents are usually complex and involve several factors. Previous works of many researchers proved that the main factors can be divided into four separate categories such as human factors, the vehicle, the roadway, and the environment. According to Austroads, (1994), road accidents occurred as a result of one, or more than one of the following factors: -

- A) Human factors;
- B) Vehicle factors; and
- C) Road and environmental factors.

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

2.3.1. Human factors

Human factors are described as that which the person did, or did not do at the time of the accident. It includes the following characteristics: speeding, inappropriate speed for circumstances, traffic violations, alcohol, drugs, negligence, driver error and age. Human factors are without doubt the most complex and difficult to separate, as they are virtually all very momentary in nature. Ideally speaking, what existed at the time of the crash may not exist some instants later. Consider sensory capabilities, knowledge, decision making, attitude, attentiveness, fitness, health, driving skill, age, weight, strength and freedom of movement. Of these, the emotional dynamics are the greatest variable attributes and the most difficult to ascertain. They are also subject to the most adjustment with the least remaining evidence (Lisa, David et al.,2005). Elvik and Vaa, (2004) indicate that, even if all road users complied with all road rules, fatalities would only fall by around 60% and injuries by 40%. Specifically, they note that around 37% of fatalities and 63% of serious injuries do not involve non-compliance with road rules. This indicates that routine human error leading to crashes, rather than deliberate or unintentional breaking of road rules, is a feature of human existence and road use. Overall, human factors in vehicle collisions include all factors related to drivers and other road users that may contribute to a crash.

2.3.2. Vehicle factors

These factors refer to the design or mechanical faults of a vehicle, that include equipment condition, view obstructions, distractions, instruments, signaling devices, control sensation, comfort, automatic controls and devices, weight, performance, dimensions and stability. Vehicle speed, as a factor, must also exist, if neither vehicle had any speed, there could not have been collision (Mustakim F., 2005). In addition, physical parameters of the vehicle specifically discuss about the physical dimensions of the vehicle such as its length, width, number of axles, engine power etc.

2.3.3. Road and Environmental Factors

These factors include the possible road characteristics and environmental conditions that are responsible to cause road traffic accident. The road characteristics related factors can be categorized as constant and variable factors where factors like highway or intersection capacity, intersection control, land use and the geometric aspects of the road are classified under constant factors. And variable factors imply factors that depends on other factors like traffic flow characteristics and surface condition.

On the other hand, the physical and climatic environment surrounding a transportation vehicle can also be a factor in the occurrence of transportation crashes with the most common being weather. (Nicholas J. Garber and Lester A. Hoel, 2009). It also comprises any temporary conditions like a construction and detours.

2.4. Road Safety Management Approaches

There are two main engineering approaches for dealing with traffic safety problems: the proactive and reactive approach. The proactive approach is an accident prevention approach that tries to prevent unsafe road conditions from occurring in the first place. The reactive approach, or retrofit approach, on the other hand, consists of making the necessary improvements to existing hazardous sites in order to reduce accident frequency and severity at these sites (Sayed, T. et al, 2010).

2.4.1. Proactive Approach

The primary objective of the proactive approach is to ensure that road safety aspect is an explicit priority in transportation planning and design. And the stated objective of the approach might seem redundant at first. After all, the most common definition of transportation engineering is that it is the application of science and technology in order to provide for the safe and efficient movement of people and goods. This definition gives the impression that existing transportation planning and design policies and standards lead to the construction of safe roads (Sayed et al, 2008). In addition, the proactive approach is to design roads in such a way that a minimum number of crashes takes place (Qu et al.,2014, Jin et al., 2011).

However, the level of safety that is built into the road system by following these policies and standards is largely unknown. At the planning stage, existing transportation policies call for the preparation of statements assessing the impact of different transportation plans on traffic mobility, air pollution, and noise pollution among other issues.

However, the impact of these plans on safety is usually neither called for nor addressed. At the design stage, highway and traffic engineers produce designs whose safety consequences are not known. By law, they are required to produce designs that do not violate existing standards and codes. There is no doubt that these standards and codes were written with safety in mind, but the level of safety that they introduce into the road system is largely unknown. (Sawalha, Z.A., 2002).

2.4.2. Reactive Approach

The reactive approach to safety management focuses on identifying and remedying safety problems in the existing road networks. Most road authorities have established road safety improvement programs, otherwise known as black spot programs, whose main goal is to identify hazardous locations in road networks and to establish countermeasures for correcting the problems at these locations.

In broad terms, road safety improvement involves the following three stages:

- ✓ Detection of black spots, otherwise known as hazardous or accident-prone locations.
- ✓ Diagnosis of the problems that cause the detected locations to be hazardous.
- ✓ Remedy of the diagnosed problems by establishing and implementing countermeasures that are effective in alleviating them (Sayed et al, 2008).

2.4.2.1. Process of Black Spot Management

According to the works of Elvik R. (2007), the process of eliminating or improving accident black spots in a road network is composed of several activities. This includes identify the black spots, study the problems (diagnosis) at each spot, design suitable countermeasures, estimate their effects, set priorities, implement, and finally, follow up and evaluate the results. The entire process of black spot management is presented on Figure 2-1.

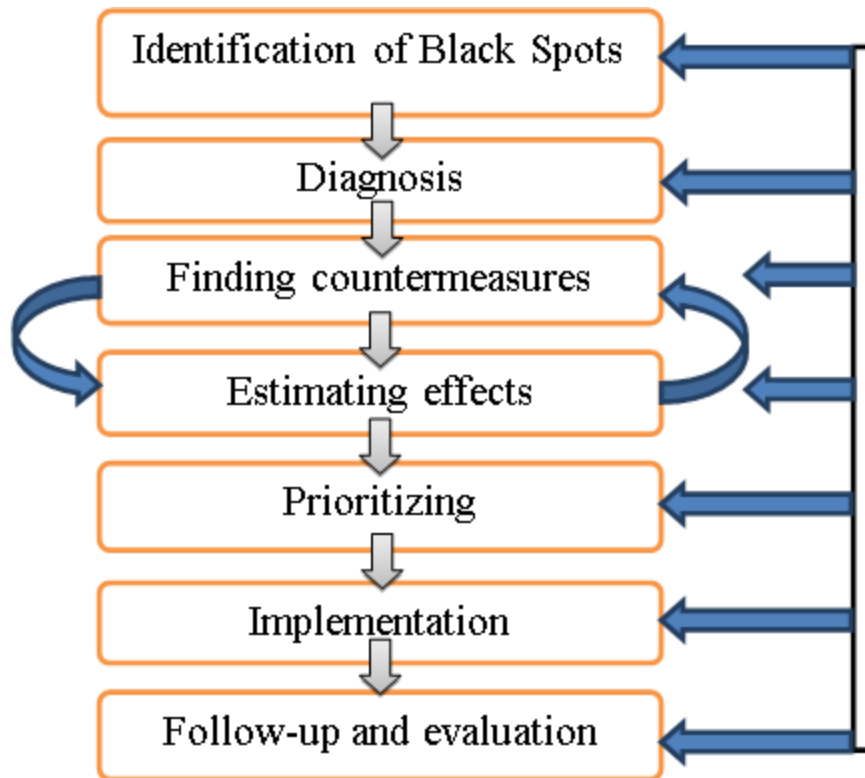


Figure 2-1. Processes of Blackspot Management.

Source: (Black spot Manual: Traffic Safety Project, December 2001).

As it can be easily noticed from Figure 2-1, the first step which should be executed prior to providing the relevant diagnosis and countermeasures is the identification process. Consequently, the identification process should be made using some reference guideline or speculated definition. As such many scholars, transportation agencies, researchers and several institutions have been setting their own definition which they think it will explain the real situations of their countries study area. Moreover, the next section encompasses several black spot definitions which were adopted by different countries, transportation agencies and institutions.

2.5. Road Accident Black Spot Definition Reviews

2.5.1. Introduction

Many definitions of accident black spots are available however, research emphasizes that there is no comprehensive and universally quoted definition of what is accepted as a black spot (Geurts K. and Wets G., 2003). Thus, black spots are defined in different ways by several scholars, transportation agencies, engineering teams, researchers and regional safety boards.

For instance, black spot can be defined as any locations where there is a high concentration of accidents. Conversely, according to TRACECA report, black spot is defined as “Any location on a road with a maximum length of 300 meters, at which at least four fatal crashes have been recorded during the last three years” (TRACECA March, 2015).

Moreover, Overgaard Madsen (2005) discusses in great detail criteria for identifying black spots. He proposes that an adequate definition of a hazardous road location should satisfy three, or possibly four, criteria:

1. It should control for random fluctuations in the number of accidents.
2. It should account for as many of the factors that are known to influence road safety as possible.
3. It should identify sites at which fatal and serious injury accidents are over-represented.
4. It should identify sites at which local risk factors related to road design and traffic control make a substantial contribution to accidents.

2.5.2. Commonly Used Black Spot Definitions

More recent works of the following scholars recommends that (Persaud, Lyon and Nguyen 1999, Hauer et. al. 2002A, Vistisen 2002, Overgaard Madsen 2005) a distinction can be made between the following common definitions of road accident black spots:

1. Numerical definitions – is a definition which is based on accident number and accident rate or a combination of the two.
2. Statistical definitions – is an approach of defining black spot using critical value of accident number or critical value of accident rate.
3. Model-based definitions – a way of defining black spot based on the following two developed models namely Empirical Bayes and Dispersion value.

Furthermore, definition of black spots based on the above stated approaches will be presented in three separate topics as follows:

2.5.2.1. Numerical Definition of Road Accident Black Spot

This definition does not make any reference to the traffic volume or to the normal number of accidents, nor does it specify the type of location considered (Elvik, 2008). For instance, a Norwegian official adopted accident number as a criterion for defining black spots and defined it as “A black spot is any location with a maximum length of 100 meters, at which at least 4 injury accidents have been recorded during the last 5 years.” This definition does not make any reference to traffic volume or to the normal number of accidents, nor does it specify the type of location considered, except by stating that the location should not extend for more than 100 meters. The identification of black spots relies on the use of a “sliding window” with a length of 100 meters.

While an accident rate definition of a black spot would be: “A black spot is any location (junction, section, curve, etc.) at which the number of injury accidents per million vehicles (or vehicle kilometers), estimated for the most recent four years, exceeds the value of 1.5 (arbitrarily chosen)”. This definition differs from the simple accident number definition by taking account of traffic volume, and thus implicitly referring to what is regarded as a normal number of accidents (Elvik, 2002).

2.5.2.2. Statistical Definition of Road Accident Black spot

A statistical definition of an accident black spot bank on the comparison of the recorded number of accidents to a normal number for a similar type of location. For example, a junction will be classified as a black spot if the recorded number of accidents in a specific period is significantly higher than the normal number of accidents for this type of junction. Depending on how the normal number of accidents is estimated, a statistical definition may come close to a model based definition of a black spot.

2.5.2.3. Model based Definition of Road Accident Black spot

Model-based definitions of road accident black spots are derived from a multivariate accident prediction model. An example is the Empirical Bayes (EB) definition of a black spot (site with promise) given by Persaud et. al. (1999). Models were developed for intersections and road sections, and the 20 highest ranked locations were identified according to the EB estimate of the expected number of accidents.

Persaud et. al. (1999) tested the performance of two interpretations of a model-based Empirical Bayes black spot concept. According to the first definition, black spots were simply those 20 intersections that had the highest expected number of accidents, according to the EB-estimate. According to the second definition, borrowed from Mc Guigan (1981), a black spot was defined in terms of the potential for accident reduction, defined as follows:

$$\text{Safety potential} = m - P \dots \dots \dots \text{Equation 2.5.2.3.}$$

In which m is the EB-estimate of the expected number of accidents for a specific site and P is the model estimate of the normal expected number of accidents for similar sites.

2.5.3. Definition of Road Accident Black Spots in European Countries

In Denmark, black spot is defined by following certain clearly defined criteria's in which firstly the road networks are classified in to different sections and intersections (Vistisen 2002, Overgaard Madsen 2005).

While in Flanders a site is said to be black spot if it passes through two procedures 1) if it has experienced three or more accidents the last three years and it scores a priority value (S) calculating using the following formula, equals 15 or more.

$$S = LI + 3SI + 5DI \dots \dots \dots \text{Equation 2.5.3}$$

Where:

LI = Total number of slight injuries,

SI = Total number of serious injuries (Each causality that is admitted more than 24 hours in hospital)

DI = Total number of death injuries (Each causality that died within 30 days after the accident).

In Germany, a site is considered a black spot if a large number of accidents occur on a very small section of a road network, i.e. if a certain number of accidents is reached or exceeded on the one-year and/or three-year map. Typical frequent-accident spots may include intersections, road/road and road/off-road track junctions, bends, humps, railway crossings and inclines. A preliminary investigation of a frequent accident spot should be conducted if one of the limit values shown in the table below is reached or exceeded. The limit values suggested in the table apply to the road network both within and outside built-up areas as well as motorways (Road and transport research association of Germany, 2006).

Table 2-1. limiting values for identification of black spots in Germany.

(Source: German road and transport research association, 2006).

Source of data	Critical count of accident	Length of period
1-year map	5 of similar type	12 months
3-year map	5 injury accidents	36 months
3-year map	3 serious injury accidents	36 months

Hungarian define black spots using accident number and rate approach which is quite similar with that of the numerical definition. Generally, they proposed two deferent definitions on the basis of built up areas. Outside built up areas, black spot is defined as a location where at least four accidents have been recorded during three years on a road sections no longer than 100 meters. On the other hand, inside built up area, a black spot is defined as a location where at least four accidents have been recorded in three years on a road section no longer than 100 meters.

According to Norwegian speculation, black spot is defined as any location with a length of not more than 100 meters where at least four injury accidents have been recorded in the last five years. And the period used to identify black spots was recently extended from 4 years to 5 years (Statens Vegvesen, handbook 115, 2006, draft version).

In Portuguese, black spot detections are carried out for roads belonging to the national road network, which is managed by the Portuguese road agency (Estradas de Portugal – EP). Therefore, according to the Portuguese road agency black spots are defined in two ways.

- I) A black spot is a road section with a maximum length of 200 meter, with five or more accidents and a severity indicator greater than 20, in the year of analysis. And no distinction is made between intersection and non-intersection accidents.
- II) While the other defines black spot as it is a geographical area where the expected accident frequency is greater than in similar (not necessarily adjacent) areas, due to the influence of road characteristics peculiar to the area.

In the case of Switzerland, the definition of accident black spots is not applying for practical or institutionalized purpose, rather it is functional only for counselling purpose. Basically, they define black spot as a section of road or an intersection, where the number of accident is “well above” the number of accidents at the threshold value which vary depending on the type of road and refer to a

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

period of two years. The threshold values which are used to determine the possible black spots are presented on table 2-2: -

Table 2-2. Road type and location with threshold values in Switzerland.

Road type and location	Threshold values		
	Number of all crashes	Number of crashes with injuries and/or fatalities	Number of crashes with fatalities
Motorways (per direction)	10	4	2
Entrance/exit ramps	10	4	2
Rural roads (intersection and open roads)	10	4	2
Main road in built-up areas – open roads	8	5	2
Main roads in-built-up areas – intersections.	10	6	2

Furthermore, most currently employed definitions of road accident black spots are theoretically unsatisfactory, mainly because they are not clear about whether black spots should be defined in terms of the expected number of accidents or in terms of the recorded number of accidents. In conclusion, from a more theoretical point of view black spots can be defined as any locations that has a higher expected number of accidents than other similar locations, as a result of local risk factors. (Elvik 1988, 2007).

2.6. Accident Prediction Model

2.6.1. Definition

An APM is, in essence, a mathematical equation that expresses the average accident frequency of an entity as a function of traffic flow and other road characteristics. The coefficients of APMs cannot be estimated by the traditional ordinary least squares or weighted least squares regression methods. This is because the assumptions for these methods are violated by the discrete, non-negative nature of accident count data and the reality that the variance in the number of accidents increases as the traffic flow increases. Thus, it is now common to estimate the coefficients of APMs by using maximum likelihood methods to calibrate what are referred to as generalized linear models (GLMs) (Lord D. and Persaud B, 2000).

2.6.2. Uses of Accident Prediction Model

Accident Prediction Model (APM) it is applicable for a variety of purposes; most frequently to estimate the expected accident frequencies from various roadway entities (highways, intersections, interstates, etc) and also to identify geometric, environmental and operational factors that are associated with the occurrence of accidents. Thus, it is important to examine the nature of relationships between roadway, environmental and operational factors and, accidents to understand the causal mechanisms involved in accidents on the one hand and to better predict their occurrence on the other hand. Therefore, APMs are one path of inquiry often used to gain these insights (Reurings et al., 2005).

Subsequently, according to the reviews of previously performed researches, Accident prediction models have been extensively used in the domain of road infrastructure for the estimation of the expected number of accidents on road segments and junctions (Hauer et al., 1988; Mountain et al., 1996; Greibe, 2003; Daniels et al., 2009). Several approaches have been developed to identify elements that affect the safety of road sections and intersections. These include the multiple logistic regression models, multiple linear regression models, Poisson regression models, negative binomial regression models, zero-inflated Poisson regression model, zero-inflated negative binomial regression model, random effects models and the classification and regression tree (CART) technique. These regression approaches focus on predicting total accidents with fatalities, injuries, etc for assessing the safety effects of various factors. However, effective road safety management requires knowledge of the present safety performance and what it is likely to be in future if proposed actions are taken.

In effect, reliable methods for estimating safety performance of an existing or planned roadway are required (Harwood et al., 2000).

2.7. Modelling Techniques for Analyzing Crash Data

As it was explained in the previous section, section 2.6 of the paper, a variety of methods have been applied over the years for dealing with the analysis of crash frequency data in an appropriate manner. This section provides a listing of methods previously applied to crash-frequency analysis along with their strengths and weaknesses. Thus, the most common types of methods which were adopted to perform the accident data analysis comprises Poisson regression model, negative binomial regression model, Poisson-lognormal model, zero-inflated Poisson and Zero-inflated negative Binomial, generalized estimating equation model, negative multinomial models and bivariate/multivariate regression models. And detailed explanations of the above stated model is presented accordingly through section 2.7.1 to section 2.7.7 as follows.

2.7.1. Poisson regression model

Because crash-frequency data are non-negative integers, the application of standard ordinary least-squares regression (which assumes a continuous dependent variable) is not appropriate. Given that the dependent variable is a non-negative integer, most of the recent thinking in the field has used the Poisson regression model as a starting point. In a Poisson regression model, the probability of roadway entity (segment, intersection, etc.) i having y_i crashes per some time period (where y_i is a non-negative integer) is given by:

$$P(y_i) = \frac{EXP(-\lambda_i)\lambda_i^{y_i}}{y_i!} \dots \dots \dots \text{Equation 2.7.1.}$$

where $P(y_i)$ is the probability of roadway entity i having y_i crashes per time period and λ_i is the Poisson parameter for roadway entity i , which is equal to roadway entity i 's expected number of crashes per year, $E[y_i]$. Poisson regression models are estimated by specifying the Poisson parameter λ_i (the expected number of crashes per period) as a function of explanatory variables, the most common functional form being $\lambda_i = EXP(\lambda X_i)$, where X_i is a vector of explanatory variables and λ is a vector of estimable parameters. Although the Poisson model has served as a starting point for crash-frequency analysis for several decades, researchers have often found that crash data exhibit characteristics that make the application of the simple Poisson regression (as well as some extensions of the Poisson model)

problematic. Specifically, Poisson models cannot handle over and under-dispersion and they can be adversely affected by low sample means and can produce biased results in small samples.

2.7.2. Negative Binomial (Poisson-Gamma) Regression Model

The negative binomial (or Poisson-gamma) model is an extension of the Poisson model to overcome possible over dispersion in the data. The negative binomial/Poisson-gamma model assumes that the Poisson parameter follows a gamma probability distribution. The model results in a closed-form equation and the mathematics to manipulate the relationship between the mean and the variance structures is relatively simple.

The negative binomial model is derived by rewriting the Poisson parameter for each observation i as: -

$$\lambda_i = \text{EXP}(\lambda X_i + \lambda_i) \dots\dots\dots \text{Equation 2.7.2.}$$

Where $\text{EXP}(\lambda_i)$ is a gamma-distributed error term with mean 1 and variance λ . The addition of this term allows the variance to differ from the mean as $\text{VAR}[y_i] = E[y_i][1 + \lambda E[y_i]] = E[y_i] + \lambda E[y_i]^2$. The Poisson regression model is a limiting model of the negative binomial regression model as λ approaches zero, which means that the selection between these two models is dependent upon the value of λ . The parameter λ is often referred to as the over dispersion parameter. Usually the over dispersion parameter or its inverse is assumed to be fixed.

The Poisson-gamma/negative binomial model is the probably the most frequently used model in crash-frequency modeling. However, the model does have its limitations, most notably it's incapable to handle under dispersed data, and dispersion-parameter estimation problems when the data are characterized by the low sample mean values and small sample sizes (Lord, 2006; Lord et al., 2009).

2.7.3. Poisson-Lognormal Model

Recently, some researchers have proposed using the Poisson-lognormal model as an alternative to the negative binomial/Poisson-gamma model for modeling crash data (Miaou et al., 2003; Lord and Miranda-Moreno, 2008; Aquero-Valverde and Jovanis, 2008). The Poisson-lognormal model is similar to the negative binomial/Poisson-gamma model, but the $\text{EXP}(\lambda_i)$ term used to compute the Poisson parameter is lognormal rather than gamma distributed. Although the Poisson-lognormal potentially offers more flexibility than the negative binomial/Poisson-gamma, it does have its limitations.

For example, model estimation is more complex because the Poisson-lognormal distribution does not have a closed form and the Poisson-lognormal can still be adversely affected by small sample sizes and low sample mean values (Miaou et al., 2003).

2.7.4. Zero-inflated Poisson and Negative Binomial

Zero-inflated models have been developed to handle data characterized by a significant number of zeros or more zeros than the one would expect in a traditional Poisson or negative binomial/Poisson-gamma model. Zero-inflated models operate on the principle that the excess zero density that cannot be accommodated by a traditional count structure is accounted for by a splitting regime that models a crash-free versus a crash-prone propensity of a roadway segment. The probability of a roadway entity being in zero or non-zero states can be determined by a binary logit or probit model (Lambert, 1992; Washington et al., 2003, 2010).

Since its inception, the zero-inflated model (both for the Poisson and negative binomial models) has been popular among transportation safety analysts (Shankar et al., 1997; Carson and Mannering, 2001; Lee and Mannering, 2002; Kumara and Chin, 2003; Shankar et al., 2003). Despite its broad applicability to a variety of situations where the observed data are characterized by large zero densities, others have criticized the application of this model in highway safety. For instance, Lord et al. (2005, 2007) argued that, because the zero or safe state has a long-term mean equal to zero, this model cannot properly reflect the crash-data generating process.

2.7.5. Generalized Estimating Equation Model

The generalized estimating equation model has been applied to highway safety analysis by Lord and Persaud (2000) to model crash data with repeated measurements. As discussed previously, one often has data from roadway entities (roadway segments or intersections) over multiple time periods which set up a serial correlation problem (Liang and Zeger, 1986). The generalized estimating equation is not actually a regression model per segment, but a method used to estimate models with data characterized by serial correlation. The generalized estimating equation model offers different approaches to handle serial correlation including independence, exchangeable, dependence, and auto-regressive type 1 correlation structures.

Usually, the correlation structure in the estimation process has a minimal influence on the modeling output when count-data models are used with a complete dataset (few if any omitted variables), however, the selection of the correlation type can be critical when the database has omitted variables (Lord et al., 2005a; Halekoh et al., 2006; Lord and Mahlawat, 2009).

2.7.6. Negative Multinomial Models

The problem of correlation among observations can also be addressed with a negative multinomial approach (Guo, 1996). This model is similar to the negative binomial in that it uses $\lambda_i = \text{EXP}(\lambda X_i + \lambda_i)$, except now $\text{EXP}(\lambda_i)$ is associated with a specific entity (roadway segment, intersection) as opposed to a specific observation. This is an important distinction because, for example, if one is considering annual crash frequencies and with 5 years of data, each roadway entity will produce 5 observations that would each have their own $\text{EXP}(\lambda_i)$ in a standard negative binomial, which would create a potential correlation problem. For the negative multinomial model, at the segment/intersection level, the $\text{EXP}(\lambda_i)$ is again assumed a gamma-distributed error term with mean 1 and variance λ . Shankar and Ulfarsson (2003) presented an application of the negative multinomial model to crash frequency data and compare estimation results to standard negative binomial and random-effects negative binomial models (Hauer, 2004; Caliendo et al., 2007). Negative multinomial models cannot handle under dispersion and are susceptible to problems in the presence of low sample means and small sample sizes.

2.7.7. Bivariate/Multivariate Models

Bivariate/Multivariate models become necessary in crash-frequency modeling when, instead of total crash counts, one wishes to model specific types of crash counts (for example, the number of crashes resulting in fatalities, injuries, etc.). Modeling the counts of specific types of crashes (as opposed to total crashes) cannot be done with independent count models because the counts of specific crash types are not independent (that is, the counts of crashes resulting in fatalities cannot increase or decrease without affecting the counts of crashes resulting in injuries and no injuries). To resolve this problem, Bivariate/multivariate models are used because they explicitly consider the correlation among the severity levels (for example) for each roadway entity (Miaou and Song, 2005; Bijleveld, 2005, Song et al., 2006). Bivariate models are used for jointly modeling two crash types (Subrahmaniam, 1973; Maher, 1990; N'Guessan et al., 2006; Geedipally and Lord, 2009; N'Guessan, 2010). Extensions to more than two crash types (multivariate-model formulations) have been proposed including the

multivariate Poisson model (Ma and Kockelman, 2006), the multivariate negative binomial model (Winkerlman, 2003), and the multivariate Poisson-lognormal model (Park and Lord, 2007; Ma et al., 2008; El-Basyouny and Sayed, 2009a; Park et al., 2010). On the downside, bivariate/multivariate models are complex to estimate in that they require a formulation of a correlation matrix. In conclusion, this research was focused on modeling the cumulative effects of significant traffic and geometric related explanatory variables on the possible occurrence of road traffic accidents.

2.8. Explanatory Variables Used in Recently Developed Models

Numerous empirical relationships between vehicle accidents and the possible explanatory variables have been established in several recent previous studies, multiple linear regression, generalized linear model and negative binomial regression models were the most common among the possible methods used. In those models, the independent variable (either number of accidents or accident rate) is a function of series of independent variables.

Traffic conditions and Road geometry were considered as predictors in accident prediction model by Kalokota and Seneviratne (1994) but the selected geometry variables are different where degree of curvature, section length, vertical grade, number of lane, and right shoulder width and traffic volume were employed as predictors to develop a reliable accident prediction model. And the model was developed to identify the suitable black spots on the selected road network using multiple regression analysis.

Moreover, Golob and Recker (2003, 2004) used linear and non-linear multi-variable regression analysis to compare the correlations between crashes and traffic flow, lighting and weather conditions. In a subsequent study, Golob et al. evaluated the effects of changes in traffic flow on road safety. Similarly, Hong et al. (2005) also used multiple regression methods in order to develop a crash prediction model but they focused more on road geometry compared to traffic conditions in choosing the independent variables.

In addition, Mustakim et al. (2008) proposed an accident prediction model based on the dataset of Federal Route 50 in Malaysia. In this study, he considered number of access point per kilometer of the roadway, hourly traffic volume, time gap between vehicle and 85th percentile speed. Multiple linear regression models resulted in good accuracy level.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Another study by Mustakim et al. (2008) also employed regression analysis in which road and traffic related factors were considered as independent variables and number of accidents as the dependent variable. The study found that the number of access points to the road stretch; low lighting conditions and the Annual Average Daily Traffic (AADT) are major contributors for the occurrence of frequent number of accidents.

In contrary, Shankar et al. (1995) made accident frequency prediction model using negative binomial regression. They considered both the road geometry and weather factors to develop the model. Additionally, E. Hauer (2004) developed similar statistical regression equations to predict the number of crashes per year in relation to geometric roadway features and traffic flow. The crash data were analyzed using binominal negative distribution. An innovative aspect of this study is the introduction of an alternative instrument to measure the adequacy of accident prediction models, called the Cumulative Residuals method.

The study conducted by Greibe, (2003) dealt with the development of simple realistic model for the prediction of accidents in an urban junction and road stretch. The applications of the model were to identify the various factors responsible for the accident occurrence and determine the 'black spots' in the study area. And the model was developed using traffic and geometric variables as an independent explanatory variable. The results of the study show that the accident frequencies of the road links and junctions considered were related to the various factors causing them by means of generalized linear modelling.

Hong. et al (2005), developed models considering the characteristics of roadway alignment and traffic characteristics. He developed models that can be used to predict the accident rates on new or improved roads. While Olugbenga and Makinde, (2010) discussed on regression models developed with dependent variables as number of accident and independent variables as number of people killed in the accident, number of people injured, number of people involved in the accident. The model has provided good coefficient of correlation and coefficient of determination "R²" value.

Awe and Mumini, (2011) developed regression models to capture the interconnectedness among accident related variables in Nigeria. His study focused on determining the degree of association between those who are killed in road crash. Variables considered are number of vehicles involved, number of accidents recorded, number of injuries and month of the accident occurred.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

William and Mohammad, (2015) made an attempt to develop prediction model for road traffic crashes occurring on the rural sections of the highways in the Ashanti Region of Ghana. This model was developed for all injury crashes occurring on selected rural highways.

Similar research by Berhanu, (2003) have taken 10 variables such as vehicle-kilometer, lane width, number of lanes, median width, U-turn median openings, width and surfacing of sidewalk, presence of kerb, grade, road curviness, pedestrian traffic, parking, number of minor junctions, traffic density, and 85th percentile speed. Murthy and Srinivasa Rao, (2015) used factors that influences road accidents and has analyzed using Statistical Package for Social Sciences (SPSS), a mathematical toll for development of regression models. His objective is to review relation between accident per year and intersection. He has suggested improvement measures to prevent road accidents.

Furthermore, as per the review of Greibe, (2003) and AASHTO, (2010); for road segment data, some of the common contributing factors that have been found to be significant in a number of studies are presented on Table 2-3.

Table 2-3. Review of crash contributing factors by Greibe, 2003 and AASHTO, 2010.

N_o	Contributing factors	Unit
1	Traffic volume	AADT
2	Length of road sections	Meter
3	Speed limit	Km/hr
4	Presence of median	No
5	Median width	Meter
6	Shoulder width	Meter
7	Road width	Meter
8	Number of lanes	Number
9	One/two-way traffic	Number
10	Speed reducing measures	No
11	Number of minor crossings	No
12	Cyclist facilities	No
13	Foot path	No
14	Parking facilities	No
15	Bus stop	No
16	Land use	No

In conclusion, this research was executed to develop accident prediction model for identifying the possible black spot locations along mid-blocks of the road networks in the city of Addis Ababa. And the model incorporates the prevalent traffic and geometric characteristics of the road sections. Besides, as likely as Murthy and Srinivasa Rao, it adopted SPSS software package for making the correlation and regression analysis between accident frequency and the proposed explanatory independent traffic and geometric characteristics of the road segments.

2.9. A Review of Previously Developed Statistical Models

A number of statistical models have been used to estimate accident rates and/or accident frequencies at a specific location over a given interval of time. Brief reviews of previously developed accident prediction models are presented as follows:

Desai and Patel, 2010 focused on the development of accident prediction model based on regression analysis. He has made attempt to develop accident model based on linear regression techniques. The model exhibits satisfactory goodness-off it and a good prediction of success rate.

Foldvary (1979), Jovanis and Delleur (1983) have used simple models using mean and variance. These models are used to study variations in accident rates for different levels of exposure. But they are not able to incorporate the effect of risk factors on accident involvement.

In Oppe (1979), Ceder and Livneh (1982) used multiple linear regression models. In these models, the dependent variable (either number of accidents or accident rate) is a function of a series of independent variables such as speed or traffic volume. Accident occurrence in these models is assumed to be normally distributed. These models generally lack the distributional property that is necessary to describe adequately the random and discrete vehicle accident events on the road and they are inappropriate for making probabilistic statements about accident occurrence.

On account of the probabilistic nature of accident occurrence Saccomanno and Buyco (1988) and Blower et al (1993) have used a Poisson log linear model to explain variations in accident rates. This Poisson regression model is especially suitable for handling data with large numbers of zero counts. However, this model could be inappropriate for road accident counts, since it fails to account for extra-Poisson variation (the value of the variation could exceed the value of the mean) in the observed accidents counts.

Moreover, for the sake of solving the problem of extra-Poisson variation, several authors such as Maycock and Hall (1984), Hauer and Persaud (1987), Persaud (1990), Miaou (1994), Shankar et al (1995), Maher and Summersgill (1996), Kulmala (1995), and Hauer (1997) have used negative binomial regression models. Miaou (1994) developed two types of negative binomial models, one using a maximum likelihood method and one using a method of moments. The maximum likelihood model was found to be more reliable than the Poisson regression model in predicting accidents where over dispersion is present.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Persaud incorporated an empirical Bayesian adjustment in his negative binomial model arguing that adjusting historical data by statistical estimates yields improved predictability. Furthermore, the issue of extra-Poisson variation in road accident data was addressed further by Hauer and Persaud (1987). They extended the generalized linear model of Maycock and Hall (1984) who allowed for systematic differences in accident frequencies between locations by relating the mean in the Poisson distribution to a number of location characteristics such as traffic flow and various geometric variables. In their model, the Poisson mean was allowed to vary between locations beyond what may be explained by differences in characteristics. The Poisson-gamma generalized linear model set up in Hauer and Persaud (1987) has been supported by Maher and Summersgill (1996), and is now widely accepted (see e.g. Kulmala (1995) and Hauer (1997)). A few extensions to this model have been pursued. As an example, in Tunaru (1999), the parameter in the gamma distributions as well as the regression variables are modeled as random variables.

Accident prediction model which was developed by Persaud and Dzbik presented relationships between the number of accidents and the traffic flow expressed as average daily traffic (ADT) and hourly volume. The analysis was based on generalized linear models and the result demonstrated that the accident rate increases with traffic flow (Persaud, B and L. Dzbik, 1993).

In conclusion, most of the above specified researches were done in western and Asian countries. Hence, the applicability and suitability of the models are limited to their context. The first place, the models are developed by considering the accident database system of their own country. On the other hand, the models were practically limited to the traffic, road and environmental condition of their own transportation facilities.

Unlike developed countries the traffic accident data recording system of our country is characterized by having many problems such as under-reporting, lack of registering the specific accident locations etc. Besides, as compared to the criticality of the situation, the availability of research regarding the subject matter in our country, Ethiopia is insignificant. Therefore, this research was aimed and executed to develop the relevant accident prediction model for identifying the black spot locations on the mid blocks of the road networks. Moreover, the research proposed the possible low-cost engineering counter measures in the context of our country Ethiopia, specifically Addis Ababa. Most importantly, the research will be used as a platform for executing further related studies.

2.10. Model Goodness-of-Fit Assessment Techniques

2.10.1. Goodness-of-Fit Test

Several types of goodness-of-fit measures were developed to check the significance of the model. Pearson Chi-squares, Deviance, Likelihood Ratio Test, Akaike Information Criteria (AIC) and Bayesian Schwartz Information Criteria (BIC) are among the possible testing approaches. But, the two most frequently employed measurements that are used to determine the goodness of fit of Generalized Linear Models are Pearson chi-square and the deviance methods (Abdul Aziz Jemain et al, 2006).

2.10.1.1. Pearson Chi-Square Test

The Pearson chi-square statistics is equivalent to:

$$\sum_i \frac{(y_i - u_i)^2}{\text{var}(y_i)} \dots \dots \dots \text{Equation 2.10.1.1}$$

For an adequate model, the statistics has an asymptotic chi-square distribution with $n - p$ degree of freedom, where n denotes the number of rating classes and p the number of parameters (Ismail N. et al, 2007).

2.10.1.2. Deviance

Generally, the deviance parameter is equivalent to:

$$D = 2(l(y; y) - l(u; y)) \dots \dots \dots \text{Equation 2.10.1.2}$$

Where $l(y; y)$ and $l(u; y)$ are the model's log likelihood evaluated respectively under u and y . For an adequate model, D also has an asymptotic chi-square distribution with $n - p$ degree of freedom. If the values for both Pearson Chi-square and D are close to the degrees of freedom, the model may be considered adequate (Ismail N. et al, 2007).

2.10.1.3. Likelihood Ratio Test

The advantage of using the maximum likelihood method is that the likelihood ratio test may be employed to assess the adequacy of the Negative Binomial I (MLE) or the Generalized Poisson I over the Poisson because both Negative Binomial I (MLE) and Generalized Poisson I (NILE) will reduce to the Poisson when the dispersion parameter, a , equals zero (Ismail N. et al, 2007).

For testing Poisson against Negative Binomial I (MLE), the hypothesis may be stated as

$H_0: a = 0$ against $H_1: a > 0$. The likelihood ratio statistic is,

$$T = 2(l_1 - l_2) \dots \dots \dots \text{Equation 2.10.1.3.}$$

Where l_1 and l_2 are the model's log likelihood under the respective hypothesis.

2.10.1.4. AIC and BIC

A. AIC

When several maximum likelihood models are available, one can compare the performance of alternative models based on several likelihood measures which have been proposed in the statistical literature. Two of the most regularly used measures are the Akaike Information Criteria (AIC) and the Bayesian Schwartz Information Criteria (BIC) (Ismail N. et al, 2007). The AIC is defined as (Akaike, 1973),

$$\text{AIC} = -2l + 2p \dots \dots \dots \text{Equation 2.10.1.4A.}$$

Where l denotes the log likelihood evaluated under mean value and P the number of parameters. For this measure, the smaller the AIC, the better the model is.

B. BIC

BIC is defined as (Schwartz, 1978),

$$\text{BIC} = -2l + p \text{Log}(n) \dots \dots \dots \text{Equation 2.10.1.4B.}$$

Where l denotes the log likelihood evaluated under mean value, p is the number of parameters and n is the number of rating classes. For this measure, the smaller the BIC, the better the model is.

2.10.2. Omnibus Test

Omnibus test is employed to determine the significance of the model from statistical point of view. According to the standard specification, If the p -value is less than 0.05, then researchers have statistically significant model and should continue interpreting the results.

2.10.3. Residuals

Residuals can be thought of as the error associated with predicting or estimating outcomes using predictor variables. Residual analysis is extremely important for meeting the linearity, normality, and homogeneity of variance assumptions of the negative binomial regression. If there are not significant deviations away from 0 and 95%, the residuals are under absolute value of 2.0, then the model is thought to fit the data.

2.10.4. Outliers

Outlier analysis is also used to figure out the presence of irrelevant data samples within the given research data so as to increase the relevancy and significance of the study. Besides, Normality and equal variance assumptions apply to negative binomial (NB) regression analyses. And one way of analyzing the outlier effect is performed by determining the validity of the standardized Pearson residual.

CHAPTER 3 - MATERIAL AND METHODOLOGY

3.1. Introduction

The major aim of this research was to develop an accident prediction model which will be used for identifying accident black spot locations using the prevalent geometric and traffic related explanatory variables in Arterial roads of Addis Ababa. In addition, it aims to propose low cost engineering countermeasures for reducing the frequency of accidents that will be likely to occur due to improper provision of geometric features and traffic characteristics.

Hence, the study was primarily executed for modeling the cumulative effect of those factors on the occurrences of frequent number of accidents. Moreover, the research was executed by employing three principal arterial streets of the Addis Ababa, which has a total length of 13.1 kilometers.

The entire methodology that was adopted for accomplishing the objective of the study was based on: data collection, analysis of accident data, identification of accident blackspot locations, site investigation, identification of the prevalent geometric and traffic characteristics of the road segment, elimination of the non-significant explanatory variables, development of an accident prediction model using generalized linear modeling (GLM) technique, and finally evaluating the model for its goodness of fit.

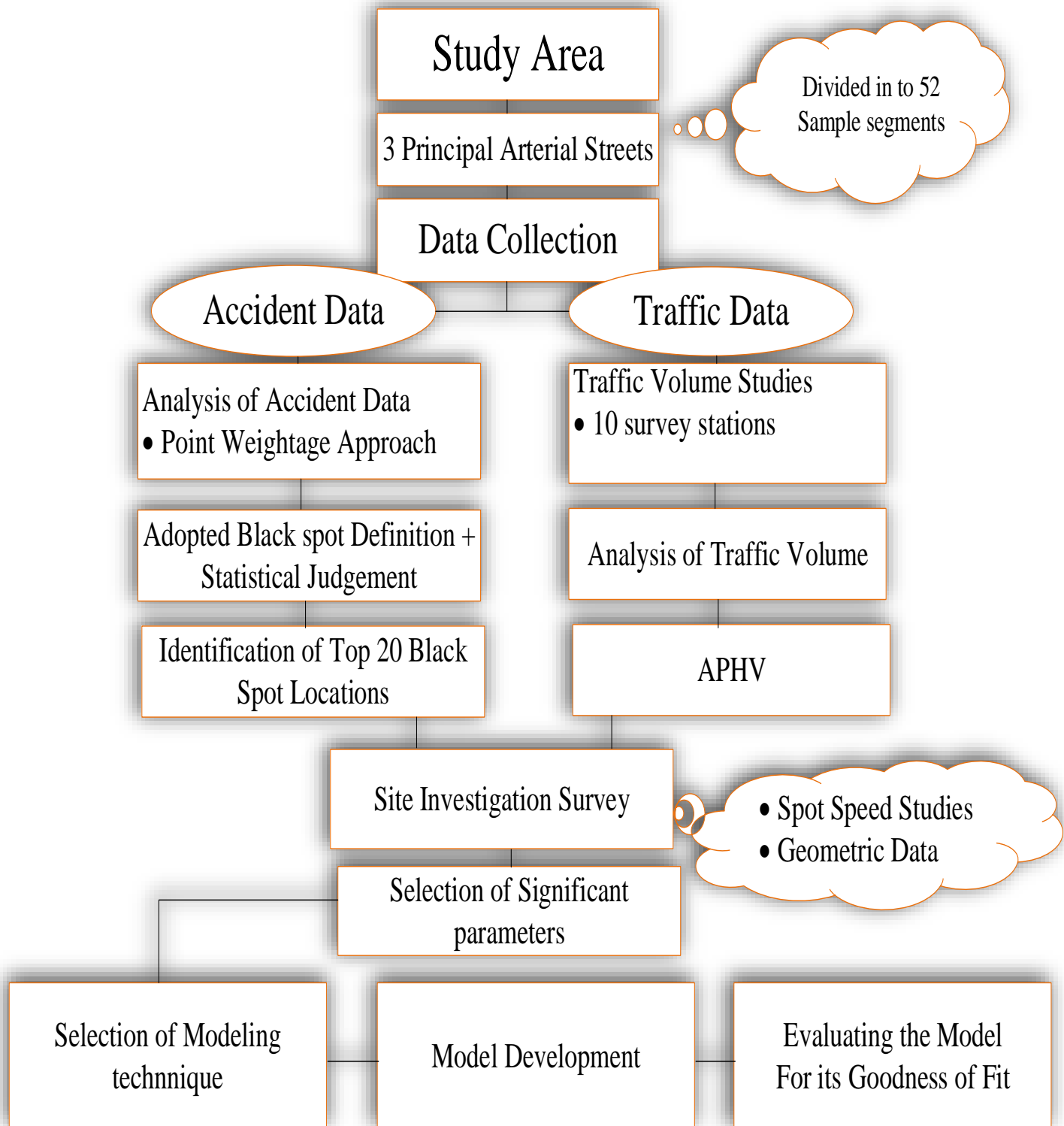


Figure 3-1. Methodology of the Research.

3.2. Study Area

3.2.1. Sampling Method and Procedure

The sampling method of the research was systematic approach where the sample sizes were determined as per the specified criteria that was set on the subsequent section of the paper, section 3.2.2.

3.2.2. Selection Criteria

Generally, it is a rational way to divide the road safety works in to intersection and road section based traffic safety management because there in general are different traffic safety problems and possible measures in intersections and road sections (Sorensen, 2006).

This research was executed on mid-block sections of three principal arterial streets of Addis Ababa and the road segments were selected on the basis of five main criteria. Hence, the basic criteria's which were employed to select the possible road networks include: -

- ✓ The availability of better accident database at the respective police stations compared to other road networks of the city;
- ✓ The potential susceptibility of the road networks to the occurrences of frequent number of accidents.
- ✓ Road networks with functional classification of principal arterial street (Updated road network of AACRA. 2010).
- ✓ Median divided road networks.

3.2.3. Sample Size

As it was stated in the foremost section of the paper, the research samples were selected according to the pre specified criteria which were presented in detail on section 3.2.2. Hence, the sample size of the paper are 52 road segments where they were extracted from three principal arterial streets of the city. Moreover, brief explanation regarding the research samples are presented on the subsequent section, section 3.2.4.

3.2.4. Selected Road Networks

According to the publication of RIPCORDER, (2005), it is highly recommended to select three to five types of roads for preparing relevant accident prediction model. For instance, P. Bahat et. al, (2013) considered three-kilometer-long road stretches for the purpose of developing relevant accident prediction model, where they divided the road section in to ten homogenous sections of 300 meters

each for the purpose of analysis. Similarly, a research by Mustakim, (2005) took a length of 5 kilometer road section along Federal Route No 50 to develop an accident prediction model using multivariate regression analysis. Conversely, this research adopted three principal arterial streets of Addis Ababa where their total length is approximately about 13.1 km long. In addition, each road segment was divided into several sample segments of similar length, i.e. 200 meter.

Due to the differences in engineering concepts, geometric design, traffic pattern and safety provision among intersection and mid-blocks, intersection types such as roundabouts, four-leg junctions etc. were excluded from the study. A study by Berhanu, (2003) also excluded major junctions up to approximately 30 m on approach roads from stop lines due to their influence on the road sections.

The selected road networks of the study were:

- ✓ Africa Avenue (*Bole - Welosefer – Dembel - Meskel-Square*);
- ✓ Mexico Square - AU Square – *Sarbet – Mekanisa Abo – Mekanisa - German Square*;
- ✓ *Sarbet Square – Karl Square – Biserate Gabriel Square – Sost Kutir Mazoria*;

Moreover, according to the recommendation of the state-of-the-art and best practice guideline approach, it is highly recommended to divide the road system in to clearly defined population and length (Elvik, 2007). But the approach experiences a problem in identifying black spots that is local accident peaks might be divided between two segments and thus not identified as a black spot. Conversely, the research finding by other researcher proved that this problem can be handled by reducing the road segment in to smaller section (Haure et al. 2002). Therefore, it is persuasive to divide the selected road networks into manageable and fixed roadway sections or length.

All in all, this research used to make its study by dividing the selected road networks into manageable segments of length, 200 m. Consequently, the reliability and predictive capability of the accident prediction model can be enhanced more.

3.2.4.1. Road Network Descriptions

Generally, the selected road networks are located in the city of Addis Ababa, specifically under the administration of three sub cities such as *Bole, Kirkos* and *Nifas silk*. *Bole – Meskel Square* is a road network which starts from *Bole square* and runs through *Welosefer* and *Dembel* to its final destination, *Meskel square*.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

The road network is 4,300-meter-long, excluding the junction with its effect, the overall studied length became 3000-meter long. Besides, it is under the administration of two sub cities namely *Bole* and *Kirkos* sub city. Specifically, the road network which extends from *Bole* square to Rwanda overpass is situated under *Bole* sub city whereas the network from Rwanda overpass to *Meskel* square fall under the territory of *Kirkos* sub city. Furthermore, the accident history data of the road network was fetched from the stated two sub cities.

Although the road network from Mexico square through AU square, *Mekanisa Abo* square, *Mekanisa* to German square is 6,000 meters in length and it is found under the administration of *Nifas silk* sub city. Furthermore, excluding the intersection along with its influence zone, the entire mid-block length of the road network that was subjected for further study was about 4,200 meters long.

As likely as the second road system, the road network that extends from *Sarbet* through Karl square, *Bisrate Gebriel* to *Sost Kutir Mazoria* is situated in *Nifas silk* sub city and its total length is about 3,100-meter long. In addition, with similar approach as the preceding networks 2,630-meter length of the road section was considered under the study. Table 3-1 below presents the study roads. Subsequently, Figure 3-3, 3-3 and 3-4 illustrate *Bole – Meskel* square, Mexico square – German square and *Sarbet – Sost Kutir Mazoria* road networks respectively.

Table 3-1. The study Road Networks.

Street ID	Street name	Street classification as per AACRA	Total length
BM	Africa Avenue (<i>Bole</i> to <i>Meskel</i> square)	Principal Arterial Street	4,100 meters
MG	Mexico Square to German Square	Principal Arterial Street	6,000 meters
SS	<i>Sarbet</i> square to Carl to <i>Sost Kutir Mazoria</i>	Principal Arterial Street	3,000 meters
Total			13,100 meters

Likewise, the specified road networks are presented through Figure 3-2 to Figure 3-4 accordingly.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Google Maps

Airport Road, Addis Ababa, Ethiopia to Meskel Square,
Addis Ababa, Ethiopia

Drive 4.3 km, 10 min



Figure 3-2. Bole - Meskel square road network. (Source: Google Earth)



Figure 3-3. Mexico square to German square road network. (Source: Google Earth).

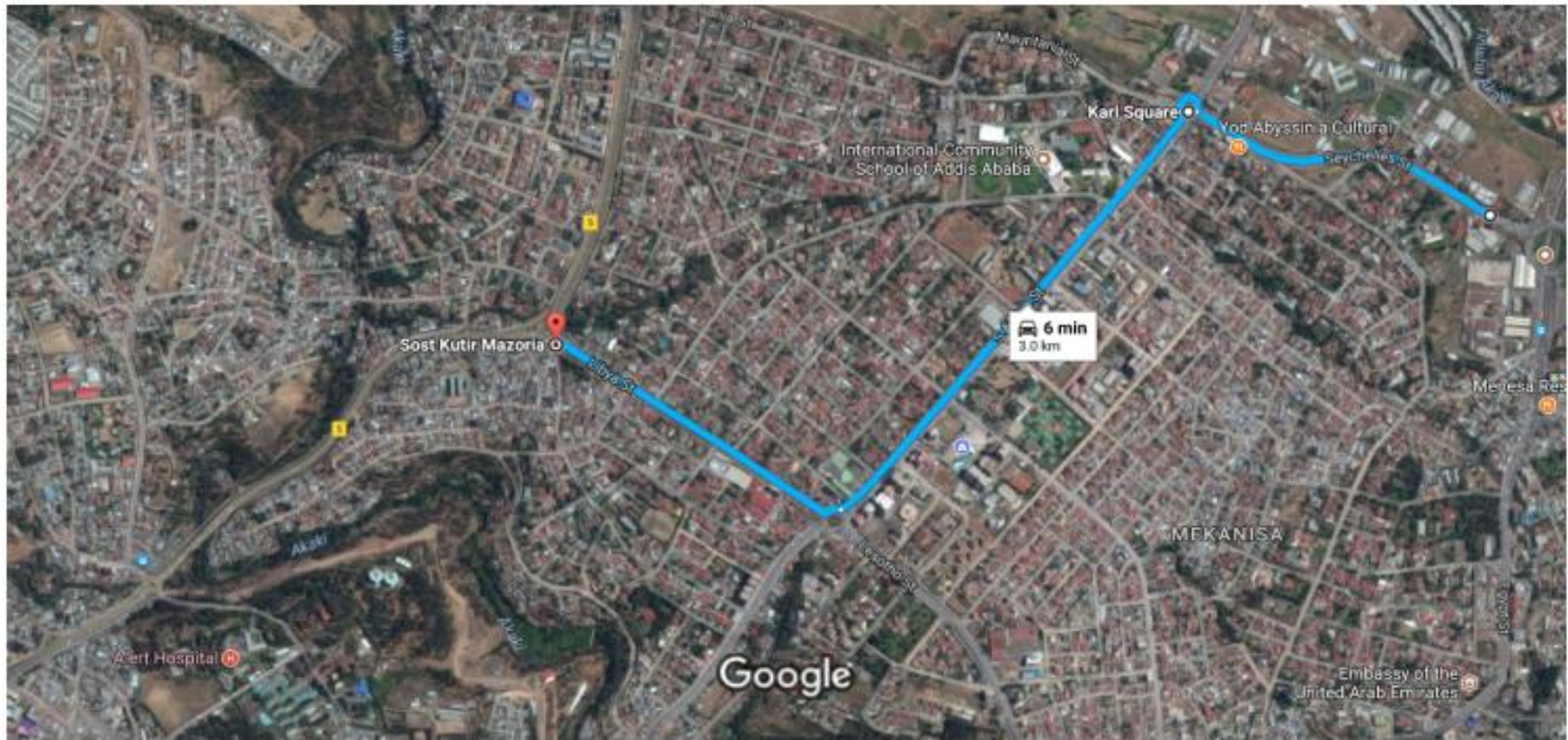
Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Google Maps

8.9953094, 38.7371155 to Sost Kutir Mazoria, Addis Ababa, Ethiopia

Drive 3.0 km, 6 min

Sarbet to Sost Kutir Mazoria



Imagery ©2017 DigitalGlobe, Map data ©2017 Google Global 200 m

Figure 3-4. Sarbet to Sost Kutir Mazoria road network. (Source: Google Earth)

The report of Permit Writers Workshop, (2002) revealed that spot (short roadway) lengths should include the area of influence around a hazard. Besides, the accident analysis should be considered separately on mid-blocks and intersections of road networks. For instance, the analysis of intersections should include all accidents that occur within a specified radius of 250 feet, from the center of the intersection. Driveway accidents occurring within 250 feet or 76 meters from the center of an intersection should, therefore, be included in the count of accidents for that intersection. Logically, it should be the stopping sight distance, plus the queue length at intersections (Valerian Kwigizile.et.al, 2013).

On the other hand, analysis of accident with in the mid-block sections should exclude all accidents that occur at intersections along with its influence zone where it extends up to 76 m from the center of intersection. Hence, the effect of the intersections on the mid-blocks were assumed to be handled in a relevant manner. Figure 3-5 illustrates the influence zone of an intersection.

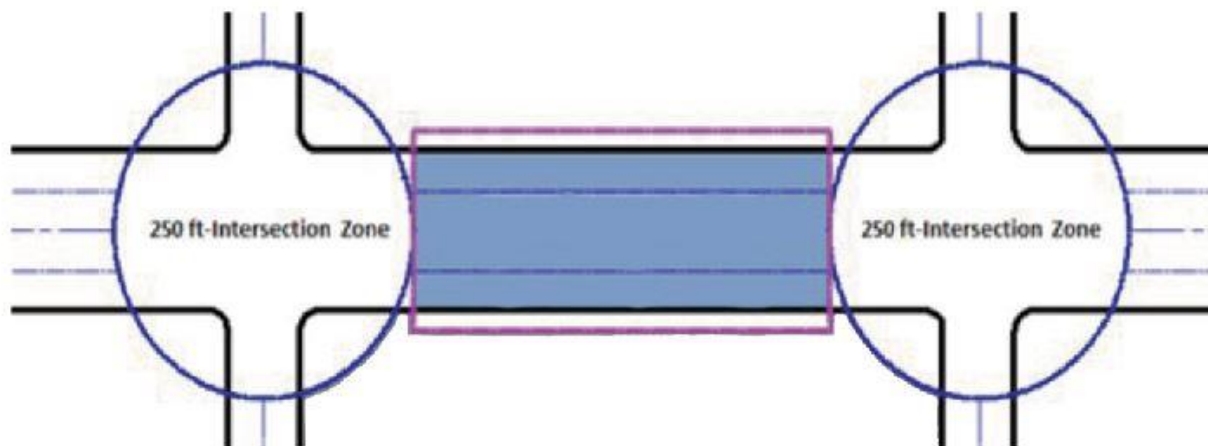


Figure 3-5. Influence Zone of an Intersection.

Source: Valerian Kwigizile.et.al, (2013).

The selected mid blocks incorporate different road features and geometric designs. Where road layout comprises straight road section, horizontal and vertical curves while geometric features encompass various types and sizes of median width, U-turn, walkway width, lane width, lane number etc.

3.3. Road Network Classification

Generally, division of the road sections in to road segments of the specified length, particularly smaller lengths will enhance the predictive ability and reliability of the prediction model. Thus, the roadway network can be divided in to spots and/or segments. Isolated curves, mid-blocks, bridges, and intersections are examples of spot locations. A study made by two scholars also revealed that classification of the road networks in to segment sections and intersections should be executed prior to identifying the black spot locations (Vistisen 2002, Overgaard Madsen 2005).

A comprehensive review paper by Elvik R., (2007) also concluded that it is advisable to divide the road systems in to smaller roadway elements (Elvik. R, 2007). However, there exists a problem while dividing the road segment in to non-overlapping sections, which in particular is a risk that the division will not correspond to the accident pattern. Besides, the accident peaks might also be divided between two segments and not identified as a black spot. However, the study by Hauer et.al disclosed that this issue will be responded well by adopting smaller road segment length (Hauer et al. 2002). Additionally, best practice guidelines recommended that, division of roadway elements for black spot analysis should not be greater than 0.5 km (Sorensen, 2007).

P. Bahat et. al, (2013) employed the stated approach in to their study where they used to divide 3 kilometer road stretches in to ten homogenous sections of 300 meters each for the purpose of making Black spot analysis. Segments are typically defined by a particular length (e.g., 300 feet, 0.1-mile, 1.0 mile, etc.) or as the section of highway between two defined spots (Analysis of Accident Statistics, Permit Writers Workshop). Therefore, on the basis of the above stated explanations, the study road networks were divided in to segment length of 200 meters. Additionally, the classification of mid-blocks in to the specified segment length was accomplished by the integrated effort of site investigation survey and Google earth Software package.

Moreover, the road network which extends from *Bole* through *Welosefer*, and *Dembel* to *Meskel* square comprises 20 road segments. From which three sections encompasses intersections while 17 segments are mid-blocks of different layout such as straight segment and curved features. Correspondingly, the road network from Mexico square to German square were divided in to a total of 24 segments. All in all, 21 road segments were fall under the scope of the research while three segments were excluded from the study owing to their nature, i.e they are intersections.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Furthermore, the road system which runs from *Sarbet* through Carl Square to *Sost Kutir Mazoria* was classified in to 16 road segments among which two of them are intersections. Conversely, 14 road segments were adopted for making further analysis. All in all, the entire sample segments which were subjected to the study encompass 52 segments. Table 3-2 below shows the selected principal arterial streets along with their divided sections.

Table 3-2. Selected road networks along with their coding.

Network ID	Road section	Total length (km)	Study length (km)	Segment length (km)	No of divided segment	Number of Execluded intersections
BM	Africa Avenue	4.1	3.0	0.2	20	3
MG	Mexico Square – German Square	6.0	4.2	0.2	24	3
SS	<i>Sarbet – Sost Kutir Mazoria</i>	3.0	2.63	0.2	16	2
Total		13.1	9.83		60	8

Furthermore, the respective divided road sections of the selected road networks are presented accordingly through Table 3-3 to 3-5.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 3-3. Classified road segments of *Bole* - Meskel square Road network.

Network ID	Starting point	End point	length	Description
BM01	<i>Bole</i> NOC	Millenium Hall Entrance	200 m	
BM 02	Millenium Hall entrance	Snap plaza	200 m	
BM 03	Snap plaza	Senegal residential	200 m	
BM 04	Senegal residential	Garden Court bar and restaurant	200 m	
BM 05	Garden Court bar and restaurant	<i>Fantu</i> Supermarket	200 m	
BM 06	<i>Fantu</i> Supermarket	Werbek House	200 m	
BM 07	Werbek House	<i>Mulmul</i> Bakery (Bole)	200 m	
BM 08	<i>Mulmul</i> Bakery (Bole)	<i>Muller</i> Real state	200 m	
BM 09	<i>Muller</i> Real state	Dashen Bank SC	170 m	
BM 10	Dashen Bank SC	Rodeo Restaurant	380 m	Intersection + Underpass
BM 11	Rodeo Restaurant	<i>Sabit</i> Building	200 m	
BM 12	<i>Sabit</i> Building	Sangam Indian Restaurant	200 m	
BM 13	Sangam Indian Restaurant	#2 Pelican Pharmacy	200 m	
BM 14	#2 Pelican Pharmacy	<i>Getu</i> Commercial	200 m	
BM 15	<i>Getu</i> Commercial	City café	150 m	
BM 16	City café	EIC	330 m	Intersection + Underpass
BM 17	EIC	Oromia State Council	200 m	
BM 18	Oromia State Council	Sunshine Laundry	200 m	
BM 19	Sunshine Laundry	Martyrs Memorial Museum	200 m	
BM 20	Martyrs Memorial Museum	<i>Meskel</i> square	70 m	Intersection
Total length			4,100 m	

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 3-4. Classified road segments of Mexico Square - German Square Road network.

Station	Starting point	End point	length	Description
MG 01	EEPCO	Shell	200 m	
MG 02	Shell	<i>Tiyet Fabrica</i>	200 m	
MG 03	<i>Tiyet Fabrica</i>	National Tobacco & Matches	200 m	
MG 04	National Tobacco & Matches	Metec	200 m	
MG 05	Metec	<i>Hossa Pharmacy</i>	200 m	
MG 06	<i>Hossa Pharmacy</i>	DHL	350 m	Intersection
MG 07	DHL	International Evangelical Church	200 m	
MG 08	International Evangelical Church	<i>Idget Cotton Factory</i>	500 m	Intersection + Underpass
MG 09	<i>Idget Cotton Factory</i>	Menesa Restaurant	200 m	
MG 10	Menesa Restaurant	NIB	200 m	
MG 11	NIB	Indonesia Embassy	200 m	
MG 12	Indonesia Embassy	<i>Mela Building</i>	200 m	
MG 13	<i>Mela Building</i>	Embassy of UAE	200 m	
MG 14	Embassy of UAE	Mekane Eyesus Church	200 m	
MG 15	Mekane Eyesus Church	Peace Bui'g	350 m	Intersection
MG 16	Peace Bui'g	<i>Mekanisa Market</i>	200 m	
MG 17	<i>Mekanisa Market</i>	<i>Mekanisa Primary School</i>	200 m	
MG 18	<i>Mekanisa Primary School</i>	<i>Awash wine</i>	200 m	
MG 19	<i>Awash wine</i>	<i>Ethiopia Areke Factory</i>	200 m	
MG 20	<i>Ethiopia Areke Factory</i>	D.A Packaging PLC	200 m	
MG 21	D.A Packaging PLC	Joint Language school	200 m	
MG 22	Joint Language school	Ethiopian Revenue Authority	200 m	
MG 23	Ethiopian Revenue Authority	Baker Patesserie	200 m	
MG 24	Baker Patesserie	<i>Girma Bul'g</i>	200 m	
Total			5,400 m	

*Identification and Countermeasures of Accident Black Spot Locations Using
Statistical Modeling (A Case Study of Addis Ababa)*

Table 3-5. Classified road segments of Sarbet – Sost kutir mazoria Road network.

Station	Starting point	End point	length	Description
SS 01	<i>Idget Cotton Factory</i>	<i>Tomoca Coffee</i>	200 m	
SS 02	<i>Tomoca Coffee</i>	<i>Queens Bakery</i>	200 m	
SS 03	<i>Queens Bakery</i>	<i>Dodi Restaurant</i>	200 m	
SS 04	<i>Dodi Restaurant</i>	<i>Habesha Fashion</i>	200 m	
SS 05	<i>Habesha Fashion</i>	<i>Right Fresh Farm</i>	196 m	Intersection
SS 06	<i>Right Fresh Farm</i>	<i>Africana Bar and Restaurant</i>	150 m	
SS 07	<i>Africana Bar and Restaurant</i>	<i>Tivoli Restaurant</i>	200 m	
SS 08	<i>Tivoli Restaurant</i>	<i>INSA</i>	200 m	
SS 09	<i>INSA</i>	<i>St. Biserate Gebriel church</i>	200 m	
SS 10	<i>St. Biserate Gebriel church</i>	<i>Planet Cheese</i>	200 m	
SS 11	<i>Planet Cheese</i>	<i>Shoa Supermarket</i>	200 m	
SS 12	<i>Shoa Supermarket</i>	<i>EPHRAM</i>	119 m	Intersection + IZ
SS 13	<i>EPHRAM</i>	<i>Norwegian Residence</i>	200 m	
SS 14	<i>Norwegian Residence</i>	<i>Dima Cultural Restaurant</i>	200 m	
SS 15	<i>Dima Cultural Restaurant</i>	<i>Das Meda Restaurant</i>	200 m	
SS 16	<i>Das Meda Restaurant</i>	<i>Sost Kutir Mazoria</i>	95 m	
Total			2,630 m	

3.3.1. Accident Data

Data on road traffic accident were obtained from the respective police departments and AAPC. According to the analysis of Accident Statistics Guide by Permit Writers Workshop (2002), accident data for the most recent 1 to 3-year period is normally used and is generally sufficient. A study by two researchers, Cheng and Washington, (2005), also proved that the length of period which is used to identify black spots varies from one year to five years but a period of three years is frequently used. In addition, they also proved that the gain in the accuracy of identification obtained by using a longer period of three years is marginal and declines rapidly as the length of the period is increased.

Having the above stated reasoning's in mind, three years of accident data (January 1, 2014 - January 1, 2017) were obtained from the police department stations for performing the traffic accident analysis where they provided information regarding severe injury, slight injury, and property damage only (PDO) related accidents. Conversely, three years of fatal accident data along the study area and six-years of statistical accident data of the city were obtained from Addis Ababa Police Commission (AAPC). Moreover, since the statistical accident data at the police stations lacks quality in describing the specific location where particular accident occurs, additional information was obtained by referring supplementary information from individual accident investigation files documented for prosecuting the offender in accidents.

Moreover, the collected accident data comprises information on accident time, accident date, accident feature, demographic history of pedestrian who was a victim of an accident (except for PDO type of accident), the type of vehicle involved in particular incident, and the particular locations where the accident occurs. Statistically speaking, a total of 2,497 accidents were recorded along the entire mid-blocks of the selected road networks for a period of 3 years. Among which 48 accidents were fatal types while accidents which results in severe injury, slight injury and PDO level of severity are 162, 174 and 2,113 respectively.

3.3.1.1. Collected Accident Data Along the Road Networks

The entire accident data that were obtained from the respective police departments and AAPC were registered appropriately on the prepared database according to their level of severity. And sample manual and computer coded accident data along *Bole – Meskel* square are presented on [Appendix A.1](#) and [Appendix A.2](#), respectively.

3.3.2. Traffic Data

The traffic data which were employed to execute the analysis of the research comprises two major parameters which are namely traffic volume (the average peak hour traffic volume, APHV) and the 85th percentile spot speed. The chosen data collection procedures of these two parameters is described in the following subsequent sections.

3.3.2.1. Traffic Volume

Traffic volume is one of the most important factors in crash data analysis. This is due to the fact that zero traffic volume means no crashes whereas the more the number of vehicles on the road, the more chances there are of a crashes. Studies have shown that AADT of the road networks have a significant effect on crash frequency (Vogt, 1999; Greibe, 2003; Pei et al., 2011; Chiou, 2013; Meng and Qu, 2012b). In addition, many researchers also disclosed that traffic volume is the most commonly adopted and persuasive parameter that should be included in any accident prediction model (Kalokota and Seneviratne, (1994), Golob and Recker, (2003), Mustakim et al, (2005), Hauer, (2004), Hong et al, (2005)).

Therefore, as per the reviewed literatures and subjective engineering judgement, this research considered the traffic volume parameter (AHTV) among with the prevalent explanatory variables that were presumed to explain the occurrences of frequent number of accidents along the selected road networks.

The major purpose of making traffic volume studies is to identify the peak hour volume. And for any traffic infrastructure design and accident study peak hour traffic volume is necessary. In addition, the selection of study method should be determined using the count period, in which duration of count depends on the objective of data collection. The study by Sanchari Halder, et.al (2013) mentioned that short duration count at peak period is conducted for traffic control and

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

management or operational studies whereas it is advisable to make long duration count for planning and design purpose (Sanchari Halder, et.al, 2013).

Moreover, the count period should be representative of the time of day, day of month, and month of year for the study area. The count period should avoid special event or compromising weather conditions (Sharma 1994). And the traffic count periods may range from 5 minutes to 1 year. Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday and afternoon peaks, and 12 hours for daytime periods (Smith D. et al, 2002).

For instance, two Indian researchers made their study on identification and improvement of black spot locations by adopting four-hour traffic volume count where the peak hour traffic volume was found from the traffic analysis made on all spots in terms of Passenger Car Unit (PCU) (Rakesh Saini et al, 2015). In addition, a study by Mustakim, (2005) took 6-hour traffic count at Pintas Punding for one day. Besides, he used to fetch the required peak hour volume for incorporating the parameter in the final accident prediction model where separated two-hour traffic volume count was made for the morning, mid-day and evening peak.

In the context of this research, manual traffic counting method was adopted for executing the traffic studies where it was further used to gather data for determination of vehicle classification, direction of travel and vehicle occupancy. In addition, it has been preferred to the other methods due to the limitation of time and resources. Besides, two days of traffic study (which is on the presumed representative week days i.e on Tuesday and Thursday) were carried out at a total of 10 traffic survey stations along the selected routes. Four of them were conducted along Mexico square to German square while three stations were positioned along both '*Bole*' to '*Meskel*' square, and '*Sarbet*' to '*Sost kutir mazoria*'. Moreover, the selected survey stations were located at intermediate mid-blocks between intersections. Furthermore, the specific counting locations were selected as per the Guidelines for Traffic Data Collection and Analysis of Botswana (Traffic Data Collection and Analysis, 2004).

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

The proposed criteria were:

- ✓ The road section should have uniform geometric characteristics along the road length and be away from junctions;
- ✓ Location should be on a horizontal (flat) and geometrically straight road section; and
- ✓ Section of the road to have an uninterrupted traffic flow.

Thus, the traffic count follows classified counts approaches where it has been carried out for 15-minute interval using the prepared Tally sheet. In addition, the vehicle classifications, that was chosen to make the relevant traffic volume studies, was adopted from the brake down approved by ERA. The employed vehicle classification is presented accordingly in Table 3-6 below.

Table 3-6. Vehicle Classification.

Vehicle code	Types of vehicles	Descriptions
1	Small cars	Passenger cars, minibuses (up to 24-passenger seats), taxis, pick-ups, and Land Cruisers, Land Rovers, etc.
2	Buses	Medium and large size buses above 24 passenger seats
3	Medium trucks	Small and medium sized trucks including tankers up to 7 tons load
4	Heavy trucks	Trucks above 7 tons load
5	Articulated trucks	Trucks with trailer or semi-trailer and Tanker Trailers

(Source: ERA pavement design manual: - chapter 2)

The traffic studies were conducted on the previously specified survey stations on 2nd, 4th, 9th, 11th, 16th and 18th of May, 2017 where the first two consecutive days were spent to conduct the traffic studies along *Bole-Meskel* square road network. Whilst, the subsequent separate two days were used to perform the required traffic studies along Mexico square – German square, and *Sarbet – Sost Kutir Mazoria* respectively. Further, the difficulty in managing simultaneous traffic volume counts on the entire survey stations along the selected routes forced the research to make the traffic studies on similar days of different weeks.

For instance, the traffic count along *Bole* to *Meskel* square was executed on Tuesday and Thursday of the first week while the count along the remaining two road networks were computed on similar days of the consecutive two weeks. Moreover, the traffic volume counts were made for a period of 6 hours a day where separate 2-hour continuous count were made for the morning, mid-day, and afternoon peak on both directions of travel (North and South bound) where consecutive eight 15 minute counts were performed for acquiring the required traffic volume within the individual peak hours.

Besides, eight individuals were involved to record the traffic count along the selected routes. Furthermore, the presumed time interval for the morning, mid-day and afternoon peaks were between 7:00 A.M – 9:00 A.M, 12:00 P.M – 2:00 P.M and 4:00 P.M – 6:00 P.M respectively. Sample traffic count at survey Station 1 (Friendship Business Center) along *Bole – Meskel* square road network is presented on [Appendix A.3](#). The detailed traffic volume studies at the specified survey stations of the selected road networks are presented in three separate topics as follows: -

A) Bole to Meskel square

The road network from *Bole* to *Meskel* square is an urban principal arterial road that has a total length of 4,300 meters. In addition, it belongs under the administration of *Bole* and *Kirkos* sub cities. The road network is composed of two roundabouts (*Welosefer* and *Olompiya*), straight segments, curved features, two underpass sections which extends through *Welosefer* and *Olompiya* roundabouts.

Moreover, the relevant survey stations which were adopted for making the traffic studies were located between intersections. Since the research scope is limited to mid-block sections of the road network, the two roundabouts were excluded from the consideration of the study along with their influence zone. Therefore, the total length of the midblock sections that was subjected under the consideration of the study was about 3,320 meters long. Generally, as it was mentioned in the preceding section, three survey stations were selected along the entire road network for making the required traffic studies, which in particular are situated at Friendship business center, Infront of Bole Printing press, and Infront of Sunshine Laundry respectively. Besides, the selected survey stations are presented accordingly through Figures 3-6 to 3-8.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

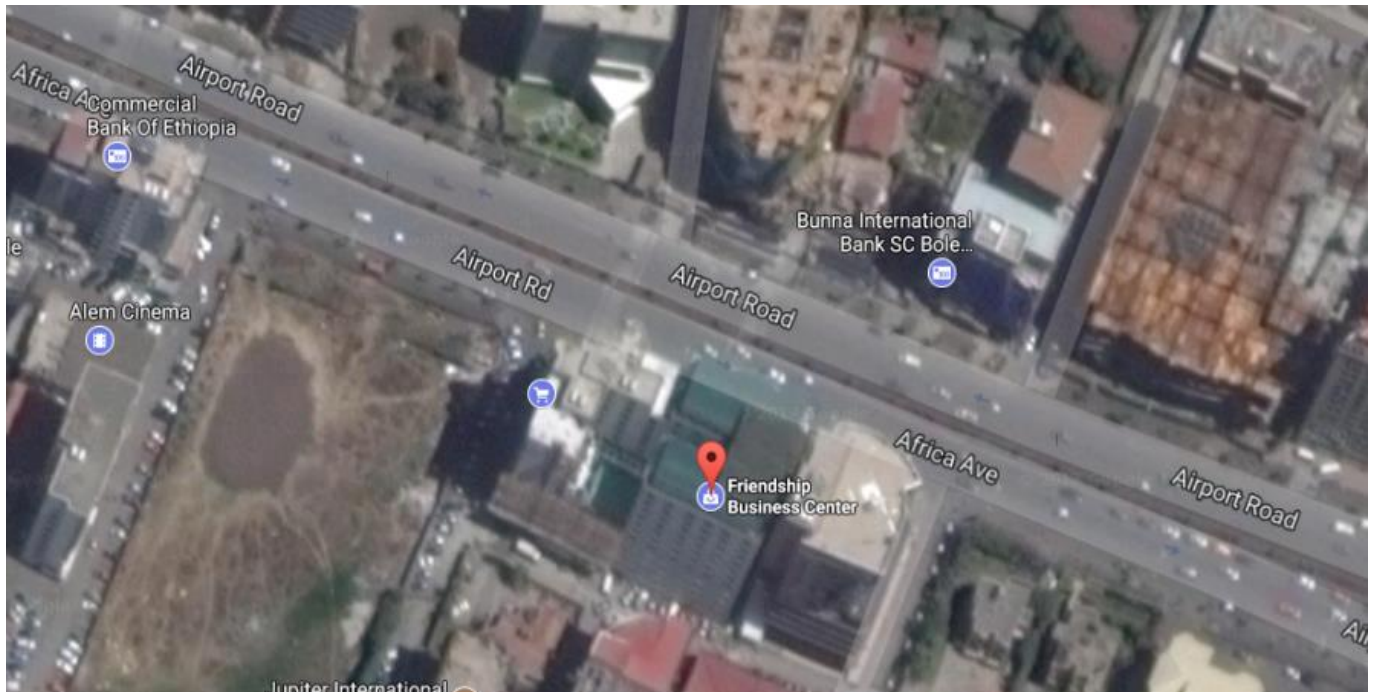


Figure 3-6. Traffic Counting Station 1 Infront of Friendship Business Center.



Figure 3-7. Traffic Counting station 2 @ Bole Printing Press.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)



Figure 3-8. Traffic Counting station 3 @ Sunshine Laundry.

As it can easily be noticed from Table 3-7, maximum traffic volume was recorded at the evening peak between 5:00 A.M - 6:00 P.M, which has a total volume of 4,669 PCU. The maximum fifty-minute traffic volume was also recorded at the evening peak, that is equivalent to 1,191 PCU. Subsequently, the maximum adjusted average peak hour volume of the two days' count will be subjected to the modelling process. The procedure that was followed to compute the maximum adjusted average hourly traffic volume is described later on section 4.2.2.1.

*Identification and Countermeasures of Accident Black Spot Locations Using
Statistical Modeling (A Case Study of Addis Ababa)*

Table 3-7. Summarized Directional Volume Counts at Friendship Business Center (Day 1).

Station ID: - Section 1					
Date: - May 2nd, 2017		The Maximum Traffic Volume is 4669 between 5:00 - 6:00			
Tuesday					
	Direction				
Time	South bound	North bound	Total	Max 15-minute traffic volume	Hourly Sum
07:00 - 07:15	419	428	847	1191	
07:15 - 07:30	508	450	958		
07:30 - 07:45	521	510	1030		
07:45 - 08:00	578	575	1153		3988
08:00 - 08:15	511	554	1065		
08:15 - 08:30	556	441	997		
08:30 - 08:45	537	527	1065		
08:45 - 09:00	454	491	945		4070
12:00 - 12:15	443	447	890		
12:15 - 12:30	517	469	986		
12:30 - 12:45	548	513	1060		
12:45 - 01:00	541	460	1001		3936
01:00 - 01:15	485	498	983		
01:15 - 01:30	543	437	981		
01:30 - 01:45	448	470	918		
01:45 - 02:00	462	514	976		3857
04:00 - 04:15	551	559	1110		
04:15 - 04:30	493	558	1051		
04:30 - 04:45	497	518	1015		
04:45 - 05:00	586	472	1058		4235
05:00 - 05:15	573	556	1129		
05:15 - 05:30	665	519	1184		
05:30 - 05:45	715	476	1191		
05:45 - 06:00	632	534	1165		4669
Total	12781.3	11973.6			

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

B) Mexico Square – German Square

This road network is composed of four roundabouts, straight sections, horizontal and vertical curves, and its total length is approximately 6,000 meters. Among all, 4,200 meters of road network was considered under the analysis of the study for preparing the relevant accident prediction model. As it was explained on the previous section, four counting survey stations were located along the route.

Thus, the particular positions of the stations were located at National Tobacco Enterprises, International Evangelical Church (IEC), Vatican Embassy, and lastly at *Mekane Eyesus* Management and Jazz School. The selected traffic survey stations are presented through Figure 3-9 to 3-12 as follows.



Figure 3-9. Traffic Counting station 1 @ National Tobacco and Matches Corporation.



Figure 3-10. Traffic Volume Counting station 2: Infront of International Evangelical Church.



Figure 3-11. Traffic Volume Counting station 3: Infront of Vatican Embassy.

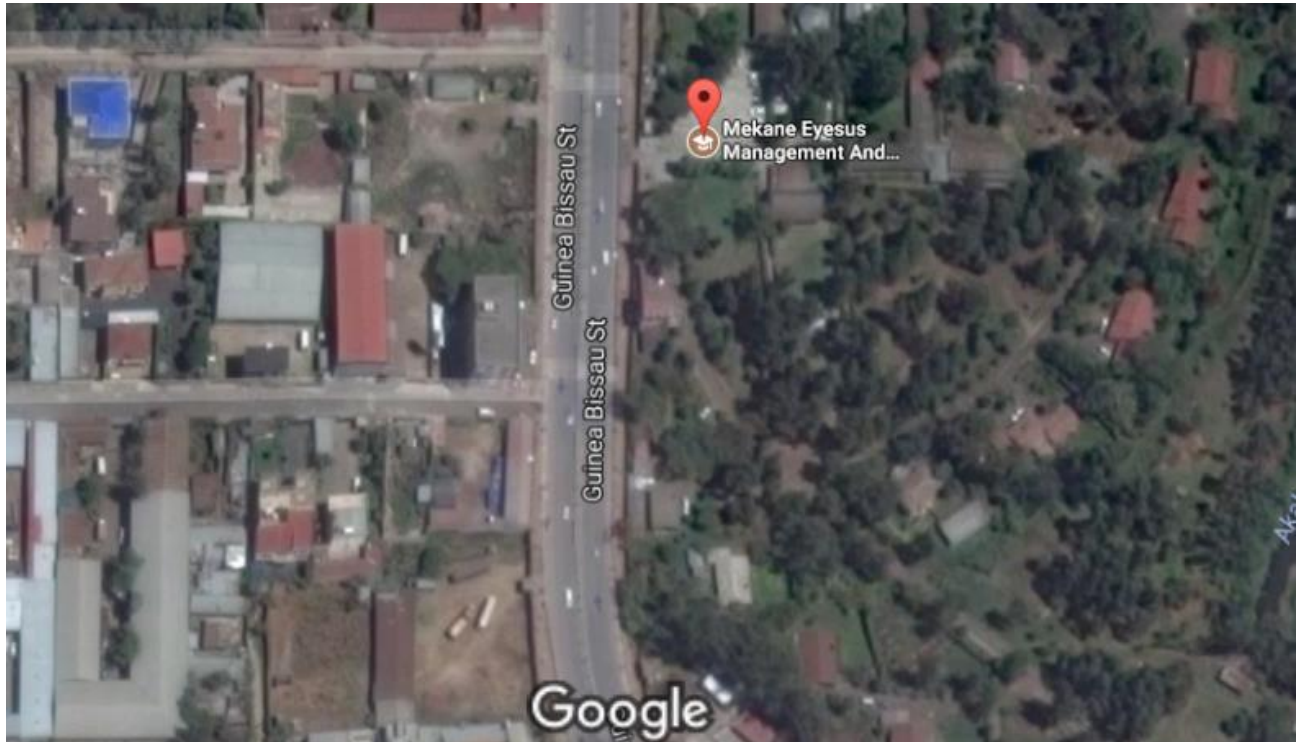


Figure 3-12. Traffic Volume Counting Station 4: Infront of Mekane Eyesus Management School.

C) *Sarbet – Sost Kutir Mazoria*

This road network extends from *Sarbet* through Karl square to *Sost Kutir Mazoria* and it has a total length of about 3,100 meters. In addition, as of the second road network, it falls under the administration of Nifas silk Sub-city. In addition, 2,630 meters of road segment were extracted as a relevant study area of the research and as of *Bole to Meskel* square road section, this segment is also characterized by having three traffic counting survey stations. The selected survey stations were located at *Tomocca* Coffee House, Embassy of Austria, and *Dimma* Cultural Restaurant. Furthermore, pictorial illustration of the selected survey stations is presented accordingly through Figure 3-13 to 3-15.



Figure 3-13. Traffic Volume Counting Station 1 @ Tomoca Coffee house.



Figure 3-14. Traffic Volume Counting Station 2 @ Embassy of Austria.



Figure 3-15. Traffic Volume Counting Station 3 @ Dimma Cultural Restaurant.

3.3.2.2. Spot Speed Studies

Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. In addition, it is used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. The eighty - fifth percentile speed is the most commonly and frequently adopted parameter that is used to develop the suitable accident prediction model. Moreover, it was found the significant explanatory variables in the study of the following scholars; Kalokota and Seneviratne, (1994); Mustakim et al, (2005); Hauer, (2004); and Hong et al, (2005). For a spot speed study at a selected location, a sample size of at least 50 and preferably 100 vehicles are usually obtained (Ewing 1999). The data could be gathered using one of the following three methods: (i) stopwatch method, (ii) radar meter method, or (iii) pneumatic road tube method. Owing to its quickest application and economic feasibility, the spot speed studies were made on the selected black spot locations using the stopwatch method. The data collection and the analysis were performed by using the following procedures (as stated by Smith et al. (2002)).

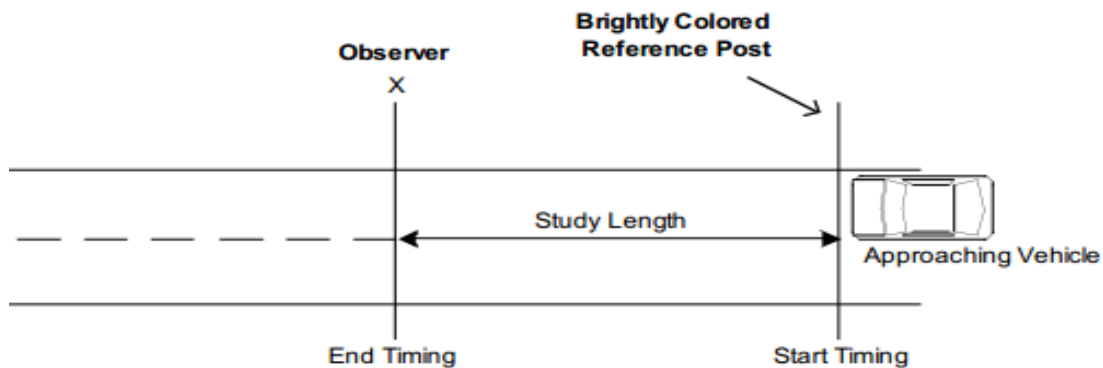


Figure 3-16; Stopwatch Spot Speed Study Layout.
Source: Handbook of simplified practice for traffic studies, (2002).

- I. Two ropes which extends to the entire width of the traffic lane were placed at the beginning and end points of the selected study road length. Besides, the spot speed study length was selected based up on the recommendation made by Smith, and McIntyre, (2002). Since the average speed of the selected road sections was within 40-64.4 Km/hr, the relevant road stretch for making the required spot speed studies was taken as 53.6 meter. Moreover, the recommended spot speed study length for the respective speed ranges are presented in Table 3-8 below.

Table 3-8. Recommended spot speed study length

Traffic Stream Average Speed (km/hr)	Recommended Study Length (m)
Below 40 km/hr	26.8
40 – 64.4 km/hr	53.6
Above 64.4 km/hr	80.5

- II. Record the observation on the stopwatch using the prepared format for the respective type of vehicle;
 - III. The speeds of each vehicle will be computed; and
 - IV. Lastly the frequency distribution table and speed percentiles would be computed.
- Furthermore, the spot speed data at the identified black spot locations were gathered through the prepared standard format. And the adopted spot speed study registration format is attached in advance on [Appendix A.5](#).

3.3.3. Geometric Design Data

As it was previously explained in the literature part of this paper, geometric designs of the road networks were frequently mentioned among with the other causative factors of road traffic accidents. In addition, they were adopted for making the relevant accident analysis and also to develop accident prediction model on many studies by various scholars such as Kalokota and Seneviratne, (1994), Hong et al., (2005), Shankar et al., (1995) etc. Thus, on account of the reviewed literatures and subjective engineering judgment, geometric parameters of the selected road networks were presumed to be the prevalent traffic accident causative factors.

The geometric designs of the road segments were principally gathered from site investigation and it generally consists of the prominent variables that are presumed to have significant effect on causing a number of traffic accidents such as road layout (straight segments or curved features), number of lane in each direction, lane width, average walkway width, average median width, availability of U-turn and number of access points. In addition, the geometric characteristics of the divided segments along the selected road networks were collected using the prepared checklist. The adopted format with sample filled data at one of the segment along Bole to *Meskel* square (BM 07) is attached in [Appendix A.6](#). Moreover, the summarized geometric data of the entire black spot locations are presented in Table 3-9 below.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Table 3-9. Summarized Geometric Data of the Entire Black Spot Locations.

Station ID	Road Layout (RL)	Lane No / direction (LN)	Lane width (LW) (m)	Average Walkway width (AWW) (m)	Average Median width (AMW)(m)	No of Access Point (NAP)	Availability of U Turns (AUT)
BM 03	Straight segment	4	3.6	4.83	2.90	1	No
BM 04	Horizontal curve	4	3.6	4.90	2.90	1	No
BM 07	Straight segment	4	3.6	4.95	2.90	3	No
BM 08	Straight segment	4	3.6	4.95	2.90	3	No
BM 11	Straight segment	4	3.6	4.70	1.50	0	No
BM 12	Straight segment	4	3.6	4.95	2.90	1	No
BM 13	Horizontal curve	4	3.6	4.70	1.50	2	Yes
BM 14	Straight segment	4	3.6	4.95	2.90	2	No
BM 18	Straight segment	4	3.6	4.95	2.90	2	No
MG 07	Horizontal curve	3	3.6	3.95	1.40	1	Yes
MG 11	Horizontal curve	3	3.6	4.45	0.90	1	Yes
MG 14	Horizontal curve	3	3.6	4.50	0.85	0	No
MG 17	Horizontal curve	3	3.6	3.95	0.60	0	Yes
MG 18	Horizontal curve	3	3.6	3.95	4.10	0	No
MG 20	Horizontal curve	3	3.6	4.25	0.90	1	No
MG 22	Straight segment	3	3.6	4.25	0.90	2	Yes
SS 07	Straight segment	3	3.6	4.45	0.90	0	No
SS 09	Straight segment	3	3.6	4.45	0.90	2	Yes
SS 13	Straight segment	3	3.6	4.35	0.90	2	Yes
SS 14	Straight segment	3	3.6	4.35	0.90	2	Yes

CHAPTER 4 - ANALYSIS AND RESULT

4.1. Introduction

Primarily, this section presented with the detailed analysis of both primary and secondary data where primary data analysis dealt with computation and organization of data acquired from site investigation survey such as traffic volume studies, spot speed studies and geometric data analysis. Whereas, secondary data analysis dealt with the detailed analysis of accident pattern along the study areas. Subsequently, black spot locations along the selected road networks were identified through the integrated effort of the adopted black spot definition and subjective statistical decisions using the analysis of accident data.

Consequently, the prevalent geometric and traffic explanatory variables were selected based on their significant effect on causing frequent number of accidents. The procedure and analysis that was employed to extract the model parameters are explained under this section. Moreover, the next sub topic discussed regarding the major concepts and justifications which were employed to select the appropriate modeling technique for fitting the given data. Consecutively, estimation methodology of the selected model was explained in detail under the sub topic of parameter estimation where it was followed by the procedure and results of the accident prediction model. In conclusion, the two successive sections of the Chapter deals with the discussions and assessment of the model for its goodness of fit respectively.

4.2. Analysis of Collected Data

As it was explained in chapter three of the paper, the research data were collected from primary and secondary data sources. Besides, the entire analysis of the research was performed by analyzing the gathered data in an independent and subsequent manner. Thus, primarily the secondary data, i.e the accident data was analyzed to figure out the black spot locations that were susceptible to the occurrences of frequent number of accidents. Then, the primary data were analyzed on the basis of the output of the accident data analysis. Moreover, analysis of primary data was executed under two separate sections such as traffic volume analysis [computation of adjusted average peak hour volume (APHV)] and spot speed analysis (determination of 50th and 85th percentile spot speeds).

4.2.1. Analysis of Secondary Data

This section involves the analysis of traffic accident data using the data obtained from the respective police stations, and Addis Ababa Police Commission (AAPC). Hence, the collected accident data were sorted out and coded relevantly according to the specific location of the mid-block sections. Then, it was analyzed to determine the accident pattern of the studied locations. Moreover, the accident pattern of the selected road networks was analyzed in terms of temporal variation, accident cause, type of collision, vehicle type and accident location. Consequently, the analyzed accident data along *Bole-Meskel* square, Mexico square – German square, and *Sarbet - Sost kutir mazoria* are summarized and presented accordingly under three consecutive sub topics.

4.2.1.1. Accident Analysis of *Bole-Meskel* square

Generally, the road network from *Bole – Meskel* square had experienced a total of 1, 252 accidents with in a period of three years i.e. from January 1, 2014 to January 1, 2017. Besides, the number of fatal, severe, slight and PDO types of accidents were 24, 71, 58 and 1,099 respectively. Moreover, the accident pattern along the road network is presented subsequently in terms of detailed temporal variation, accident cause, collision type, vehicle type involved in particular incident and locations of accident occurrence.

A) Accident number Vs Temporal variation

As it can be easily noticed in Table 4-1 below, the maximum number of accident occurred between the hours of 9:00 – 10:00 P.M, which accounted for about 8.47 % of the total accidents. While the second and third highest traffic accidents were recorded during 11:00 A.M – 12:00 P.M and 10:00 A.M – 11:00 A.M, which are about 7.99% and 7.83% of the total recorded accidents respectively. Conversely, the three consecutive time periods that were less susceptible for the occurrences of frequent number of accidents were 4:00-5:00 A.M, 5:00-6:00 A.M and 24:00-1:00 A.M. and their contribution in terms of percentage is about 1.20%, 1.20% and 1.12% respectively. Figure 4-1 below illustrates temporal accidents.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-1. Accident number Vs Temporal variation (Bole-Meskel square).

Time	Fatal	Severe Injury	Slight Injury	Damage to property	Total	%age
06:00 – 07:00	1	3	3	18	25	2.00
07:00 – 08:00	2	5	2	39	48	3.83
08:00 – 09:00	0	5	7	62	74	5.91
09:00 – 10:00	1	5	1	74	81	6.47
10:00 – 11:00	2	3	7	86	98	7.83
11:00 – 12:00	0	1	4	95	100	7.99
12:00 – 13:00	1	3	0	69	73	5.83
13:00 – 14:00	0	8	4	61	73	5.83
14:00 – 15:00	1	1	2	73	77	6.15
15:00 – 16:00	0	2	3	101	106	8.47
16:00 – 17:00	0	1	2	85	88	7.03
17:00 – 18:00	0	4	3	66	73	5.83
18:00 – 19:00	0	3	5	43	51	4.07
19:00 – 20:00	0	4	5	45	54	4.31
20:00 – 21:00	1	5	2	23	31	2.48
21:00 – 22:00	1	4	2	25	32	2.56
22:00 – 23:00	2	4	0	23	29	2.32
23:00 – 24:00	2	2	1	17	22	1.76
24:00 – 01:00	2	1	2	9	14	1.12
01:00 – 02:00	1	3	0	18	22	1.76
02:00 – 03:00	4	1	0	18	23	1.84
03:00 – 04:00	2	2	2	22	28	2.24
04:00 – 05:00	1	0	0	14	15	1.20
05:00 – 06:00	0	1	1	13	15	1.20
Total	24	71	58	1099	1252	100.00
%age	1.92	5.67	4.63	87.78	100.00	

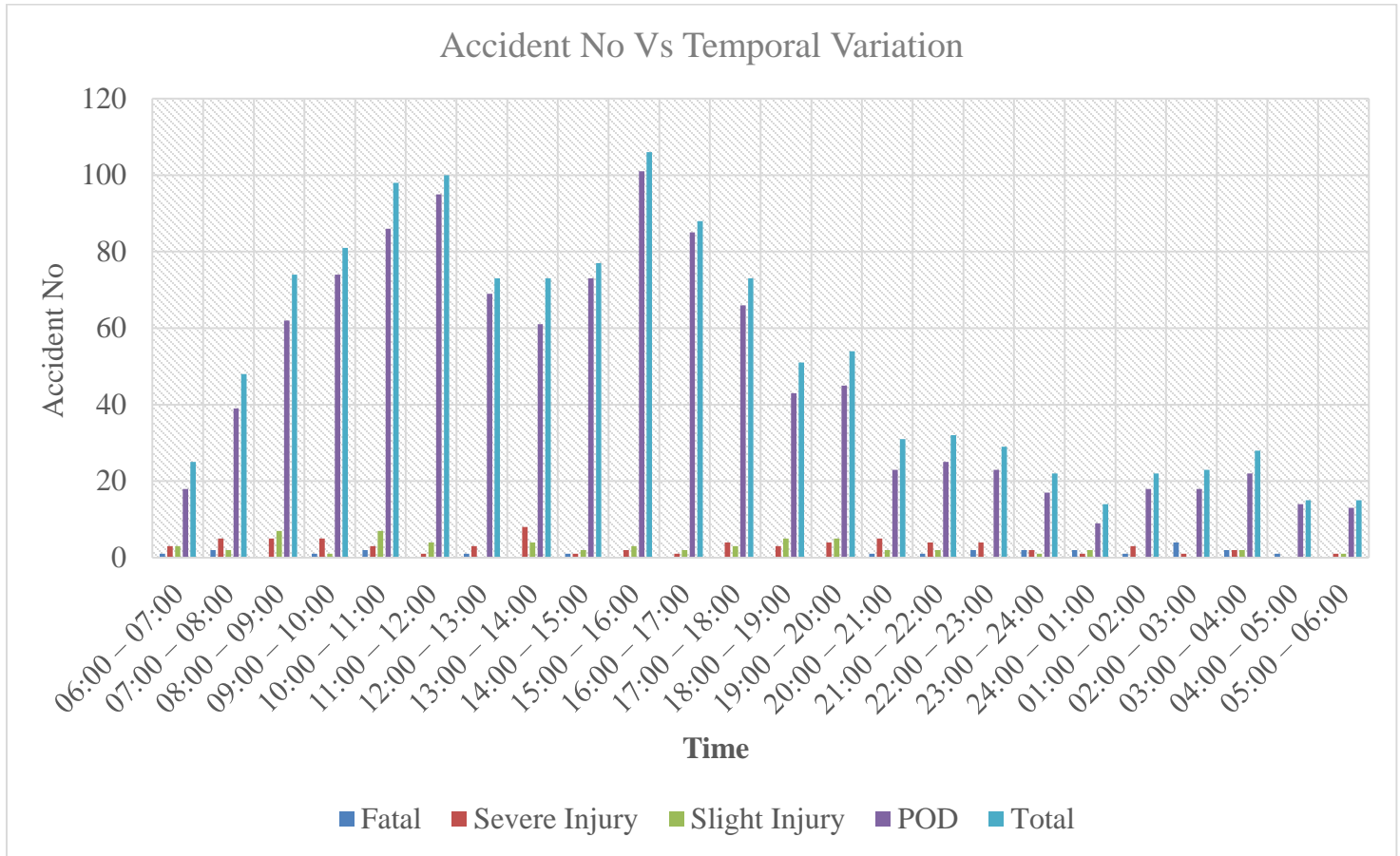


Figure 4-1. Severity of Accident Number Vs Temporal Variation.

B) Accident number Vs Causes of accident

As it can be seen in Table 4-2 below, about one third (1/3) of the total recorded accidents occurred due to lack of maintaining minimum gaps between among the vehicles, which accounted for about 33.63% of the total accidents. Subsequently, lack of giving priority for pedestrian, and other vehicles contributed its share causing about one fifth (1/5) of the total number of accidents which was 22.2% of the overall recorded accident.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-2. Accident number Vs its cause.

Accident Cause	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Door Opening	0	0	1	4	5	0.40
Minimum Gap	0	1	3	417	421	33.63
Off the Road	3	0	0	8	11	0.88
Overload	0	0	0	2	2	0.16
Overturning	4	0	1	18	23	1.84
Passing with right	1	0	0	14	15	1.20
Priority	15	48	37	178	278	22.20
Rear Driving	0	1	1	86	88	7.03
Reckless Driving	1	5	4	33	43	3.43
Standing from Rest	0	0	0	11	11	0.88
Technical problem	0	0	0	7	7	0.56
Violating traffic sign	0	0	0	7	7	0.56
Wheel to Z Left	0	6	4	153	163	13.02
Wheel to Z Right	0	9	7	155	171	13.66
Unknown	0	1	0	6	7	0.56
Total	24	71	58	1099	1252	100

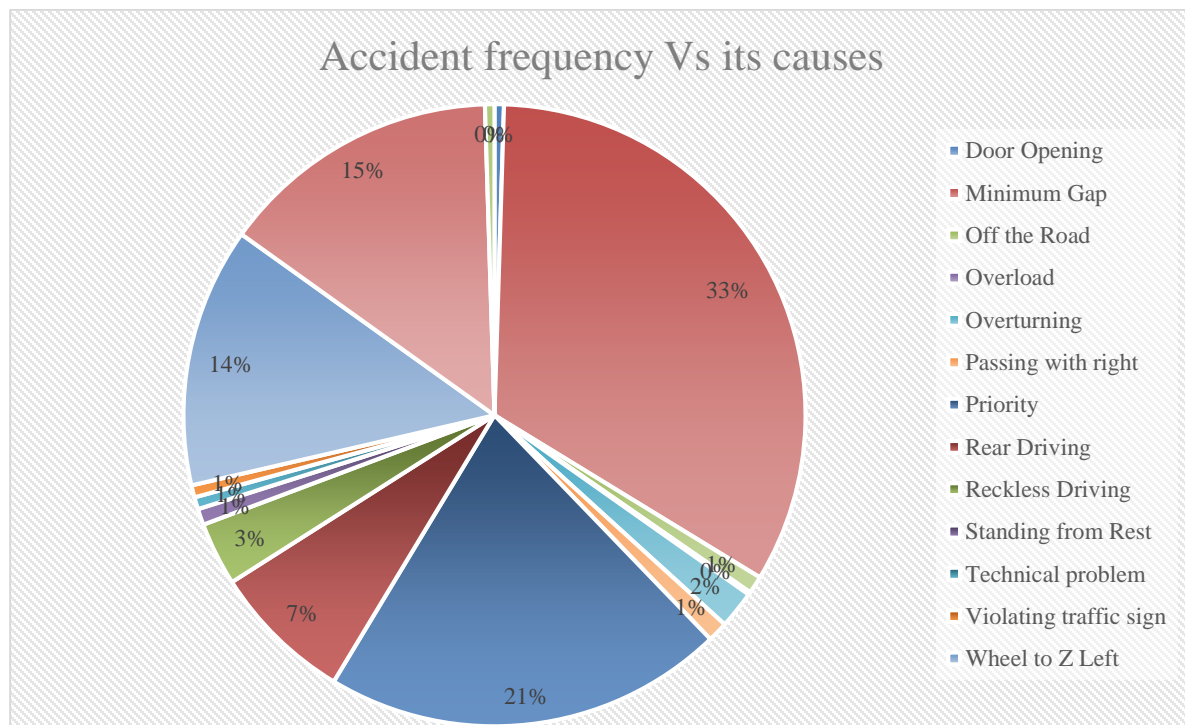


Figure 4-2. Accident number and its cause.

C) Accident number Vs Collision type

The majority of accidents that occurred along the road network were hit from back type of collisions and it accounts about 48.8% of the total number of recorded accidents. Whereas, side collisions were 360 that was equivalent to 28.75 % of the total number of accidents. In contrary, crashed down type of collision were responsible for the occurrence of least number of accidents where it was approximately 0.24% of the total recorded accident. Whilst the consecutive least number of accident that weighs about 0.56% of the total recorded accident were occurred with unknown causes. The detailed accident pattern as per collision type is presented below in Table 4-3.

Table 4-3. Accident Classified According to Type of Collision.

Type of Collision	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Hit from Front	0	0	0	0	0	0.00
Hit from Back	0	6	3	602	611	48.80
Hit from Side	1	8	4	347	360	28.75
Hit Fix Object	3	4	3	142	152	12.14
Hit Pedestrian	20	51	48	0	119	9.50
Crashed down	0	1	0	2	3	0.24
Unknown	0	1	0	6	7	0.56
Total	24	71	58	1099	1252	100.00

D) Accident number Vs Vehicle type

Generally, smaller cars hold the first rank in causing frequent number of accidents along the selected road network, which particularly weighs about 79.63% of total number of accidents. Additionally, it was also responsible for 18 fatal accidents that is equivalent to 75% of the total death which were recorded along the entire road network. While Heavy trucks were responsible for 4.31% of the total recorded accidents. In contrary, as compared to the other types of vehicles, machines and bicycles caused the least number of traffic accidents i.e below 1%, they specifically accounted for about 0.08% of the total number of accidents. Table 4-4 below presents the total accidents by vehicle type.

Table 4-4. Accident Classified According to Type of Vehicle Involved in Accident.

Type of Vehicle	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	% age
Smaller Cars	18	64	47	997	1126	79.63
Bus	1	1	1	12	15	0.96
Medium Truck	2	2	3	23	30	1.84
Heavy Truck	3	1	1	54	59	4.31
Articulated Truck	0	0	0	5	5	0.40
Machine	0	0	0	1	1	0.08
Motorcycle	0	2	6	6	14	0.48
Bicycle	0	1	0	1	2	0.08
Total	24	71	58	1099	1252	100

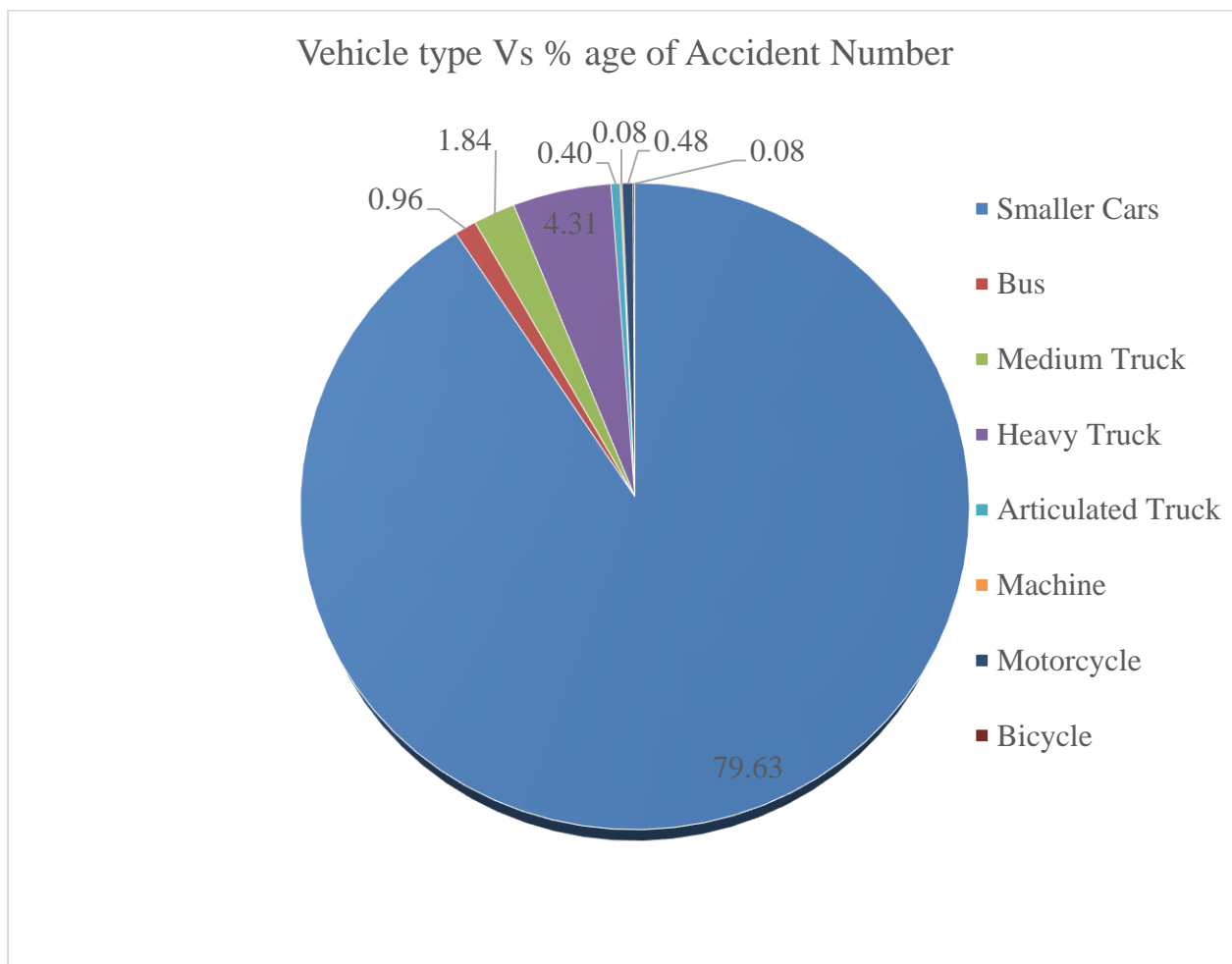


Figure 4-3. Accident number by Vehicle type.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

E) Accident number Vs Accident location

Excluding the improper and incomplete datasets, the total recorded accidents were encoded as they were referenced in the police accident database. Generally, the accidents were recorded with reference to nearby building names, company names, supermarkets, common local names, and commercial centers. Hence, the recorded accident numbers as per their specific locations are summarized on table 4-5.

Table 4-5. Accident number by locations.

Accident Location	Station ID	Fatal	Severe Injury	Slight Injury	Damage to Property	Total
<i>Alem Building</i>	BM 04	0	4	3	34	41
<i>Bole Mini</i>	BM 02	0	0	0	2	2
<i>Bole Printing Press</i>	BM 12	0	8	5	81	94
<i>DH Geda tower</i>	BM 03	0	1	0	10	11
<i>Filamingo</i>	BM 18	0	4	7	80	91
<i>Friendship Building</i>	BM 03	0	5	1	37	43
<i>Getu Commercial</i>	BM 14	4	10	7	89	110
<i>Around Japan</i>	BM 07	1	1	0	22	24
<i>London café</i>	BM 01	0	0	0	1	1
<i>Mega Building</i>	BM 10	2	5	2	106	115
<i>Mega Printing</i>	BM 09	0	0	0	2	2
<i>Meridian Hotel</i>	BM 06	0	1	0	13	14
<i>Mellinium Hall</i>	BM 01	0	2	1	56	59
<i>Bole Shewa dabo</i>	BM 11	0	0	0	1	1
<i>New York café</i>	BM 11	1	1	0	19	21
<i>Novis Supermarket</i>	BM 07	0	1	2	2	5
<i>Olompiya</i>	BM 13	0	0	5	63	68
<i>Oromia State Council Office</i>	BM 18	0	2	2	53	57
<i>Bole Picoc</i>	BM 14	0	0	0	13	13
<i>Rwanda</i>	BM 07	6	10	2	128	146
<i>Say cake</i>	BM 05	0	0	0	24	24
<i>Martyrs Memorial Museum</i>	BM 19	0	0	2	27	29
<i>Shoa Dabo</i>	BM 18	0	0	0	21	21
<i>Shoa Supermarket (Bole)</i>	BM 11	0	2	1	29	32
<i>Snap Plaza</i>	BM 02	0	0	0	1	1

Accident Location	Station ID	Fatal	Severe Injury	Slight Injury	Damage to Property	Total
Snap Plaza	BM 02	0	0	0	1	1
Sunshine Laundry	BM 18	1	4	5	50	60
Wassamar Hotel	BM 06	0	0	0	7	7
<i>Welosefer</i>	BM 08	6	10	13	94	123
<i>Werbek</i> Building	BM 06	1	0	0	9	10
<i>Yeshi</i> Building	BM 11	0	0	0	1	1
Total		24	71	58	1099	1252

4.2.1.2. Accident Analysis of Mexico Square – German Square Network

The road network from Mexico square through AU roundabout, *Sarbet*, *Mekanisa Abo* square to German square had experienced 17 fatal, 71 Severe, 93 light injury and 587 PDO accidents within a specified period of three years. In addition, as of the preceding road network, the detailed classification of the recorded accidents as per its temporal variation, accident cause, collision type, vehicle type and accident location are explained sections below through A to E while the tabular data of the classified accidents are attached in advance through Appendix B.1 to Appendix B.5.

A) Accident number Vs Temporal variation

In light of temporal variation, the maximum number of accidents occurred between 10:00 A.M - 11:00 A.M, with 7.29%. Whereas, the maximum number of accidents that induces severe injury occurred between 14:00 – 15:00, 16:00 – 17:00, 18:00 – 19:00 and 19:00 – 20:00. Conversely, the highest number of light injury type of accidents occurred between 9:00 A.M – 10:00 A.M and 19:00 – 20:00. The summarized data is attached on [Appendix B.1](#).

B) Accident number Vs Causes of accident

The causes of accident for about 29.69% of total number were lack of maintaining the required minimum gap. Subsequently, 26.04% of the total number of accidents occurred due to priority problem. While the minimum accident number occurred due to door opening, technical problem and traffic sign violation and their total share were approximately 0.26%, 0.13%, 0.13% respectively. The analyzed data according to the causes of accidents is attached in advance on [Appendix B.2](#).

C) Accident number Vs Collision type

The highest number of accident that was recorded along the entire road network was hit from back type of collisions where it contributes 41.02% of the total number of accidents. In contrary, hit from side, pedestrian hit, hit fix object and hit from front type of collisions accounted for about 35.55%, 9.24%, 7.03% and 6.51% respectively. Besides, the minimum number of accident was categorized under rollover or crashed down type of collision. Moreover, the entire summary of the accident analysis against the collision type is presented on [Appendix B.3](#).

D) Accident number Vs Vehicle type

The vehicle types that were involved in road accidents along the road network were categorized in to seven categories; namely, smaller cars, buses, medium trucks, heavy trucks, articulated trucks, machines, motorcycles and bajajs.

In addition, among the categorized vehicle types smaller cars are responsible for the occurrences of 58.2% of the total accidents. While heavy trucks, medium trucks, buses and articulated trucks hold the next subsequent positions with a respective percentage value of 7.94%, 4.43%, 2.86% and 1.95%. Moreover, Bajajs were responsible for 0.52% of the total accidents and it holds sixth position as compared to the other vehicle types. Furthermore, both machines and motorcycles hold the seventh position with 0.13% percentage. The detailed analysis of accident data in terms of the type of vehicle involved in an accident is presented in [Appendix B.4](#).

E) Accident number Vs Accident location

Twenty-one (21) locations were found susceptible for the occurrences of frequent number of accidents. Besides, the highest number of accident were recorded at Mekanisa primary and secondary school i.e. 4.08% of the total number of accidents. Whereas, the next two consecutive ranks were handed by *Mekane Eyesus Church* and *Sarbet Pepsi* with a percentage share of 3.18% and 2.59% respectively. The summarized statistical data of the accident frequency in light of their location is presented in [Appendix B.5](#).

4.2.1.3. Accident Analysis of Sarbet square – Sost Kutir Mazoria Network

Excluding junction accidents, the road network from *Sarbet* to *Sost kutir mazoria* has been experienced 7 fatal, 20 slight injuries, 21 severe injuries and 429 property damage only type of accidents. Compared to the entire length of the road, it can be concluded that the road is very much susceptible for the occurrences of frequent number of accidents. Moreover, the accidents were summarized under five major topics and summarized through A to E as follows.

A) Accident number Vs Temporal variation

The maximum number of accidents occurred between the time period of 16:00 – 17:00 (4:00 – 5:00 P.M), which is equivalent to a total of 106 accidents. Besides, it holds the first rank with a percentage share of 8.39% of total number of accidents. Subsequently, the next two maximum number of accidents occurred within time periods of 8:00 A.M – 9:00 A.M and 12:00 – 13:00 (12:00 – 1:00 P.M) with percentages of 7.76% and 7.34% respectively. the summarized analysis of the accident data in terms of temporal variation is attached in [Appendix C.1](#).

B) Accident number Vs Causes of accidents

According to the descriptive analysis of the accident data, the highest number of accident occurred due to lack of maintaining minimum gap, which accounts for about one third (1/3) of the total number of accidents, 31.45%. Conversely, violation regarding priority aspect results for the occurrences of 30.19% of the total accident number. The summarized accident number according to the nature of its violation type is presented on [Appendix C.2](#).

C) Accident number Vs Collision type

The maximum number of recorded accident along the road network were categorized under hit from back type of collisions, approximately it accounts about half of the total number of accidents, i.e. 46.75%. Hit from side type of collision and pedestrian crashes holds the next two consecutive positions where each contributes about 33.96% and 7.55% respectively. The summarized analysis of accident data as per the collision type is presented on [Appendix C.3](#).

D) Accident number Vs Vehicle type

As the previous two road networks, small cars were accountable for an occurrence of 393 number of accidents, which in percentage is equivalent to 74.21% of the total number of accidents. Secondly, both medium and heavy trucks were responsible for causing 5.03% of the total number of accidents. In contrary, motorcycle and machines were accountable for 0.63% and 0.42% of the total number of accidents respectively. Moreover, the detailed accident pattern by vehicle type is presented on [Appendix C.4](#).

E) Accident number Vs Accident location

The maximum number of accident was recorded at Biserate Gebriel and it was numerically equal to 179. Subsequently, 65 accidents recorded in front of the Ethiopian Medicine Factory (EPHARM). INSA and Yod Abyssinia experienced the least number of traffic accidents along the whole road network. Meanwhile, the entire data of the accident frequency according to their location is presented on [Appendix C.5](#).

4.2.1.4. Accident Data by Accident Location.

Accidents at various severity levels should be placed with common references for making further analysis. Hence, point weightage approach is the suitable way which was adopted in the studies of previous researchers for analyzing the four categories of accidents such as property damage only (PDO), slight injury, severe injury and finally fatal type of accidents. Therefore, this research adopted point weightage factors where fatal accidents were multiplied by 6.0, while serious injuries was multiplied by 3.0, slight injury was multiplied by 0.8 and damage only was multiplied by 0.2 (Mustakim, et.al, 2008). The Point weightage approach adopted by Mustakim was employed for analyzing the accident data. This was preferred for two core reasons; firstly, the weight was developed for the study of developing country situation, i.e. for Malaysia and subsequently it allocates larger point for fatal accident compared to other reviewed point weight approaches.

Table 4-6 through Table 4-8 below presents the overall accidents and blackspot locations by the classified station.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-6. Overall accidents and black spot locations according to classified station.

Station ID	Road layout	Fatal	Severe Injury	Slight Injury	Damage to Property	Accident number by Point Weightage/3yrs
MG 01	Straight segment	0	0	0	0	0
MG 02	Straight segment	0	3	2	19	14
MG 03	Straight segment	0	0	0	1	0
MG 04	Vertical Curve	0	0	0	0	0
MG 05	Vertical Curve	0	1	3	17	9
MG 06	Intersection	0	0	0	0	0
MG 07	Horizontal Curve	0	10	6	87	52
MG 08	Intersection	0	0	0	0	0
MG 09	Straight segment	0	0	2	5	3
MG 10	Vertical Curve	0	0	0	0	0
MG 11	Horizontal Curve	2	13	19	130	92
MG 12	Straight segment	0	1	0	3	4
MG 13	Horizontal Curve	0	2	2	13	10
MG 14	Horizontal Curve	2	7	16	60	58
MG 15	Intersection	0	0	0	0	0
MG 16	Straight segment	0	0	0	0	0
MG 17	Horizontal Curve	6	9	6	38	75

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-7. Overall accidents and black spot locations according to classified station Con'd.

Station ID	Road layout	Fatal	Severe Injury	Slight Injury	Damage to Property	Accident number by Point Weightage/3yrs
MG 18	Horizontal Curve	3	12	14	80	81
MG 19	Vertical Curve	1	0	1	3	7
MG 20	Horizontal Curve	2	10	16	88	72
MG 21	Horizontal Curve	0	0	0	0	0
MG 22	Straight segment	1	3	6	43	28
MG 23	Horizontal Curve	0	0	0	0	0
MG 24	Straight segment	0	0	0	0	0
BM 01	Straight segment	0	2	1	57	18
BM 02	Straight segment	0	0	0	3	1
BM 03	Straight segment	0	6	1	47	28
BM 04	Horizontal Curve	0	4	3	34	21
BM 05	Straight segment	0	0	0	24	5
BM 06	Straight segment	1	1	0	29	15
BM 07	Straight segment	5	12	4	142	98
BM 08	Horizontal Curve	6	10	13	94	95
BM 09	Straight segment	0	0	0	2	0
BM 10	Straight segment	0	0	0	0	0
BM 11	Horizontal Curve	1	3	1	50	26
BM 12	Straight segment	0	8	5	81	44
BM 13	Straight segment	2	5	7	169	66
BM 14	Straight segment	4	10	7	102	80
BM 15	Straight segment	0	0	0	0	0
BM 16	Straight segment	0	0	0	0	0
BM 17	Vertical Curve	0	0	0	0	0
BM 18	Straight segment	1	10	14	204	88
BM 19	Straight segment	0	0	2	27	7
BM 20	Straight segment	0	0	0	0	0
SS 01	Straight segment	0	1	0	18	7
SS 02	Horizontal Curve	0	0	0	0	0
SS 03	Horizontal Curve	0	0	0	0	0
SS 04	Straight segment	0	0	0	1	0
SS 05	Intersection	0	0	0	0	0
SS 06	Straight segment	0	0	0	0	0

Table 4-8. Overall accidents and black spot locations according to classified station Con'd.

Station ID	Road layout	Fatal	Severe Injury	Slight Injury	Damage to Property	Accident number by Point Weightage/3yrs
SS 07	Straight segment	2	1	2	84	33
SS 08	Straight segment	1	0	0	6	7
SS 09	Straight segment	2	8	6	177	76
SS 10	Straight segment	0	1	2	18	8
SS 11	Straight segment	0	2	3	16	12
SS 12	Intersection	0	0	0	0	0
SS 13	Straight segment	0	3	2	60	23
SS 14	Straight segment	2	4	6	50	39
SS 15	Straight segment	0	0	0	0	0
SS 16	Straight segment	0	0	0	0	0
Total		44	162	172	2104	1308

4.2.2. Analysis of Primary data

The traffic and geometric parameters of the identified black spot locations were analyzed on the basis of the collected data as stated in sections 3.3.2 and 3.3.3. Hence, traffic parameter such as average peak hour volume (APHV), 50th and 85th percentile spot speeds of the selected spots were determined. Whereas, the geometric data of the selected black spot location which were collected during site inventory survey were sorted out and organized for further analysis, where it includes parameters such as type of road layout, availability of U-turn, average median width, average walkway width, lane width, number of lane, and number of access points.

Moreover, site inventory survey was adopted to gather sufficient information regarding the geometric and traffic parameters of the selected spots. As it was mentioned earlier, this section mainly focused on the analysis of traffic and geometric related explanatory variables on the identified black spots such as road layout, availability of U-turn, number of lane, lane width, walkway width, 85th percentile spot speeds, traffic volume (APHV), number of access points etc. Furthermore, the survey was carried out on 20 black spot locations, where they were identified according to the adopted definition and subjective engineering judgement on the subsequent section, section 4.3 of the paper.

4.2.2.1. Analysis of Traffic Volume Studies

The purpose of making traffic volume study was to determine the vehicle composition and average peak hour volume along the selected road networks. It has been revealed that for any traffic infrastructure, design and accident study peak hour traffic volume is necessary (Rakesh Saini et al, 2015).

The total number of traffic volume that was aggregated with in the fifty (15) minute intervals were computed using the recommended PCU equivalency factor. Where Passenger Car Units (PCU) is a unit of measure whereby various vehicle types are converted to passenger cars using multiplication factors. This allows a more flexible platform to deal with mixed traffic streams more accurately than if someone had assumed all vehicles were physically similar. According to ERC, 2015, the recommended Personal car unit (PCU) conversion factor for different vehicle types in Addis Ababa city were reviewed and are presented in table 4-9.

Table 4-9. Suggested Passenger Car unit (PCU) equivalent.

No	Vehicle classification	Suggested Passenger car equivalent factors
1	Bicycles	0.3
2	Motorcycles	0.4
3	Cars and vans	1.0
4	Light vehicles (Bus and 1- Axle truck)	2.0
5	Medium trucks (2 Rear Axle trucks)	2.5
6	Heavy and Articulated trucks (4-Axle Truck & Large)	3.0

Source: ERC, (2015).

I) Peak Hour Traffic Volume (PHV)

Peak hour traffic volume is the maximum volume of vehicle flow which is recorded at the specified time of the day. But, this research employed the average peak hour traffic volume from the collected two-days counts. Besides, the volume of the traffic flow at the respective fifty-minute intervals were computed by summing up the two-directional vehicle flow together. Afterall, the mean traffic volume of the road section was determined thoroughly from the two days of traffic count.

Peak-Hour - is the hour of the day that observes the largest utilization of capacity, or the hour of the day in which the largest number of vehicles use the intersection approach or lane of interest.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Peak-Hour Factor - the ratio of the number of vehicles utilizing the road network during the peak hour to four times the number of vehicles utilizing the network during the peak 15-minute period. In the absence of field information, a value of 0.85 is normally used.

The first step is to find the total traffic volume for each 15-minute period in terms of passenger car units. As it was explained earlier, it was computed by multiplying the number of heavy and articulated trucks by 3.0, the number of medium trucks by 2.5, the number of light vehicles (bus and 1-Axle trucks) by 2.0, the number of cars and vans by 1.0, the number of motorcycles by 0.4.

Then, the above stated numbers are added together to get the total volume of traffic serviced in each interval. Once the total volume at each interval is determined, the hour with the highest volume and the 15-minute interval with the highest volume were located respectively. Therefore, the peak hour volume is just the sum of the volumes of the four consecutive 15-minute intervals within the peak hour. For instance, the summarized traffic volume analysis of the sample data on Table 4-8 shows that the highest hourly traffic volume and the peak 15-minute volume are 4,491 pcu and 1,183 pcu respectively. Accordingly, the peak hour factor (PHF) is computed by dividing the peak hour volume by four times the peak 15-minute volume, which is calculated as follows:

$$\mathbf{PHF = 4,491 / (4 * 1,183) = 0.949}$$

Moreover, the actual (design) flow rate can be calculated by dividing the peak hour volume by the PHF, $4,491/0.949 = 4,732$ pcu/hr, or by multiplying the peak 15-minute volume by four, $4 * 1,183 = 4,732$ pcu/hr. It is to be noted that the actual (design) flow rate is represented by the adjusted average peak hour volume throughout the research.

As likely as the provided sample calculation, the adjusted peak traffic volumes of the entire traffic survey stations were computed accordingly. Furthermore, sample peak hour volume analysis, summarized traffic volume studies along the *Bole-Meskel Square*, and summarized traffic volume studies of the entire road networks are presented accordingly through Tables 4-10 to 4-12.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-10. Peak Hour Volume Analysis at Bole Printing Press.

Station ID: - Section 2	Bole Printing Press					
APHV	The Maximum traffic volume is 4491 between 5:00 – 6:00 P.M					
Time	Direction		Total	Max of 15 minutes	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	443	445	888	1183		4491
07:15-07:30	470	478	948			
07:30-07:45	538	522	1060			
07:45-08:00	533	565	1098		3994	
08:00-08:15	572	611	1183			
08:15-08:30	495	563	1058			
08:30-08:45	523	543	1066			
08:45-09:00	490	529	1019		4327	
12:00-12:15	515	504	1019			
12:15-12:30	495	481	976			
12:30-12:45	477	531	1007			
12:45-01:00	517	486	1003		4006	
1:00 - 1:15	535	453	989			
1:15 - 1:30	489	455	945			
1:30 - 1:45	495	482	978			
1:45 - 2:00	476	500	976		3887	
4:00 - 4:15	478	551	1028			
4:15 - 4:30	537	544	1081			
4:30 - 4:45	491	572	1063			
4:45 - 5:00	571	553	1124		4296	
5:00 - 5:15	617	543	1160			
5:15 - 5:30	566	533	1099			
5:30 - 5:45	572	568	1140			
5:45 - 6:00	584	508	1092		4491	
Total	12478.5	12522.45	25001			

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Table 4-11. Traffic Volume studies along Bole – Meskel square.

Station Name (C1)	Station No	15-minute Peak Traffic Volume	Average Peak Hour Traffic Volume	Peak Hour Factor (PHF)	Adjusted Average Peak Hour Traffic Volume
Freindship Business Center	1	1216	4729	0.972	4864
Bole Printing Press	2	1183	4491	0.949	4732
Sunshine Laundry	3	1141	4319	0.947	4563

Table 4-12. Summarized Average peak hour volume of the entire study areas.

Adjusted average Peak Hour Volume (APHV) along Bole – Meskel Square.			
Station No	Station name	APHV	Blackspot station ID
1	Friendship Bussines Center	4864	BM 03, BM 04, BM 07 and BM 08
2	Bole Printing Press	4732	BM 11, BM 12, BM 13 and BM 14
3	Sunshine Laundry	4563	BM 18
Adjusted average Peak Hour Volume (APHV) along Mexico Square – German Square.			
1	Ethiopian Tobacco Enterprise	3857	
2	International Evangelical church	3424	MG 07
3	Vatican Embassy	2982	MG 11, MG 14, MG 17 & MG 18
4	Mekane Eyesus Management School	3578	MG 20, MG 22
Adjusted average Peak Hour Volume (APHV) along Sarbet – Sost Kutir Mazoria.			
1	Tomocca Coffee	2,450	
2	Austria Embassy	2,390	SS 07, SS 09
3	Dimma Cultural Restaurant	2,382	SS 13, SS 14

4.2.2.2. Spot Speed Analysis

The vehicle speeds were computed by using the predetermined study length and the elapsed time it took the vehicle to move through the course (as recorded on the stopwatch data form) in the following formula (Robertson 1994):

$$V = \frac{D}{T} \dots\dots\dots \text{Equation 4.2.2.2.}$$

Where, **V** = spot speed (km/hr), **D** = road length (km), and **T** = elapsed time (seconds).

Speed percentiles are tools used to determine the effective and adequate speed limits of the road networks. The two speed percentiles most important to understand are the 50th and the 85th percentiles. The 50th percentile is the median speed of the observed data set. This percentile represents the speed at which half of the observed vehicles are below and half of the observed vehicles are above. The 50th percentile of speed represents the average speed of the traffic stream while the 85th percentile is the speed at which 85% of the observed vehicles are traveling at or below (Smith, 2002). This percentile is used in evaluating/recommending posted speed limits based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe (Homburger et al.,1996). In other words, the 85th percentile of speed is normally assumed to be the highest safe speed for a roadway section.

Moreover, frequency distribution table is the common and convenient way to determine speed percentiles. The frequency of vehicles is the number of vehicles recorded at each speed while the cumulative frequency is the total of each of the numbers (frequencies) added together row by row from lower to higher speed. Then running percentage of the cumulative frequency were calculated accordingly.

The 50th and 85th percentiles spot speed were determined from the cumulative percent column. Consequently, the two percentiles are computed by interpolation using percentages and speeds from the prepared distribution table. The equation which is used for calculating the speed percentile is presented below: -

$$SD = \frac{PD - P_{min}}{P_{max} - P_{min}} ((S_{max} - S_{min}) + S_{min}) \dots\dots\dots \text{Equation 4.2.2.3.}$$

Where S_D – Desired speed;

P_D - Desired percentile;

P_{min} - Lower cumulative percentile;

P_{max} – Higher cumulative percentile;

S_{max} - Higher speed; and S_{min} - Lower speed.

I) Spot Speed Analysis along Bole-Meskel square

As it was mentioned in the above section, the 50th and 85th percentile spot speeds were determined from the cumulative percentage column using the specified formula on equation 4.2.2.2. Thus, looking to the computation of sample spot speed analysis along Bole to Meskel square in Table 4-13, the 50th and 85th percentile speeds were found to be 48.3 km/hr and 59.1km/hr respectively, which in essence, are beyond the posted speed limits i.e. 50 km/hr. Table 4-13 below presents sample spot speed analysis of station BM 13.

Sample Calculation

$$S_{50\text{th}} = \frac{50 - 35}{52 - 35} ((48.2 - 45.9) + 45.9)$$

$$S_{50\text{th}} = 48.0 \text{ km/hr}$$

$$S_{85\text{th}} = \frac{85 - 79}{88 - 79} ((60.3 - 56.8) + 56.8)$$

$$S_{85\text{th}} = 59.1 \text{ km/hr}$$

Table 4-13. Sample Spot Speed Analysis of Station BM 13.

Analysis of Spot speed @ BM 13						
Time Interval	Speed (km/hr)	Frequency of vehicles	Cumulative frequency	Cumulative percent	Speed percentile	
4:00 A.M– 4:30 A.M	38.6	0	0	0.00		
	40.2	6	6	6.00		
	41.9	7	13	13.00		
	43.9	10	23	23.00		
	45.9	12	35	35.00		
	48.2	17	52	52.00	48.0	50th
	50.8	9	61	61.00		
	53.6	8	69	69.00		
	56.8	10	79	79.00		
	60.3	9	88	88.00	59.1	85th
	64.3	8	96	96.00		
	68.9	0	96	96.00		
	74.2	3	99	99.00		
	80.4	1	100	100.00		

Furthermore, Figure 4-4 below illustrates spot speed versus cumulative percentage.

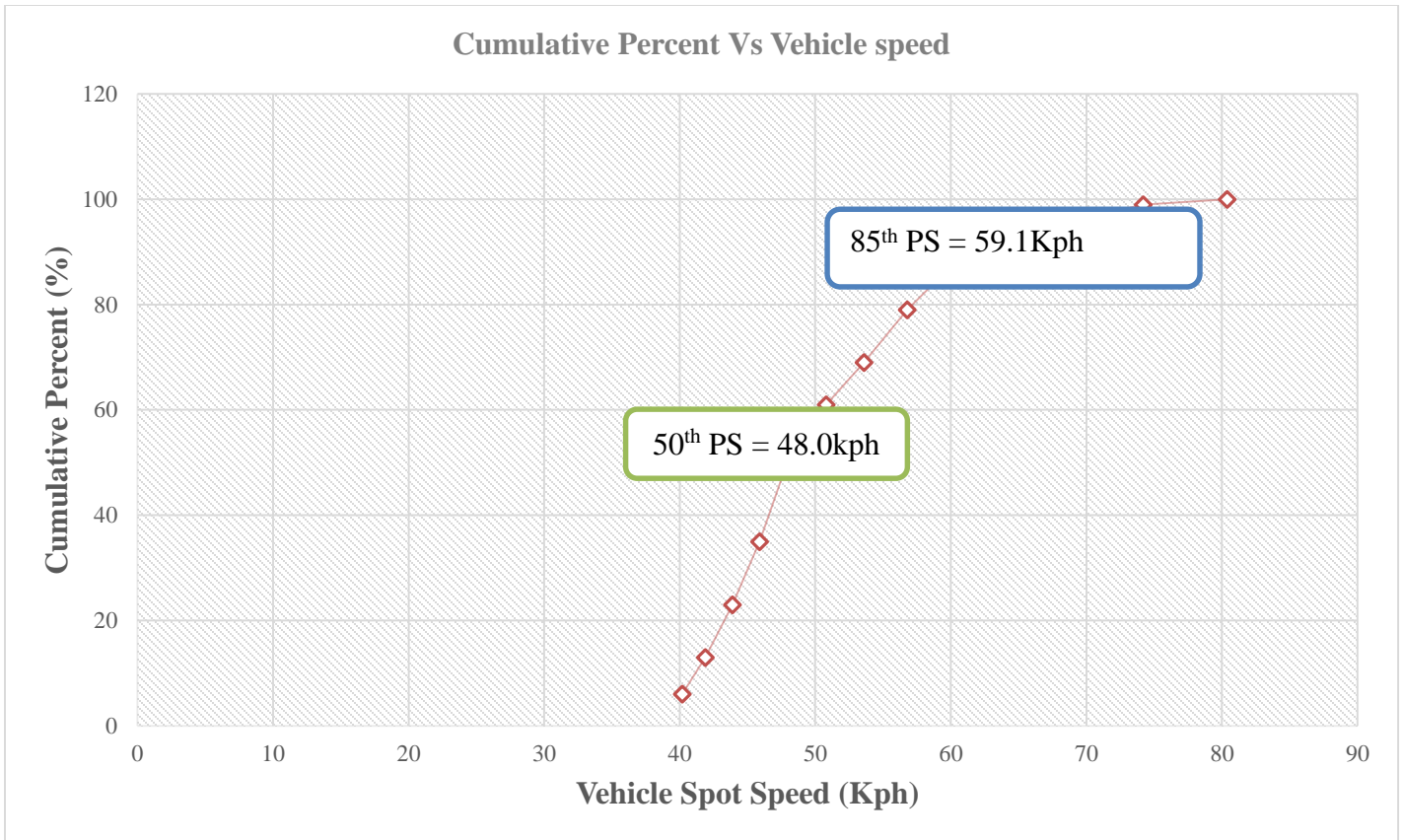


Figure 4-4. Spot speed Vs Cumulative percentage chart at BM 13.

II) Summarized Spot Speed Analysis along the whole Road Network

As likely as the sample spot speed analysis, individual spot speed analysis was executed for the entire black spot segments and sample tabular analysis is presented for each road network on [Appendix G](#). The summarized 50th and 85th percentile spot speed values of the entire road networks are presented accordingly in Table 4-12 where the highest 50th percentile speed was found to be 54.78 km/hr and it was recorded at station BM 07 (*Werbek House to Mulmul Bakery*). Whereas, the maximum 85th percentile speed was recorded at station BM 08 (*Mulmul Bakery to Muller Real State*) and it was found to be 67.9 km/hr. Moreover, the posted speed limit of the entire road networks is 50 km/hr. But, excluding station BM 03, all road segments were characterized by having higher percentile speed values (85th PS) beyond the posted speed limit i.e. 50 km/hr. Table 4-14 below presents the spot speeds of the entire blackspot locations.

Table 4-14. Summarized Spot Speed of Blackspot Locations Along the Entire Road Networks.

Black Spot Station ID	50th Percentile Speed (Km/hr)	85th Percentile Speed (Km/hr)
BM 03	43.72	50.00
BM 04	43.60	51.40
BM 07	54.78	63.70
BM 08	52.80	67.90
BM 11	46.60	52.00
BM 12	49.10	56.10
BM 13	48.00	59.10
BM 14	50.50	61.00
BM 18	47.95	63.00
MG 07	50.80	57.70
MG 11	49.00	61.00
MG 14	50.50	60.60
MG 17	48.50	56.80
MG 18	53.30	62.60
MG 20	53.40	59.90
MG 22	44.70	55.70
SS 07	50.00	57.10
SS 09	51.80	60.70
SS 13	43.85	48.70
SS 14	45.11	53.00

4.3. Adopted Black Spot Definition and Identification

4.3.1. Black Spot Definition

This research identified the relevant black spot locations through comparing the recorded traffic accidents with the threshold value of observed accident numbers where the adopted threshold or limiting value was taken from the recommendation set by three scholars, in which they used to develop a threshold value for the context of developing countries. Hence, this step is aimed to identify the list of high accident frequency locations within the sample of locations established by dividing the road into sections and spot. Such identification was based on the threshold values of observed numbers of injury accidents at every site in the sample in three consecutive years. Moreover, the threshold values of observed accident numbers at every sample in three consecutive years can be determined using the following equation (Nguyen.et.al, 2016): -

Threshold value = $\text{Max}[\bar{X}, m]$Equation 4.3.1.

Where \bar{X} = average value of accident number and m = median value of the sample.

Therefore, any sample with observed number of accidents higher than the threshold value is listed as a high accident frequency location, in technical term it is said to be a blackspot location.

4.3.2. Blackspot Identification Strategy

After the accident pattern of the studied locations were determined, the relevant black spot locations were identified using the definition adopted in the proceeding section, Section 4.3.1. In addition, prior to the identification procedure, the four types of accident severity levels (Fatal, Severe, Slight and PDO) were multiplied by the preferred point weights and summed up together to find the total frequency of accident at a particular road station. Indeed, it is the severity of accident that is further taken into account by weighting factors and damage -only type of accident (Mustakim, 2005).

Many scholars also recommend that the concept of accident severity should be included in any traffic accident analysis using point weightage approach where it offers the opportunity to include all accidents in the identification process. In other words, both number and severity of registered accidents are taken into consideration, which is to prefer (Taylor and Thompson 1977. Ogaden 1996, Overgaard and Madsen 2005).

Moreover, the chosen point weightage approach is based on the value that has been contributed by The Transport Research Laboratory (TRL) from Interim Guide in Identifying, Prioritizing and Treating Hazardous Locations on Roads in Malaysia. Accordingly, the point weights have been assigned on the basis of severity principle where fatal, serious and slight injury type of accidents are account for 6, 3 and 0.8 points respectively whilst property damage only (PDO) type of accident weights 0.2 point.

The point weightage equation by Malaysian TRL was found relevant, and employed for analyzing the accident analysis of the research. The two basic justifications behind adopting the above approach are: i) as likely as our country, Malaysia is classified under the category of developing countries and ii) the equation gives greater weight for fatal type of accident and lower point for that of property damage only type of accident. Thus, it offers intense considerations and priority for locations with severe type of accidents than that of locations with PDO type of accidents.

Consequently, the total aggregated frequency of accident was computed by treating each severity using the respective point weights. The general weightage formula is presented in equation 4.3.2 as follows: -

$$AN = (6 \times F) + (3 \times S) + (0.8 \times L) + (0.2 \times P) \dots\dots\dots\text{Equation 4.3.2.}$$

Where F: Fatal accident;

S: Severe Injury;

L: Slight Injury;

P: Property Damage Only. (Source: TRL)

Many scholars also adopted the above-mentioned point weights due to its comprehensive nature, that it is capable in explaining the accident occurrences by encompassing the four types of accident severity levels. (Mustakim F., 2008, Noorliyana O. et al, 2016).

Subsequently, frequency analysis on the given accident data was executed using SPSS software package, version 20 for determining the threshold value of the sample. Hence, the result of the SPSS analysis in Table 4-15, has shown that the mean (average) value of accident frequency is much greater than its median. Therefore, as per the employed definition, the threshold value was equivalent to the mean value of the sample data, i.e. **37.2**.

$$\text{Threshold value} = \text{Max} (37.2, 26)$$

$$\text{Threshold value} = 37.2.$$

Table 4-15. Frequency Statistics of the Accident Data.

Statistics		
Total number of accidents by point weightage / 3years		
N	Valid	35
	Missing	0
Mean		37.2
Median		26.0

Having determined the threshold value, total accident number of the individual stations were compared against the threshold value. As a result, fourteen segments were found beyond the threshold value and they were regarded as black spot locations. But in light of statistical concept smaller sample sizes may results in biased estimates, which in turn may reduce the accuracy and applicability of the final accident prediction model. So, in order to minimize or tackle such kinds of problems and to augment the significance of the model, the top twenty (20) locations were considered as the relevant black spot locations along the selected road networks.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Moreover, the pictorial representation of the twenty (20) black spot locations along the entire road networks were sketched using Auto CAD software package, version 2013 and are presented in [Appendix I](#) through I.1 to I.3. Hereafter, lists of black spot locations are demonstrated along with the respective accident numbers, in Table 4-16.

Table 4-16. Top twenty Black spot locations along the study area.

Station ID	Fatal	Severe Injury	Slight Injury	Damage to Property	Total Accident using Point weightage approach / 3yr
BM 03	0	6	1	47	28
BM 04	0	4	3	56	26
BM 07	5	12	4	142	98
BM 08	6	10	13	94	95
BM 11	1	3	1	50	26
BM 12	0	8	5	81	44
BM 13	2	5	7	169	66
BM 14	4	10	7	102	80
BM 18	1	10	14	204	88
MG 07	0	10	6	87	52
MG 11	2	13	19	130	92
MG 14	2	7	16	60	58
MG 17	6	9	6	38	75
MG 18	3	12	14	80	81
MG 20	2	10	16	88	72
MG 22	1	3	6	43	28
SS 07	2	1	2	84	33
SS 09	2	8	6	177	76
SS 13	0	3	2	60	23
SS 14	2	4	6	50	39

4.4. Choices of Model Explanatory Variables

There seems to be a belief among many safety researchers that the more variables in an APM the better the model. In addition, the choice of explanatory variables to be included in majority of the previously developed accident prediction model ought to be based on theory (Fridstrom et al 1995). Conversely, the theoretical way of identifying explanatory variables for developing the model was found to be non-practical (Hauer, 2004). Thus, selection of explanatory variables through the integral efforts of

theoretical approach and engineering judgement was found to be the better way on researches of several scholars (Hauer, 2004; Elvik, 2007).

Accordingly, the recommended approach for selection of predominant explanatory variables by Elvik states that, explanatory variables should include variables that:

- I) Have been found in previous studies to exert a major influence on the number of accidents;
- II) Can be measured in a valid and reliable way;
- III) Are not endogenous, that is independent on the other explanatory variables included or on the dependent variable in the model. (Elvik, 2007).

In addition, the selection of explanatory variables for developing the relevant accident prediction model should also consider the concept of generality. i.e the model should be applicable for other locations in the same region having similar geometric and traffic characteristics as the location that was considered under the model development procedure. Moreover, a model need to be developed in accordance with the principle of parsimony, which calls for explaining as much of the variability of the data using the least number of explanatory variables. Besides, the idea behind the principle of parsimony is to avoid over-fitting while it is tempting to include many variables in a model in an effort to make it fit the observed data as closely as desired (Sawalha, 2003).

4.4.1. Principle of Parsimony of the Model

The capability of the explanatory variable to be retained in the final prediction model was decided on the basis of two main criteria. Primarily, the presumed individual explanatory variables were checked for the strength of relationship among other variables where it can be determined through developing appropriate correlation matrices. Implies, the correlation matrices were developed to figure out independent variables that have strong relationship with other variables. As a result, correlated explanatory variables were not adopted together in the development of the accident prediction model. Secondly, as per the suggestion of Sawalha (2003), the other criterion that is useful for employing a variable to the proposed model depends on the effects of the variables to drop the magnitude of the scaled deviance value at a confidence interval of 95%.

Speaking of statistical significancy, a study by Elvik, (2007) concluded that it is not usually an appropriate way to rely on statistical significance to decide whether or not a variable should be included in the model because it might produce a biased result (Elvik, 2007). Some researchers have also even

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

reported models containing variables with highly insignificant parameters based on the belief that such variables would still improve model prediction. Such variables are hardly of any value for explaining the variability of the specific accident data used in generating the model much less of any value for predicting accident frequencies at new locations not used in the model development. In contrary, explanatory variables that have statistically significant model parameters, on the other hand, contribute to the explanation of the variability of the accident data, and their inclusion in the model therefore improves its fit to this data (Sawalha, 2003).

All in all, as per the above stated explanation and reviews, eight explanatory variables were selected for performing the proposed research. Subsequently, they were subjected to correlation analysis to determine the degree and strength of relationship among each other. As a result, either of the variable which was found to be highly correlated with other independent explanatory variable was removed from the study. Hence, independent explanatory variables that have less correlation with other variables were extracted and taken for further analysis. The presumed explanatory variables of the study are presented in Table 4-17 below.

Table 4-17. The Hypothesized Geometric and Traffic Explanatory Variables.

No	Variable Label	Description of Explanatory variables	Variables type
		Geometric variables	
1	LN	Number of lane	Categorical; 0 – 3 lanes, 1 – 4 lanes
2	LW	Lane width	Continuous (m)
3	AMW	Average Median width	Continuous (m)
4	AWW	Average Walkway width	Continuous (m)
5	NAP	Number of access points	Continuous (count)
6	AUT	Availability of U-Turn	Categorical; 0 – Absent; 1 – Present
7	RL	Road Layout	Categorical; 0 - Straight segment; 1- Horizontal curves.
Traffic variables			
1	APHV	Adjusted average peak hour volume	Continuous (veh/hr)
2	85th PS	85 th Percentile Spot speed	Continuous (km/hr)

Ideally speaking, lane width was excluded from the short list due to its constant nature throughout the given data. In addition, for further elimination of non-prevalent explanatory variables, a correlation matrix was developed through Bi-variate correlation analysis using SPSS software package.

Identification and Countermeasures of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Hence, two independent correlation matrices were developed using Pearson and Spearman coefficients where Pearson correlation matrix was developed to figure out the strength of relationship among continuous explanatory variables such as adjusted average peak hour volume (APHV), average walkway width (AWW), average median width (AMW), number of access points (NAP), and 85th percentile spot speed (85th PS). On the other hand, the Spearman correlation matrix was employed to provide the research with the degree of interaction among the categorical independent explanatory variables (lane number, availability of U-turn and road layout).

Meanwhile, the interpretation of the correlation matrix was made according to the standard correlation reference table where the correlation coefficient is represented by absolute value of r_s : where $-1 < r_s < 1$. Moreover, range of values and their respective interpretations are presented in Table 4-18 below.

Table 4-18. Standard Correlation table.

No	Correlation Type		Relationship Strength
	Pearson Correlation	Spearman Correlation	
1	0.00-0.19	0.00-0.19	Very weak
2	0.20-0.39	0.20-0.39	Weak
3	0.4-0.59	0.4-0.59	Moderate
4	0.6-0.79	0.6-0.79	Strong
5	0.8-1.0	0.8-1.0	Very strong

The independent explanatory variables which showed less correlation coefficients ($r_s < 0.5$) with other parameters were sorted out from the correlation matrix and employed for further analysis. The contingency table of the entire explanatory variables and the two developed correlation matrices are presented from Tables 4-19 to 4-21.

N.B: The highlighted figures on the correlation matrices represent the presence of strong relationship among the respective parameters.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Table 4-19. Contingency Table of the Selected Explanatory Variables.

Station ID	Accident number by point weightage No/ 3 yr (AN/3years)	Lane No (LN)	Road Layout (RL)	Average Walkway width (AWW)(m)	Average Median width (AMW)(m)	No of Access Point (NAP) per divided segment	Availability of U-turn (AUT)	Ln of Average Peak Hour Volume (LnAPHV)	85 th % Spot Speed (85 th PS) (km/hr)
BM 03	28	4	Straight segment	4.83	2.90	1	No	8.49	50.00
BM 04	26	4	Horizontal curve	4.90	2.90	1	No	8.49	51.40
BM 07	98	4	Straight segment	4.95	2.90	3	No	8.49	63.70
BM 08	95	4	Straight segment	4.95	2.90	3	No	8.49	67.90
BM 11	26	4	Straight segment	4.70	1.50	0	No	8.46	52.00
BM 12	44	4	Straight segment	4.95	2.90	1	No	8.46	56.10
BM 13	66	4	Horizontal curve	4.70	1.50	2	Yes	8.46	59.10
BM 14	80	4	Straight segment	4.95	2.90	2	No	8.46	61.00
BM 18	88	4	Straight segment	4.95	2.90	2	No	8.43	63.00
MG 07	52	3	Horizontal curve	3.95	1.40	1	Yes	8.14	57.70
MG 11	92	3	Horizontal curve	4.45	0.90	1	Yes	8.00	61.00
MG 14	62	3	Horizontal curve	4.50	0.85	0	No	8.00	60.60
MG 17	75	3	Horizontal curve	3.95	0.60	0	Yes	8.00	56.80
MG 18	81	3	Horizontal curve	3.95	4.10	0	No	8.00	62.60
MG 20	72	3	Horizontal curve	4.25	0.90	1	No	8.18	59.90
MG 22	28	3	Straight segment	4.25	0.90	2	Yes	8.18	55.70
SS 07	33	3	Straight segment	4.45	0.90	0	No	7.78	57.10
SS 09	76	3	Straight segment	4.45	0.90	2	Yes	7.78	60.70
SS 13	23	3	Straight segment	4.35	0.90	2	Yes	7.78	48.70
SS 14	39	3	Straight segment	4.35	0.90	2	Yes	7.78	53.00

Identification and Countermeasure of Accident Black Spot Locations Using Statistical Modeling (A Case Study of Addis Ababa)

Table 4-20. Correlation Matrix Results of Continuous Explanatory Variables.

		Average Median Width (m)	Average Walkway Width (m)	Number of Access Point	85th Percentile Spot Speed (Km/hr)	Ln of Average Peak Hour Volume
Average Median Width (m)	Pearson Correlation	1	0.494*	0.179	0.271	0.632**
	Sig. (2-tailed)		0.027	0.451	0.248	0.003
	N	20	20	20	20	20
Average Walkway Width (m)	Pearson Correlation	0.494*	1	0.455*	0.114	0.708**
	Sig. (2-tailed)	0.027		0.044	0.632	0.000
	N	20	20	20	20	20
Number of Access Point	Pearson Correlation	0.179	0.455*	1	0.299	0.272
	Sig. (2-tailed)	0.451	0.044		0.201	0.246
	N	20	20	20	20	20
85th Percentile Spot Speed (Km/hr)	Pearson Correlation	0.271	0.114	0.299	1	0.145
	Sig. (2-tailed)	0.248	0.632	0.201		0.543
	N	20	20	20	20	20
Ln of Average Peak Hour Volume	Pearson Correlation	0.632**	0.708**	0.272	0.145	1
	Sig. (2-tailed)	0.003	0.000	0.246	0.543	
	N	20	20	20	20	20

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

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

**Table 4-21. Correlation Matrix Result of Categorical Explanatory Variables.
Correlations**

			Lane Number	Road Layout	Availability of U-Turn
Spearman's rho	Lane Number	Correlation Coefficient	1.000	-.328	-0.533*
		Sig. (2-tailed)	.	0.158	0.015
		N	20	20	20
	Road Layout	Correlation Coefficient	-.328	1.000	0.167
		Sig. (2-tailed)	0.158	.	0.482
		N	20	20	20
	Availability of U-Turn	Correlation Coefficient	-0.533*	0.167	1.000
		Sig. (2-tailed)	0.015	0.482	.
		N	20	20	20

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

The starting point in the model development process is a basic model containing the exposure variables only and the reason for this start is that any accident model should at least contain the exposure variables since no accident occurs without exposure (Sawalha, 2003). Therefore, traffic volume is the exposure variable of the research and according to the analysis result of the Bi-variate correlation analysis in Table 4-20, the average walkway width and median width have shown strong relationship with it. And owing to the above stated explanation, the exposure variable will be kept for further analysis whereas both average walkway width and median width were eliminated from the study.

Moreover, the result of Spearman correlation matrix in Table 4-21, which was developed using the categorical parameters, has shown that moderate and weak relationship were encountered among the three parameters such as lane number, availability of U-turn and road layout where lane number shows significant influence on the other two parameters, therefore it was excluded from the research consideration. In contrary, looking to the other two parameters i.e. the availability of U-turn and road layout were found to have the allowable Spearman correlation coefficients which is less than 0.5. Therefore, the two variables were taken, and further elimination of the variables were executed in the model development process on the basis of their significant effects to drop the magnitude of the scaled deviance value to its minimum value at a confidence interval of 95%.

Thus, on the basis of its significance influence to droop the scaled deviance value of the model, availability of U-turn was found prevalent and employed to the final accident prediction model. All in all, the prevalent explanatory variables which were found significant enough in explaining the given accident data includes:

- ❖ The 85th Percentile Speed (85th PS);
- ❖ Adjusted Average Peak Hour Volume (APHV);
- ❖ Number of Access Points (NAP); and
- ❖ Availability of U-turn (AUT).

4.5. Selection of Modelling Method

Statistical models can predict reliable estimates of expected accidents by relating aggregates of accidents to various explanatory measures of flow, site characteristics, and road geometry at macro level (Berhanu, 2000). Several modelling techniques have been tried to develop approximately accurate crash prediction model. However, the suitability of the model depends on the data quality and is location specific. The model that was adopted by this research to represent the crash pattern of the given data was of stochastic type where stochastic modelling approach is a logical alternative for events that occur randomly and independently over time (Okamoto et, al, (1989)).

A study by Okamoto et. al, (1989) concluded that the occurrence of traffic crashes follows stochastic distribution. In 1990, Garber et.al. also developed several models to describe the occurrence of crashes by using stochastic modeling techniques, like Poisson Regression (PR) and Negative Binomial Regression (NBR).

Generally, the most frequently adopted count models that were used to analyze the crash data are Poisson and Negative Binomial distributions. Poisson regression distribution requires the mean and variance of the dependent variable to be equal. In contrary, for most crash data, the variance of the crash frequency exceeds the mean and, in such case, the data would be over-dispersed. So, as it can easily be noticed from the table below, Table 4-22, the variance of the given data i.e. the accident frequency, exceeds its mean value. Which in turn implies the accident pattern follows a Negative Binomial (NB) distribution.

Table 4-22. Frequency Statistics of the Black spot locations.

Statistics		
Total Accident Number by Point Weightage / 3 yrs		
N	Valid	20
	Missing	0
Mean		59.2
Variance		694.2

The Highway Safety Manual (2010) specifically calls for the use of the Negative binomial model instead of Poisson model because the degree of over-dispersion in a negative binomial model is represented by a statistical parameter, known as the over-dispersion parameter that is estimated along with the coefficients of the regression equation. The larger the value of the over-dispersion parameter, the more the crash data vary as compared to a Poisson distribution with the same mean.

The study of two researchers have pointed out that negative binomial regression models has more desirable properties than Poisson models to describe the relationship between accident occurrence and road characteristics (Chin and Quddus, 2003). Additionally, the work of another researcher also proved that negative binomial model (or Poisson-Gamma) became a widely used model because it can handle over dispersed data (data where the variance of the frequencies is much greater than the mean) (Lord and Mannering, 2010). The works of many scholars also revealed that negative binomial model is an effective modeling type that can express the possible dispersion effect of the data using a dispersion parameter (Maycock and Hall, 1984; Miaou, 1994; Maher and Summersgill, 1996; Cameron and Trevedi, 1998; Park and Lord, 2007).

In conclusion, this research adopted Negative Binomial Regression (NBR) analysis for developing the relevant accident prediction model. Basically, the selection of the relevant modeling technique made its basis on two major facts. Primarily, negative binomial was found the better model to fit the given data. Besides, up on the basis of previous literatures, negative binomial is the most frequently used model in crash-frequency modelling. In addition, as it can be seen in Table 4-22 above, the mean value of the dependent variable (Accident number) was found much smaller than the variance. Hence, statistically speaking there exist over-dispersion effect on the given data and according to the SPSS result, the value of dispersion parameter was found 1.285.

4.6. Parameter Estimation

Maximum likelihood estimation method has been employed widely in estimating Poisson, negative binomial and zero inflated regression models. According to the definition of maximum likelihood estimation method the estimated parameters are best when the maximum value of likelihood is obtained (Landge, Jain & Parida, (2006)).

Therefore, the study adopted Maximum Likelihood Estimate approach (MLE) to estimate the mean and dispersion parameters and their corresponding standard errors and confidence limits. In addition, a study by Berhanu also used this approach for determining the regression coefficients of the significant explanatory variables (Berhanu, 2003). Additionally, the method is also preferred to the alternative estimator due to its properties of being consistent, asymptotically normal, and having minimum variances for large samples (White and Eberhardt, 1980).

Moreover, the coefficient of parameter estimates that maximizes the log-likelihood function was calculated using Newton-Raphson technique where it is an iterative method for solving non-linear equations, such as equations whose solution determines the point at which the function would be maximum. According to the conclusion revealed by two researchers, the likelihood ratio procedure is the relevant test that is commonly used to test the various hypothesis in the context of Negative Binomial distribution (White and Eberhardt, 1980). Table 4-23 through Table 4-25 presents the goodness of fit of the Poisson and Negative Binomial models along with the comparative analysis made in the aspects of fitting the given data well.

Table 4-23. Goodness of Fit of the given data in Poisson model.
Goodness of Fit^a

	Value	Df	Value/df
Deviance	66.178	16	4.136
Scaled Deviance	15.971	16	
Pearson Chi-Square	66.300	16	4.144
Scaled Pearson Chi-Square	16.000	16	
Log Likelihood ^{b,c}	-91.187		
Adjusted Log Likelihood ^d	-22.006		
Akaike's Information Criterion (AIC)	190.375		
Finite Sample Corrected AIC (AICC)	193.042		
Bayesian Information Criterion (BIC)	194.358		
Consistent AIC (CAIC)	198.358		

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUNturn, NAP, Eighty fifth PS, offset = LnAPHV

- a. Information criteria are in small-is-better form.
- b. The full log likelihood function is displayed and used in computing information criteria.
- c. The log likelihood is based on a scale parameter fixed at 1.
- d. The adjusted log likelihood is based on an estimated scale parameter and is used in the model fitting omnibus test.

Table 4-24. Goodness of Fit of the given data in Negative Binomial model.

Goodness of Fit^a

	Value	df	Value/df
Deviance	20.552	15	1.370
Scaled Deviance	15.989	15	
Pearson Chi-Square	19.280	15	1.285
Scaled Pearson Chi-Square	15.000	15	
Log Likelihood ^{b,c}	-80.335		
Adjusted Log Likelihood ^d	-62.500		
Akaike's Information Criterion (AIC)	170.671		
Finite Sample Corrected AIC (AICC)	174.956		
Bayesian Information Criterion (BIC)	175.649		
Consistent AIC (CAIC)	180.649		

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUNturn, NAP, Eighty fifth PS, offset = LnAPHV

- a. Information criteria are in small-is-better form.
- b. The full log likelihood function is displayed and used in computing information criteria.
- c. The log likelihood is based on a scale parameter fixed at 1.
- d. The adjusted log likelihood is based on an estimated scale parameter and is used in the model fitting omnibus test.

Table 4-25. Comparative analysis of Poisson and NB model.

Goodness of fit parameters	Value	
	Poisson	NB (MLE)
Deviance	66.178	20.552
Scaled Deviance	66.178	15.989
Pearson Chi-Square	66.300	19.280
Scaled Pearson Chi-Square	66.300	15.000
Log Likelihood ^b	-91.187	-80.335
Akaike's Information Criterion (AIC)	190.375	170.671
Finite Sample Corrected AIC (AICC)	193.042	174.956
Bayesian Information Criterion (BIC)	194.358	175.649
Consistent AIC (CAIC)	198.358	180.649

4.7. Model Development

As it was mentioned in the previous section of the paper the starting point in the model development process is a basic model containing the exposure variables only. So the exposure variable, the traffic volume, was kept relevant along with the selected geometric and traffic variables at Section 4.4 were subjected to model development process using negative binomial regression analysis. Consequently, the final accident prediction model incorporates four prevalent traffic and geometric variables among which one of them is of categorical type i.e availability of U-turn (AUT). While the other three are continuous variables such as number of access points (NAP), adjusted average peak hour traffic volume (APHV) and 85th percentile speed (85th%PS).

As per the explanation that was drawn by Elvik, (2007), the explanatory variables that are potentially relevant in accident prediction models can be placed in two categories: 1) variables describing exposure to accident risk, and 2) risk factors that influence the number of accidents expected to occur per unit of exposure. So, the traffic volume i.e APHV is considered as the exposure variable in the given data set, and its natural logarithm value was used as an offset variable in the model. However, the 85th percentile speed, availability of U-turn and number of access points are treated in the SPSS software package as the risk factors.

4.7.1. Model form

As per the citation made by Mustakim, (2005), the mathematical form used for any APM should satisfy two conditions. First, it must yield logical results, meaning it must not lead to the prediction of a negative number of accidents. Subsequently, it must ensure a prediction of zero accident frequency for zero values of the exposure variables, which, for road sections, are section length and traffic volume (AADT).

The second condition that must be satisfied by the model form is that, in order to use generalized linear regression in the modeling procedure, there must exist a known link function that can linearize this form for the purpose of coefficient estimation. These conditions are satisfied by a model form that consists of the product of powers of the exposure measures multiplied by an exponential incorporating the remaining explanatory variables. Such a model form can be linearized by the logarithm link function (Mustakim, 2005).

A comprehensive literature Review made by Elvik, (2007), concluded that the basic form of nearly all modern accident prediction models made as multivariate regression analyses is (Elvik, 2007):

$$E(\lambda) = \alpha * L^{\beta_1} * Q^{\beta_2} * e^{\sum \gamma_i * x_i} \dots \dots \dots \text{Equation 4.7.1(A)}$$

Where,

E (λ): The expected number of accidents;

L: Length of the road segment (if varies);

Q: Traffic volume;

X_i: Variables denoting risk factors; and

α, β₁, β₂ and γ_i: regression coefficients

The stated functional form was also employed by many researchers and scholars for developing the relevant accident prediction model (Mountain et al 1996; Fridstrom, 1999, Gaudry and Lassarre 2000, Ragnoy, Christensen and Elvik 2002, Greibe 2003). In addition, the estimated expected number of accidents, **E (λ)**, is a function of the exposure parameter i.e. the traffic volume, **Q**, and a set of risk factors, **X_i** (i = 1, 2, 3,n). The effect of traffic volume on the accidents is modelled in terms of an elasticity, that is a power, **β**, to which traffic volume is raised (Hauer, 1995). The elasticity shows the percentage change of the expected number of accidents, which is associated with a 1 percent change in traffic volume.

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

The effect of various risk factors that influence the probability of accident, given exposure, is generally modelled as an exponential function, that is as e (the base of natural logarithms) raised to sum of the product of coefficients, γ_i , and values of the variables, X_i , denoting risk factors. Choice of an exponential form is logical in view of the characteristics of Poisson distribution. More generally, since $E(\lambda)$ cannot be zero or negative, thus multiplicative models are the only ones that are admissible. (Elvik, 2007).

Thus, the log-linear equivalent of the basic form is:

$$\ln(E(\lambda)) = \alpha + \beta * \ln(Q) + \gamma_i * X_i \dots \dots \dots \text{Equation 4.7.1(B)}$$

Where α –

β – Coefficient of the exposure variable (Traffic volume)

Q – Traffic volume;

γ_i – Coefficients of risk factors; and

X – Risk factors

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Table 4-26. Coefficients of Variable estimates.

Parameter Estimates										
Parameter	B	Std. Error	95% Profile Likelihood Confidence Interval		Hypothesis Test			Exp(B)	95% Profile Likelihood Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	-9.754	.8323	-11.442	-8.012	137.352	1	.000	5.806E-005	1.073E-005	.000
[AUTurn=0]	-.511	.1359	-.804	-.234	14.117	1	.000	.600	.447	.792
[AUTurn=1]	0 ^a	.	.	.	.	.	.	1	.	.
NAP	-.158	.0696	-.300	-.009	5.173	1	.023	.854	.741	.991
Eighty fifth PS (Scale)	.105	.0150	.073	.135	48.829	1	.000	1.110	1.076	1.145
(Negative binomial)	.042	.0219	.013	.116						

NB: Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUTurn, NAP, Eighty fifth PS, offset = LnAPHV

a. Set to zero because this parameter is redundant.

b. Computed based on the Pearson chi-square.

Therefore, the accident prediction model that can be used to predict the accident frequency is presented in exponential function form as follows:

$$AN/3yr = APHV * e^{(-9.754 - 0.511 * (AUT) - 0.158 * (NAP) + 0.105 * (85th PS))} \dots \text{Equation 4.7.1(C)}$$

Where: APHV = Adjusted average peak hour Volume (Continuous);

AUT = Availability of U-turn (categorical): a value of “0” No and “1” for Yes;

NAP = Number of Access Point (Continuous); and

85th PS = the Eighty Fifth Percentile Speed (Continuous).

4.8. Discussions

The research was executed to develop an accident prediction model using the prevalent traffic and geometric explanatory variables using three principal arterial streets of Addis Ababa. The road networks were selected on the basis of their susceptibility for the occurrences of frequent number of accidents. In addition, the availability of resource, time and adequate accident database system were among the basic argument for selecting the stated road segments.

Accordingly, as per the adopted black spot definitions and subjective statistical consideration, top twenty (20) black spot locations were identified from fifty-two (52) divided samples. Besides, out of the twenty (20) black spot locations, twelve (12) of them were straight segments. In addition, severe type of accident was also higher on this type of road layouts. And the possible explanation is that drivers are susceptible to increase their maneuvering speed on straight segments as compared to curved features. Another similar study also proved that drivers tend to travel at higher speeds on straight road sections than on bends and the accident risk may be reduced with the increase in road curvature (Berhanu, 2003).

Moreover, as it was mentioned in the previous section, accident prediction model was developed for the selected principal arterial streets where the model was derived from negative binomial regression analysis by incorporating the prevalent traffic and geometric explanatory variables. And the adjusted average peak hour volume (APHV), the 85th percentile spot speed (85th PS), availability of U-turn (AUT), and number of access points (NAP) were found to be the significant explanatory variables.

Given the coefficient estimates of the parameters, number of access points shows unexpected result. i.e as the number of access points increases, the probability of occurrences of accident decreases. Two justifications can be drawn from the above mentioned results, one is, there might be an existence of under-reporting effect on the given crashes data (incomplete-reporting). A research by Kumara and Chin, (2005); Ma, (2009) revealed that count data models are likely to produce biased estimates when under-reporting is not considered in the model-estimation process. In addition, under-reporting crash data cannot be considered easily owing to the uncertainty in determining the magnitude of its rate for each severity level. In addition, a study by many scholars also assured that incomplete reporting of crash data has been known to be a major problem in highway safety analysis for many years (Elvik and Mysen, 1999) where fatal crashes are the most

likely to be reported, while no-injury collisions are the ones most likely not to be reported (Aptel et al., 1999). On the other hand, the other possible explanation is the likelihood in speed reduction at the adjoining location where major arterial road network meets with minor access roads.

In contrary, the regression analysis disclosed that the traffic volume parameter i.e. APHV have positive effect on the frequency of accident where an increase in 100 PCU will result in an increase in number of traffic accident by a figure of two (2), while holding the other variables constant. Similarly, the eighty fifth percentile speed (85th PS) has also positive relation with the dependent variable. Hence, as the 85th percentile speed increases, the frequency of road traffic accident also increases.

According to the explanation by Awal Mohammed, (2013), the interpretation of the estimated parameter coefficients is that, for a one-unit change in the continuous predictor variable, the log count of the expected parameter is expected to change by the respective coefficient, given the other variables in the model are held constant. So, a one-unit increase in the eighty fifth percentile spot speed (85th PS) will augment the log count of the accident frequency by a value of 1.11 whereas a one-unit increase in number of access point will make a reduction in the log count of the accident number by a magnitude of 0.854, given the other variables in the model are held constant.

In contrary, referring to the estimated exponential parameter (Exp(B)) of the significant categorical variable i.e. availability of U-turn as depicted in Table 4-26 infers that the probability of occurrence of accident on road section without U-turn opening is 0.6 times the probability resulting from the road segment with U-turn. The possible justification behind this result might be either the presence of under-reporting of crash data, which in turn results in lack of accuracy in deriving the coefficients of the parameter as it was expected by the research or drivers might get alerted when they are exposed to U-turn opening than segments with no opening.

In conclusion, the four explanatory variables, that were included in the final accident prediction model, have showed an acceptable significance figure i.e. below 0.05. Therefore, the three variables such as traffic volume (APHV), 85th percentile speed (85th PS), and availability of U-turn (AUT) were found significant at a respective value of 0.000 while number of access point (NAP) was a significant variable with a significancy value of 0.023. Further illustration about the significant variables of the model is presented on Table 4-27.

Table 4-27. The significant explanatory parameters along with their respective effects.

No	Explanatory variables	Assigned Code	Variable type	Significance value	Category	Effect
1	Average Peak Hour Volume	APHV	Continuous	0.000	Exposure	Positive
2	85 th Percentile Speed	85 th PS	Continuous	0.000	Risk factor	Positive
3	Availability of U-Turn	AUT	Categorical	0.000	Risk factor	Positive
4	Number of Access Point	NAP	Continuous	0.023	Risk factor	Negative

4.9. Assessment of Model Goodness of Fit

4.9.1. Goodness-of-fit test

Several types of goodness-of-fit measures were developed to check the significance of the model. Pearson Chi-squares, Deviance, Likelihood Ratio Test, Akaike Information Criteria (AIC) and Bayesian Schwartz Information Criteria (BIC) are among the possible testing approaches. But, the two most frequently employed measurements that are used to determine the goodness of fit of Generalized Linear Models are Pearson chi-square and the deviance methods (Abdul Aziz Jemain et al, 2006).

4.9.1.1. Pearson Chi-square test

The value at the **Value/df** column for the **Pearson Chi-Square** row is greater than 0.05, which is 1.285. Therefore, as per the specification the model does fit the data well.

i.e. P value = **1.285 > 0.05** thus the model does fit the given data.

Table 4-28 below presents the results of goodness of fit of the Negative Binomial model.

**Table 4-28. Results of Goodness of fit test.
Goodness of Fit^a**

	Value	df	Value/df
Deviance	20.552	15	1.370
Scaled Deviance	15.989	15	
Pearson Chi-Square	19.280	15	1.285
Scaled Pearson Chi-Square	15.000	15	
Log Likelihood ^{b,c}	-80.335		
Adjusted Log Likelihood ^d	-62.500		
Akaike's Information Criterion (AIC)	170.671		
Finite Sample Corrected AIC (AICC)	174.956		
Bayesian Information Criterion (BIC)	175.649		
Consistent AIC (CAIC)	180.649		

NB: Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUTurn, NAP, Eighty fifth PS, offset = LnAPHV

a. Information criteria are in small-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

c. The log likelihood is based on a scale parameter fixed at 1.

d. The adjusted log likelihood is based on an estimated scale parameter and is used in the model fitting omnibus test.

4.9.1.2. Deviance

Looking to Table 4-24, the value of scaled Pearson chi-square, deviance and degree of freedom are almost equal to 15. Therefore, as per the above speculated explanation, the model can be considered adequate.

4.9.1.3. Likelihood Ratio Test

Comparative analysis was executed to evaluate the goodness of fit of the model to the given data using Poisson and Negative Binomial (MLE) modeling techniques and the respective testing parameter values are presented in Table 4-29 below. The log likelihood figure of the Poisson and NB models is -91.187 and -80.335 respectively. Since the value of the negative binomial model is higher than that of the Poisson model, NB model is better and statistically significant approach for fitting the given data.

The deviance represents the residuals in fitting the data to the regression line and the lower the deviance value implies the better the model (Bipin Karki, 2014). Since the deviance value of the NB model is less than that of the Poisson, again the data better fits the negative binomial model. While value of deviance by degree of freedom for the Poisson model was 4.144, that is very much greater than the standard reference value i.e. 1. Hence, this value indicated that the Poisson model was over-dispersed and the over-dispersion effect should be handled relevantly by the NB model. Finally, looking to the AIC and BIC parameters, the negative binomial model shows the minimum figure and it was found the better model that fits the given data.

Table 4-29: Comparative Analysis of Poisson and NB Model.

Model	Deviance	Value/df	Log likelihood	AIC	BIC	Omnibus
Poisson	66.178	4.144	-91.187	190.375	194.358	0.000
NB	20.552	1.285	-80.335	170.671	175.649	0.000

4.9.1.4. AIC and BIC

A. AIC

For this measure, the smaller the AIC, the better the model is. Prior to the inclusion of the selected significant parameters in the NB model, i.e. when the analysis was executed without variables, the AIC value was estimated to be 193.94 while after the inclusion of the prevalent variables, its value was reduced to 170.61.

Therefore, it can be concluded that the parameters which were included in the final prediction model were suitable in representing the given traffic accident data.

B. BIC

As similarly as the AIC parameter, the BIC parameter also significantly fit the given data where minimum figure was achieved after the inclusion of the parameters. Thus, the magnitude of the BIC parameter during the inclusion of the selected variables became 175.65 but prior to the inclusion of the parameters its figure was estimated to be 195.93.

4.9.2. Omnibus test

As it can be seen in Table 4-30, the omnibus test value (P-value) of the given model is 0.00 which is below the specified value i.e 0.05. As such the model is said to be statistically significant.

Table 4-30. Results of Omnibus test.

Omnibus Test^a		
Likelihood Ratio Chi-Square	df	Sig.
22.771	3	.000

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUturn, NAP, Eighty fifth PS, offset = LnAPHV

a. Compares the fitted model against the intercept-only model.

4.9.3. Residuals

So, as it can be easily concluded from Figure 4-5, the entire observations are within the absolute value of two (2) for the confidence interval of 95%. Thus, the model does fit the given data in a relevant manner. Moreover, Figure 4-5 below illustrates the residual chart.

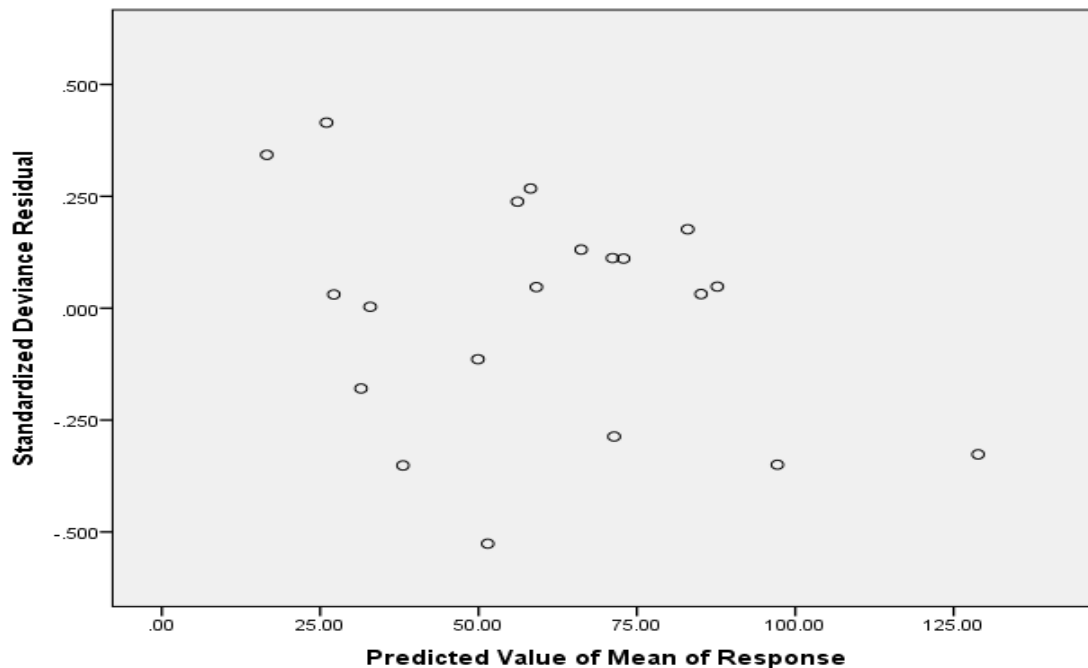


Figure 4-5. Residual chart.

4.9.4. Outliers

Normality and equal variance assumptions apply to negative binomial regression analyses. And one way of analyzing the outlier effect is performed by determining the validity of the standardized Pearson residual. Hence, up on the computation results of the SPSS software package, version 20, the individual standardize Pearson residual values of the selected blackspot locations are within the acceptable limits. i.e below the absolute values of 2. Therefore, it can be concluded that the given accident data doesn't comprise an outlier sample. Furthermore, the overall outlier analysis of the given data is presented in Table 4-31.

Table 4-31. Output of standardize Pearson residual.

Standardized Pearson Residual				
	Frequency	Percent	Valid Percent	Cumulative Percent
-1.777	1	5.0	5.0	5.0
-1.362	1	5.0	5.0	10.0
-1.336	1	5.0	5.0	15.0
-1.210	1	5.0	5.0	20.0
-1.105	1	5.0	5.0	25.0
-.632	1	5.0	5.0	30.0
-.445	1	5.0	5.0	35.0
.012	1	5.0	5.0	40.0
.113	1	5.0	5.0	45.0
.139	1	5.0	5.0	50.0
Valid .200	1	5.0	5.0	55.0
.214	1	5.0	5.0	60.0
.491	1	5.0	5.0	65.0
.496	1	5.0	5.0	70.0
.577	1	5.0	5.0	75.0
.809	1	5.0	5.0	80.0
1.071	1	5.0	5.0	85.0
1.216	1	5.0	5.0	90.0
1.233	1	5.0	5.0	95.0
1.712	1	5.0	5.0	100.0
Total	20	100.0	100.0	

CHAPTER 5 - CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSIONS

As it was identified and explained in the previous section, Section 4.3.2, twenty (20) segments were identified as found black spot locations among the divided fifty-two (52) road segments. The research also revealed that each specified black spot locations were experiencing high speeding vehicles, as compared to the proposed speed limit. Moreover, nine black spot locations were identified on a road network from *Bole* to *Meskel* square while seven black spot locations were located along Mexico to German square. In contrary, the road network from *Sarbet* to *Sost kutir mazoria* encompasses only four black spot segments.

The objective of the research was to develop an accident prediction model using the prevalent traffic and geometric explanatory variables. Hence, the adjusted average peak hour volume, the 85th percentile speed, availability of U-turn and number of access point were found as the significant parameters. Moreover, the accident prediction model was derived from generalized linear model (GLM), particularly, from negative binomial (NB) regression analysis.

According to the SPSS result, the coefficients of the 85th percentile speed showed positive relationship with the dependent variable, i.e. the frequency of accident where an increment in 85th percentile speed will increase the probability of occurrence of accident and vice versa. In addition, compared to the availability of U-turn along the road segment, the expected log count of segment without U-turn decreases by 0.511.

The variable 85th percentile speed has a coefficient of 0.105, which is statistically significant with a p-value of 0.000. And the coefficient implies, for each one-unit increase in the 85th percentile speed, the expected log count of frequency of accidents increases by 0.105. On the other hand, number of access point is significant with a coefficient of 0.158 and it infers that for a single unit increase in the number of access point, the log count of the dependent parameter i.e. the frequency of accident per three years decreases in 0.158.

5.2. RECOMMENDATION

The Addis Ababa City Road Authority (AACRA) and the National Ministry of Transport should give intense consideration towards allocating enough fund and improving the black spot locations as per the proposed countermeasures. Hence, it will be used as a helpful tool to reduce the occurrence of traffic accident due to the prevalent traffic and geometric parameters. In addition, pertinent governmental organizations should develop and apply suitable maintenance strategies to maintain the message signs and markings along the entire road networks of the city.

The appropriate road safety management agencies and institutions such as AATPMO, AARTMA and several institutions of the country should involve and play their significant roles in executing comprehensive studies for identifying black spot locations along the entire existing road networks of the country so as to set the respective low-cost countermeasures.

Moreover, the research revealed that the accident database storage system of the police stations follows a traditional system and it lacks quality in providing accurate information regarding the time, frequency, cause and specific location of the accident event. Hence, it is recommended to propose and implement well-structured and comprehensive computerized database system which is useful to encode data in detail and specific manner. Consequently, the data will be easily accessible and useful for several insurance companies, hospitals, transport agencies, and research institutions.

On the other hand, researchers should not waste their resources and time in search of input data (such as traffic, geometric design data etc.) for their studies. Instead, as likely as the methodology and approach of others countries, the available relevant stakeholder companies and governmental organization such as Ministry of Transport, ERA, AACRA, TPMO and RTMA should perform continuous assessment on the whole road networks of the country, and should provide the researchers with the required traffic volume and geometric related data.

CHAPTER 6 - DEVELOPMENT OF COUNTERMEASURES

In general, accident countermeasure implementation is divided into two major categories; i.e. high cost accident countermeasure which is a long term countermeasure and the other one is low cost countermeasure which is a short term countermeasure (Azwan Ezzany Azmi, Sm Amirullah Zainal, 2005). But this paper mainly discusses about low cost countermeasures at accident blackspots where it is defined as simple low cost measures which can significantly improve road safety problems at hazardous sites. This countermeasure is set to tackle road safety matters related to engineering, enforcement, education as well as encouragement. Besides, low cost countermeasure at accident blackspot programs mainly focused on accident blackspot elimination by the engineering approaches. Moreover, research results in the United States, Europe, and Australia have consistently proved that highway and traffic engineering countermeasures can highly be cost effective and easy to implement (Berhanu, 2000).

According to the analysis made, over speeding was the common and critical reason for the occurrences of frequent number of accidents along the selected black spot locations. Hence, it is advisable to provide the road users with relevant and continuous awareness regarding the concept of over-speeding effect on road safety aspects.

Generally, in light of an engineering setting, it is recommended to provide messaging sign and marking such as speed limits signs, speed calming measures, stop/yield control and right turn signs etc. Particularly, stop/yield control and right turn signs should be placed at the locations where minor access points join/leave the principal arterial street. While as per the results of accident data analysis, out of 20 black spot locations, 12 of them were categorized under straight road segments. Consequently, it is advisable to provide proper speed limit signs and calming measures along the segments, which in turn help drivers to reduce their speed and maintain the required minimum gap with other vehicles in safe and relevant manner. [Appendix J](#) presents with the observed problems and recommended countermeasures at the individual black spot locations.

CHAPTER 7 - DIRECTION OF FUTURE RESEARCH

This research figured out and suggested four critical issues that should be considered under the scope of future related studies. Hereafter, these four relevant issues are presented in detail under four independent sub topics such as research scope, explanatory variables, data collection methodology and finally selection of modeling type.

Research Scope: - this study focused mainly on three principal arterial road networks of Addis Ababa. Hence, the scope of the research is limited to road sections which have similar functional classifications, traffic and geometric characteristics. Therefore, it is better to execute further researches by incorporating more principal arterial streets. Moreover, it is also advisable to make further studies on other functional classification types such as sub-arterial streets, collectors, feeder roads etc.

Explanatory variables: - this research made its study by adopting the presumed traffic and geometric related explanatory variables; therefore, there is lack of accuracy in describing the accident pattern of the road networks in an exhaustive manner. Hence, it is useful to make a comprehensive research on similar topics by incorporating many more explanatory variables.

Data Collection Methodology: - the traffic volume studies were performed on the presumed two representative week days (Tuesday and Thursday), where 6-hour counts have been made for the respective day for about eight consecutive fifty minutes' interval count at the morning, mid-day and evening peak. Adjusted average peak hour volume was fetched from respective stations for developing the accident prediction model. Conversely, it is advisable to make similar studies by performing long duration traffic count. Moreover, data regarding the spot speed studies were collected using stop watch method, as a result some errors were expected to occur. Subsequently, in light of providing better prediction model, it is advisable to use radar meter or pneumatic road tube method for determining the exact spot speeds of the road segments.

Selection of Modelling type: - since the given accident data experiences an over-dispersion effect, the relevant accident prediction model was derived from negative binomial regression analysis. Conversely, the study suggested that it is advisable to make comparative studies using several modeling methods. Thus, one might be able to find another approach that will be better in handling the over-dispersion effect of the given data.

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APPENDIXES

Appendix A: - Adopted formats of the research.

- A.1. Accident recording format with sample data.
- A.2. Traffic volume counting format with sample data.
- A.3. Six-hour traffic volume counts summary format.
- A.4. Spot Speed Recording Format with Sample Data.
- A.5. Road Geometry Inspection Checklist with Sample Data.

Appendix B: - Accident analysis summary along Mexico – German Square.

- B.1. Accident Number Vs Temporal Variation.
- B.2. Accident Number Vs Causes of accident.
- B.3. Accident Number Vs Collision Type.
- B.4. Accident Number Vs Vehicle Involved in Accident.
- B.5. Accident Number Vs Their Location.

Appendix C: - Accident analysis summary along ‘Sarbet’ – ‘Sost kutir mazoria’.

- C.1. Number of Accidents with Temporal Variation.
- C.2. Number of Accidents with Nature of Accident cause.
- C.3. Number of Accidents according to Collision Type.
- C.4. Number of Accidents according to Type of Vehicle Involved in Accident.
- C.5. Number of Accidents according to Accident Location.

Appendix D: - Summarized traffic volume Analysis of ‘Bole’ – ‘Meskel square’.

- D.1. Summarized traffic volume Analysis @ Friendship Business center.
- D.2. Summarized traffic volume Analysis @ Bole Printing Press.
- D.3. Summarized traffic volume Analysis @ Sunshine Laundry.

Appendix E: - Summarized traffic volume Analysis of Mexico square – German square.

- E.1. Summarized traffic volume Analysis @ Ethiopian Tobacco Enterprise.
- E.2. Summarized traffic volume Analysis @ International Evangelical Church.
- E.3. Summarized traffic volume Analysis @ Vatican Embassy.
- E.4. Summarized traffic volume Analysis @ Mekane Eyesus Management School.

Appendix F: - Summarized traffic volume Analysis of ‘Sarbet’ – ‘Sost kutir mazoria’.

- F.1. Summarized traffic volume Analysis @ Tomocca Coffee.
- F.2. Summarized traffic volume Analysis @ Austria Embassy.
- F.3. Summarized traffic volume Analysis @ Dimma Cultural restaurant.

Appendix G: - Sample Spot speed computation

- F.1. Sample spot speed analysis along Bole – Meskel square.
- F.2. Sample spot speed analysis along Mexico square – German square.
- F.3. Sample spot speed analysis along Sarbet – Sost kutir mazoria.

Appendix H:- Output of Negative Binomial Analysis using SPSS.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Appendix A: - Adopted Formats of the Research.

A.1. Manual Accident Recording Format with Sample Data.

No	Date	Hour	Accident Cause	Accident Type	Victim Info		Vehicle Type	Accident Location	Severity Level	Sub city	Description
					Gender	Age					
29	14/6/16	14:40	Over turning	VV			pick-up	olompica	P	Bole	Roundabout
30	17/6/16	14:30	Mini. Gap	VV			Lada-Lexi	"	P	"	"
31	"	14:50	wheel to left	VV			Corolla	"	P	"	"
32	"	20:00	priority	VV			Vitara	"	P	"	"
33	18/6/16	14:10	Mini. Gap	VV			Auto	wolosefer	P	"	"
34	"	16:00	"	VV			Corolla	Sherochko	P	kirke	"
35	17/6/16	18:00	Priority	VP	M	27	Mitsubu	Mooa Bis	L	Bole	"
36	19/6/16	8:25	Priority	VP	M	25	"	Filaminco	L	kirke	"
37	20/6/16	21:45	"	VP	M	38	"	Dembel	S	"	"
38	"	12:00	"	VP	M	15	Yarda	wolo sefer	S	Bole	"
39	21/6/16	11:54	wheel to right	VV			Mitsubu	Dembel	P	kirke	"
40	24/6/16	08:00	Mini. Gap	VV			Land crawler	Filaminco	P	"	"
41	"	11:50	Reckless	VP	M	60	Mitsubu	(Gozeloo)	L	Bole	"
42	"	15:00	Rear driving	VV			Mitsubu	Jushike	P	kirke	"
43	25/6/16	16:50	Mini. Gap	VV			"	Filaminco	P	"	"
44	26/6/16	08:36	pass to right	VV			"	Seawitit	P	"	"
45	"	06:45	priority	VP	M	19	pick-up	Mpedlane	S	Bole	"
46	27/6/16	16:40	"	VP	M	38	Volswagen	Filaminco	L	kirke	"
47	"	24:30	wheel to right	VO			Mitsubu	Dembel	P	"	"
48	28/6/16	16:15	pass to right	VV			"	wolosefer	P	Bole	"
49	"	14:00	Mini. Gap	VV			Mitsubu	Aran Cirke	P	"	"
50	"	06:45	wheel to left	VV			Auto	Dembel	P	kirke	"
51	"	10:00	priority	VP	M	60	pick-up	Filaminco	P	"	"
52	29/6/16	17:50	Overload	VO			truck	wolosefer	P	Bole	"
53	"	03:50	wheel to left	VO			Auto	"	P	"	"
54	30/6/16	22:50	" " right	VV			"	Dembel	P	kirke	"
55	1/7/16	10:30	Mini. Gap	VV			Mercede	wolosefer	P	Bole	"

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

A.2. Encoded Accident Recording Format with Sample Data.

No	Date (Ethiopia)	Accident time	Accident cause	Accident type	Collision type	Accident location	Victim Info		Severity	Vehicle type	Sub- City
							Gender	Age			
1	2/5/2006	8:00	Priority	VP	Hit Pedestrian	Olompiya	F	8	L	Yaris	Kirkos
2	2/5/2006	14:30	Minimum Gap	VV	Hit from back	Welosefer			P	Nissan	Kirkos
3	2/5/2006	10:48	Minimum Gap	VVP	Hit Pedestrian	Getu Commercial	M	26	L	Cobra	Kirkos
4	3/5/2006	10:00	Minimum Gap	VV	Hit from back	Picoc			P	Automobile	Kirkos
5	3/5/2006	20:00	Priority	VV	Hit from back	Mega Building			P	Dolphin	Kirkos
6	7/5/2006	11:50	Rear Driving	VV	Hit from side	Sunshine Building			P	Corolla	Kirkos
7	8/5/2006	11:00	Minimum Gap	VV	Hit from back	Sunshine Building			P	Minibus	Kirkos
8	9/5/2006	13:10	Overtuning	VV	Hit from side	Welosefer			P	Automobile	Kirkos
9	10/5/2006	11:25	Minimum Gap	VV	Hit from back	Filamingo			P	Dx	Kirkos
10	10/5/2006	9:15	Minimum Gap	VV	Hit from back	Bole Printing			P	Dx	Kirkos
11	22/5/2006	16:00	Minimum Gap	VV	Hit from back	Welosefer			P	Rava 4	Kirkos
12	12/5/2006	19:50:00	Priority	VV	Hit from back	Filamingo			P	Minibus	Kirkos
13	12/5/2006	17:30:00	Wheel to Z Left	VOPa	Hit fix object	Olompiya			P	Pick up	Kirkos
14	19/5/2006	10:55	Standing from rest	VV	Hit from back	Mega Building			P	Automobile	Kirkos
15	23/5/2006	19:30	Minimum Gap	VV	Hit from back	Filamingo			P	Dx	Kirkos
16	23/5/2006	13:00	Overtuning	VVPa	Hit from side	Filamingo	2M, F		L	Yaris	Kirkos
17	24/5/2006	1:00	Minimum Gap	VV	Hit from back	Welosefer			P	Pick up	Kirkos
18	3/6/2006	1:30	Overtuning	VV	Hit from side	Welosefer			P	Land Cruiser	Kirkos
19	3/6/2006	15:40	Priority	VV	Hit from back	Welosefer			P	Automobile	Kirkos
20	5/6/2006	17:55	Minimum Gap	VV	Hit from back	Sunshine Building			P	Automobile	Kirkos
21	7/6/2006	12:15	Passing with right	VV	Hit from side	Filamingo			P	Corolla	Kirkos

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

A.4. Six-Hour Traffic Volume Counts Summary Format.

Period	Time	Vehicle type							
		Small cars	Medium Bus	Bus	Medium truck	Heavy truck	Articulated truck	Motorcycle	Bicycle
Morning Peak	7:00 – 7:15								
	7:15 – 7:30								
	7:30 – 7:45								
	7:45 – 8:00								
	8:00 – 8:15								
	8:15 – 8:30								
	8:30 – 8:45								
	8:45 – 9:00								
Midday peak	12:00 – 12:15								
	12:15 – 12:30								
	12:30 – 12:45								
	12:45 – 1:00								
	1:00 – 1:15								
	1:15 – 1:30								
	1:30 – 1:45								
	1:45 – 1:00								
Afternoon peak	4:00 – 4:15								
	4:15 – 4:30								
	4:30 – 4:45								
	4:45 – 5:00								
	5:00 – 5:15								
	5:15 – 5:30								
	5:30 – 5:45								
	5:45 – 6:00								
Total									

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

A.5. Spot Speed Recording Format with Sample Data.

Date: June 6 th , 2017		Start Time: 10:00 AM										
Road Network: Bole to Meskel Square		End Time: 10:30 AM										
Black spot station ID: BMT 07		Weather: Day & Good										
Posted Speed Limit: 50 km/hr												
Seconds	Km/hr for 53.6 m.	Smaller Cars		Bus		Medium Truck		Heavy Truck		Articulated Truck		Total
		Record	No.	Record	No.	Record	No.	Record	No.	Record	No.	
7	27.6											
6.8	28.4											
6.6	29.2											
6.4	30.2											
6.2	31.1											
6	32.2											
5.8	33.3											
5.6	34.5											
5.4	35.7											
5.2	37.1											
5	38.6											
4.8	40.2	|||||	5									
4.6	41.9	|||	3									
4.4	43.9	||	2									
4.2	45.9	|||||	5									
4	48.2	|||||	4									
3.8	50.8	|||	3	|	1			|||	3	|	1	
3.6	53.6	|||||	4	||	2	|||	3	|	1			
3.4	56.8	|||||||	10	|	1	|	1					
3.2	60.3	|||||||	7	|||||	6	||	2	||	2			
3	64.3	|||||||	6					|||	4			
2.8	68.9	|||||||	6	|	1	|||	3	|	1			
2.6	74.2	|||||||	6	||	2							
2.4	80.4	|||||	5									
2.2	87.7											
2	96.5											
Total			66		13		9		11		1	100

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

A.6. Road Geometry Inspection Checklist with Sample Data.

No	Black Spot Station ID: BM 07						
	Road Network ID:- BM		From: Bole		To: Market Square		
1	Presence of median	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>				
2	Road Layout	Straight Segment <input checked="" type="checkbox"/>		Vertical Curve <input type="checkbox"/>	Horizontal Curve <input type="checkbox"/>		
3	Median type	Flat <input type="checkbox"/>		Raised <input checked="" type="checkbox"/>		Flushed <input type="checkbox"/>	
4	Median width	2.90 meter					
5	Walkway width	4.95 meter					
6	No of Lane	Two <input type="checkbox"/>	Three <input type="checkbox"/>	Four <input checked="" type="checkbox"/>	Five <input type="checkbox"/>		
7	Lane width	3.60 meter					
8	U-turn Availability	Availability		Number			
		Yes <input type="checkbox"/>	No <input checked="" type="checkbox"/>	One <input type="checkbox"/>	Two <input type="checkbox"/>	Three <input type="checkbox"/>	Four <input type="checkbox"/>
9	Access Points	Availability		Number			
		Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	One <input type="checkbox"/>	Two <input type="checkbox"/>	Three <input checked="" type="checkbox"/>	Four <input type="checkbox"/>
10	Land Use	Commercial <input checked="" type="checkbox"/>		Residential <input type="checkbox"/>		Office <input type="checkbox"/>	
11	Obstruction	Masts <input type="checkbox"/>	Signs <input type="checkbox"/>	Trees <input type="checkbox"/>	Stones <input checked="" type="checkbox"/>	Buildings <input type="checkbox"/>	Others <input type="checkbox"/>
12	Message Signing	Availability		State			
		Yes <input type="checkbox"/>	No <input checked="" type="checkbox"/>	Poor <input type="checkbox"/>	Fair <input type="checkbox"/>	Good <input type="checkbox"/>	
13	Message Marking	Availability		State			
		Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	Poor <input checked="" type="checkbox"/>	Fair <input type="checkbox"/>	Good <input type="checkbox"/>	

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Appendix B: - Accident Analysis Summary Along Mexico – German Square.

B.1. Accident Number Vs Temporal Variation.

Number of Accidents with Temporal Variation							
Time	Fatal	Severe Injury	Slight Injury	Damage to property	Total	%age	Rank
06:00 – 07:00	1	1	2	9	13	1.69	18
07:00 – 08:00	0	5	7	35	47	6.12	5
08:00 – 09:00	0	4	5	42	51	6.64	3
09:00 – 10:00	0	3	10	31	44	5.73	11
10:00 – 11:00	2	2	3	49	56	7.29	1
11:00 – 12:00	0	4	7	39	50	6.51	4
12:00 – 13:00	1	4	3	37	45	5.86	9
13:00 – 14:00	2	4	4	20	30	3.91	15
14:00 – 15:00	4	6	4	32	46	5.99	7
15:00 – 16:00	2	5	6	34	47	6.12	5
16:00 – 17:00	0	6	6	41	53	6.90	2
17:00 – 18:00	1	5	5	35	46	5.99	7
18:00 – 19:00	2	6	4	22	34	4.43	13
19:00 – 20:00	0	6	9	30	45	5.86	9
20:00 – 21:00	1	1	2	19	23	2.99	16
21:00 – 22:00	0	2	3	26	31	4.04	14
22:00 – 23:00	0	0	6	12	18	2.34	17
23:00 – 24:00	0	4	4	28	36	4.69	12
24:00 – 01:00	0	2	2	6	10	1.30	20
01:00 – 02:00	0	0	1	3	4	0.52	24
02:00 – 03:00	0	1	1	6	8	1.04	22
03:00 – 04:00	1	0	0	4	5	0.65	23
04:00 – 05:00	0	0	0	4	4	0.52	24
05:00 – 06:00	0	0	1	9	10	1.30	20
Unknown	0	0	0	12	12	1.56	19
Total	17	71	95	585	768		

B.2. Accident Number Vs Causes of accident.

Accident Classified According to Nature of causes of accident							
Traffic Violation Type	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age	Rank
Door Opening	0	0	0	2	2	0.26	11
Minimum Gap	0	9	25	194	228	29.69	1
Off the Road	0	4	4	16	24	3.13	7
Overload	0	0	0	0	0	0.00	14
Overtuning	0	2	2	23	27	3.52	6
Passing with right	0	0	0	11	11	1.43	9
Priority	17	30	37	116	200	26.04	2
Rear Driving	0	3	5	46	54	7.03	5
Reckless Driving	0	2	2	10	14	1.82	8
Standing from Rest	0	0	1	9	10	1.30	10
Technical problem	0	0	1	0	1	0.13	12
Violating traffic sign	0	0	0	1	1	0.13	12
Wheel to Z Left	0	10	7	66	83	10.81	4
Wheel to Z Right	0	11	11	91	113	14.71	3
Total	17	71	95	585	768	100.00	

B.3. Accident Number Vs Collision Type.

Accident Classified According to Type of Collision						
Type of Collision	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Hit from Front	0	2	4	44	50	6.51
Hit from Back	0	14	32	269	315	41.02
Hit from Side	0	22	27	224	273	35.55
Hit Fix Object	0	5	4	45	54	7.03
Hit Pedestrian	17	28	26	0	71	9.24
Crashed down	0	0	2	3	5	0.65
Total	17	71	95	585	768	100

B.4. Accident Number Vs Vehicle Involved in Accident.

Accident Classified According to Type of Vehicle Involved in Accident							
Type of Vehicle	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	% age	Rank
Smaller Cars	14	58	77	447	596	58.20	1
Bus	0	3	2	22	27	2.86	4
Medium Truck	1	2	7	34	44	4.43	3
Heavy Truck	1	7	7	61	76	7.94	2
Articulated Truck	1	0	2	15	18	1.95	5
Machine	0	1	0	1	2	0.13	7
Motorcycle	0	0	0	1	1	0.13	7
Bajaj	0	0	0	4	4	0.52	6
Total	17	71	95	585	768	100	

B.5. Accident Number Vs Their Location.

Accident Location	Station ID	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Amigo café	MG 20	1	5	9	53	68	2.55
Mekanisa Areke Factory	MG 17	6	9	6	38	59	2.21
Azad Building	MG 09	0	0	2	5	7	0.26
Emewedesh Building	MG 06	0	0	1	3	4	0.15
Evangelical Church	MG 06	0	0	0	2	2	0.07
Vatican Gibson school	MG 13	0	2	2	13	17	0.64
Indonesia Embassy	MG 11	0	0	1	1	2	0.07
Austria Diplomat Residence	MG 03	0	0	0	1	1	0.04
Infront of Eth.Revenue	MG 22	1	3	6	43	53	1.99
Infront of Mekane Eyesus	MG 14	2	7	16	60	85	3.18
Infront of Mekanisa Condo.	MG 20	1	5	7	35	48	1.80
Infront of METEC	MG 05	0	1	3	17	21	0.79
Mekanisa Primary School	MG 18	3	12	14	80	109	4.08
Mekanisa Taxi tera	MG 19	1	0	1	3	5	0.19
Mela Building	MG 12	0	0	0	1	1	0.04
Penn Building	MG 11	0	1	1	1	3	0.11
Pepsi Sarbet	MG 06	0	6	3	60	69	2.59
Sarbet tele	MG 06	0	4	2	22	28	1.05
Sudan Embassy	MG 02	0	3	2	19	24	0.90
Vatican Embassy	MG 11	2	12	17	128	159	5.96
Wib Building	MG 12	0	1	0	2	3	0.11
Total		17	71	95	585	768	100

Appendix C: - Accident Analysis Summary Along Sarbet – Sost Kutir Mazoria.

C.1. Number of Accidents with Temporal Variation.

Time	Fatal	Severe Injury	Slight Injury	Damage to property	Total	%age
06:00 – 07:00	0	0	1	5	6	1.26
07:00 – 08:00	2	1	0	20	23	4.82
08:00 – 09:00	0	0	0	37	37	7.76
09:00 – 10:00	1	0	1	22	24	5.03
10:00 – 11:00	0	0	1	32	33	6.92
11:00 – 12:00	0	1	2	23	26	5.45
12:00 – 13:00	0	4	0	31	35	7.34
13:00 – 14:00	0	1	1	18	20	4.19
14:00 – 15:00	0	0	3	21	24	5.03
15:00 – 16:00	1	3	1	25	30	6.29
16:00 – 17:00	0	0	2	38	40	8.39
17:00 – 18:00	0	1	0	21	22	4.61
18:00 – 19:00	0	0	1	24	25	5.24
19:00 – 20:00	1	1	2	27	31	6.50
20:00 – 21:00	0	0	0	13	13	2.73
21:00 – 22:00	2	1	2	26	31	6.50
22:00 – 23:00	0	1	0	8	9	1.89
23:00 – 24:00	0	0	2	15	17	3.56
24:00 – 01:00	0	1	0	9	10	2.10
01:00 – 02:00	0	0	1	6	7	1.47
02:00 – 03:00	0	0	0	3	3	0.63
03:00 – 04:00	0	0	0	0	0	0.00
04:00 – 05:00	0	3	1	0	4	0.84
05:00 – 06:00	0	2	0	5	7	1.47
Unknown	0	0	0	0	0	0.00
Total	7	20	21	429	477	100.00

C.2. Number of Accidents with Nature of Accident cause.

Traffic Violation Type	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Door Opening	0	0	0	0	0	0
Minimum Gap	0	2	1	147	150	31.45
Off the Road	0	0	0	8	8	1.68
Overload	0	0	0	1	1	0.21
Overtuning	0	0	0	5	5	1.05
Passing with right	0	0	1	19	20	4.19
Priority	7	16	16	105	144	30.19
Rear Driving	0	0	0	32	32	6.71
Reckless Driving	0	0	2	14	16	3.35
Standing from Rest	0	0	0	5	5	1.05
Technical problem	0	0	0	0	0	0.00
Violating traffic sign	0	0	0	0	0	0.00
Wheel to Z Left	0	0	1	33	34	7.13
Wheel to Z Right	0	2	0	60	62	13.00
Total	7	20	21	429	477	100.00

C.3. Number of Accidents according to Collision Type.

Type of Collision	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	%age
Hit from Front	0	0	0	29	29	6.08
Hit from Back	0	4	0	219	223	46.75
Hit from Side	0	2	4	156	162	33.96
Hit Fix Object	0	0	0	24	24	5.03
Hit Pedestrian	7	14	15	0	36	7.55
Crashed down	0	0	2	1	3	0.63
Total	7	20	21	429	477	100

C.4. Number of Accidents according to Type of Vehicle Involved in Accident.

Type of Vehicle	Fatal	Severe Injury	Slight Injury	Damage to Property	Total	% age
Smaller Cars	5	16	18	354	393	74.21
Bus	1	1	1	12	15	2.52
Medium Truck	1	1	1	24	27	5.03
Heavy Truck	0	0	1	24	25	5.03
Articulated Truck	0	1	0	10	11	2.10
Machine	0	0	0	2	2	0.42
Motorcycle	0	1	0	3	4	0.63
Total	7	20	21	429	477	100

C.5. Number of Accidents according to Accident Location.

Accident Location	Station ID	Fatal	Severe Injury	Slight Injury	Damage to Property	Total
Biserate Gebriel	SS 09	2	7	6	164	179
Canada Embassy	SS 01	0	1	0	18	19
Dima Hotel	SS 13	2	4	6	50	62
Eth.Medi. Factory	SS 14	0	3	2	60	65
Infront of INSA	SS 08	1	0	0	6	7
Lafto Mall	SS 10	0	1	2	18	21
B. Gebriel Mulmul Bakery	SS 09	0	1	0	13	14
Samet Restaurant	SS 07	1	1	2	26	30
Shoa Supermarket (Bis. Geb)	SS 11	0	2	3	16	21
South Africa Embassy	SS 07	1	0	0	58	59
Yod Abissinia	SS 04	0	0	0	1	1
Total		7	20	21	429	477

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Appendix D: - Summarized Traffic Volume Analysis of *Bole – Meskel Square*.

D.1. Summarized traffic volume Analysis @ Friendship Business center.

Station ID :- Section 1	Friendship Bussines Center					
APHV	4729					
Time	Direction		Total	Max of 15 minutes	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	351	467	817	1216		4729
07:15-07:30	405	497	902			
07:30-07:45	521	524	1045			
07:45-08:00	578	536	1114		3878	
08:00-08:15	511	574	1085			
08:15-08:30	556	503	1059			
08:30-08:45	537	541	1078			
08:45-09:00	454	493	947		4169	
12:00-12:15	443	443	885			
12:15-12:30	517	435	952			
12:30-12:45	548	496	1043			
12:45-01:00	541	480	1021		3902	
1:00 - 1:15	485	502	986			
1:15 - 1:30	543	450	994			
1:30 - 1:45	448	450	898			
1:45 - 2:00	462	473	935		3813	
4:00 - 4:15	551	543	1095			
4:15 - 4:30	493	550	1043			
4:30 - 4:45	497	496	993			
4:45 - 5:00	586	525	1111		4241	
5:00 - 5:15	573	577	1150			
5:15 - 5:30	665	551	1216			
5:30 - 5:45	715	498	1213			
5:45 - 6:00	632	518	1150		4729	
Total	12610	12122	24732			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

D.2. Summarized Traffic Volume Analysis @ Bole Printing Press.

Station ID :- Section 2	Bole Printing Press					
APHV	4491					
Time	Direction		Total	Max of 15 minutes	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	443	445	888	1183		4491
07:15-07:30	470	478	948			
07:30-07:45	538	522	1060			
07:45-08:00	533	565	1098		3994	
08:00-08:15	572	611	1183			
08:15-08:30	495	563	1058			
08:30-08:45	523	543	1066			
08:45-09:00	490	529	1019		4327	
12:00-12:15	515	504	1019			
12:15-12:30	495	481	976			
12:30-12:45	477	531	1007			
12:45-01:00	517	486	1003		4006	
1:00 - 1:15	535	453	989			
1:15 - 1:30	489	455	945			
1:30 - 1:45	495	482	978			
1:45 - 2:00	476	500	976		3887	
4:00 - 4:15	478	551	1028			
4:15 - 4:30	537	544	1081			
4:30 - 4:45	491	572	1063			
4:45 - 5:00	571	553	1124		4296	
5:00 - 5:15	617	543	1160			
5:15 - 5:30	566	533	1099			
5:30 - 5:45	572	568	1140			
5:45 - 6:00	584	508	1092		4491	
Total	12478.5	12522.45	25001			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

D.3. Summarized Traffic Volume Analysis @ Sunshine Laundry.

Station ID :- Section 3	Sunshine Laundry					
APHV	4319					
	Direction		Total	Max of 15 minutes	Hourly Volume	Max of HV
Time	South bound	North bound				
07:00-07:15	409	422	831	1141		4319
07:15-07:30	422	437	859			
07:30-07:45	475	531	1006			
07:45-08:00	556	562	1119		3815	
08:00-08:15	547	538	1085			
08:15-08:30	532	531	1063			
08:30-08:45	530	554	1084			
08:45-09:00	510	474	984		4216	
12:00-12:15	438	462	900			
12:15-12:30	445	446	891			
12:30-12:45	426	471	897			
12:45-01:00	432	452	884		3572	
1:00 - 1:15	471	493	964			
1:15 - 1:30	487	477	964			
1:30 - 1:45	527	498	1025			
1:45 - 2:00	482	481	963		3916	
4:00 - 4:15	521	516	1037			
4:15 - 4:30	539	543	1082			
4:30 - 4:45	513	546	1059			
4:45 - 5:00	572	568	1141		4319	
5:00 - 5:15	554	484	1038			
5:15 - 5:30	527	576	1104			
5:30 - 5:45	520	513	1033			
5:45 - 6:00	496	545	1041		4216	
Total	11933	12120	24053			

Appendix E: - Summarized Traffic Volume Analysis of Mexico square – German Square.

E.1. Summarized Traffic Volume Analysis @ Ethiopian Tobacco Enterprise.

Station ID :- Section 1	Ethiopian Tobacco Enterprise					
Average of two days						
Time	Direction		Total	Max of 15 minute	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	417	412	829	964		3735
07:15-07:30	436	422	858			
07:30-07:45	485	418	903			
07:45-08:00	485	469	954		3544	
08:00-08:15	483	440	924			
08:15-08:30	464	464	928			
08:30-08:45	431	443	874			
08:45-09:00	447	415	862		3588	
12:00-12:15	449	491	940			
12:15-12:30	439	393	832			
12:30-12:45	418	405	823			
12:45-01:00	421	438	859		3453	
1:00 - 1:15	419	379	798			
1:15 - 1:30	414	390	804			
1:30 - 1:45	431	410	840			
1:45 - 2:00	401	406	807		3249	
4:00 - 4:15	441	406	847			
4:15 - 4:30	461	400	861			
4:30 - 4:45	513	425	938			
4:45 - 5:00	471	476	948		3594	
5:00 - 5:15	520	434	954			
5:15 - 5:30	461	503	964			
5:30 - 5:45	498	443	941			
5:45 - 6:00	449	427	875		3735	
Total	10853	10309	21161			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

E.2. Summarized Traffic Volume Analysis @ International Evangelical Church.

Station ID :- Section 2	International Evangelical Church					
Average of two days						
Time	Direction		Total	Max of 15 minute	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	337	376	713	856		3167
07:15-07:30	350	400	750			
07:30-07:45	379	396	775			
07:45-08:00	408	409	817		3055	
08:00-08:15	350	466	816			
08:15-08:30	407	410	817			
08:30-08:45	351	429	779			
08:45-09:00	332	423	756		3167	
12:00-12:15	307	352	659			
12:15-12:30	375	438	813			
12:30-12:45	360	323	682			
12:45-01:00	341	300	641		2794	
1:00 - 1:15	295	235	530			
1:15 - 1:30	298	336	635			
1:30 - 1:45	325	303	628			
1:45 - 2:00	330	374	704		2497	
4:00 - 4:15	378	346	724			
4:15 - 4:30	381	326	707			
4:30 - 4:45	412	310	722			
4:45 - 5:00	417	375	793		2946	
5:00 - 5:15	374	336	710			
5:15 - 5:30	465	391	856			
5:30 - 5:45	431	345	776			
5:45 - 6:00	350	291	640		2982	
Total	8752	8690	17441			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

E.3. Summarized Traffic Volume Analysis @ Vatican Embassy.

Station ID :- Section 3	Vatican Embassy					
Average of two days						
Time	Direction		Total	Max of 15 minute	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	304	304	608	746		2828
07:15-07:30	343	355	698			
07:30-07:45	336	368	704			
07:45-08:00	341	385	726		2735	
08:00-08:15	354	339	693			
08:15-08:30	370	341	711			
08:30-08:45	334	343	676			
08:45-09:00	318	308	626		2706	
12:00-12:15	283	298	581			
12:15-12:30	306	305	610			
12:30-12:45	332	389	721			
12:45-01:00	309	359	669		2581	
1:00 - 1:15	328	348	676			
1:15 - 1:30	312	337	649			
1:30 - 1:45	312	355	666			
1:45 - 2:00	318	289	607		2599	
4:00 - 4:15	317	306	623			
4:15 - 4:30	321	322	644			
4:30 - 4:45	287	371	658			
4:45 - 5:00	364	382	746		2671	
5:00 - 5:15	356	332	688			
5:15 - 5:30	391	351	742			
5:30 - 5:45	350	383	733			
5:45 - 6:00	340	325	665		2828	
Total	7928	8192	16120			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

E.4. Summarized Traffic Volume Analysis @ Mekane Eyesus Management School.

Station ID :- Section 3	Mekane Eyesus Management					
Average of two days						
Time	Direction		Total	Max of 15 minute	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	344	360	704	894		3316
07:15-07:30	392	340	732			
07:30-07:45	377	406	783			
07:45-08:00	439	456	894		3113	
08:00-08:15	444	424	868			
08:15-08:30	440	443	884			
08:30-08:45	386	414	800			
08:45-09:00	384	380	764		3316	
12:00-12:15	349	317	667			
12:15-12:30	322	322	644			
12:30-12:45	318	259	577			
12:45-01:00	321	279	600		2488	
1:00 - 1:15	332	346	678			
1:15 - 1:30	336	353	689			
1:30 - 1:45	341	339	680			
1:45 - 2:00	334	344	678		2725	
4:00 - 4:15	321	356	677			
4:15 - 4:30	338	404	742			
4:30 - 4:45	387	352	739			
4:45 - 5:00	420	367	787		2945	
5:00 - 5:15	381	361	741			
5:15 - 5:30	434	344	777			
5:30 - 5:45	403	356	759			
5:45 - 6:00	385	333	718		2995	
Total	8928	8655	17583			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Appendix F: - Summarized Traffic Volume Analysis of Sarbet – Sost kutir mazoria.

F.1. Summarized Traffic Volume Analysis @ Tomocca Coffee.

Station ID :- Section 1	Tomocca Coffee					
APHV	613 between 5:00 - 5:15					
Time	Direction		Total	Max of 15 minute	Hourly Volume	Max of HV
	South bound	North bound				
07:00-07:15	238	263	501	613		2316
07:15-07:30	248	272	520			
07:30-07:45	267	311	579			
07:45-08:00	290	278	568		2167	
08:00-08:15	335	273	608			
08:15-08:30	282	289	571			
08:30-08:45	229	280	509			
08:45-09:00	230	248	478		2167	
12:00-12:15	223	244	467			
12:15-12:30	232	225	457			
12:30-12:45	289	234	523			
12:45-01:00	238	257	495		1943	
1:00 - 1:15	241	282	523			
1:15 - 1:30	266	261	526			
1:30 - 1:45	227	266	494			
1:45 - 2:00	232	240	472		2014	
4:00 - 4:15	255	275	530			
4:15 - 4:30	285	284	570			
4:30 - 4:45	301	268	569			
4:45 - 5:00	259	307	566		2234	
5:00 - 5:15	278	335	613			
5:15 - 5:30	279	310	589			
5:30 - 5:45	247	321	568			
5:45 - 6:00	252	294	546		2316	
Total	6223	6617	12840			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

F.2. Summarized Traffic Volume Analysis @ Austria Embassy.

Station ID :- Section 2	Austria Embassy					
APHV	591 between 7:45 - 8:00					
Time	Direction		Total	Max of 15 minute	Hourly volume	Max of HV
	South bound	North bound				
07:00-07:15	231	227	458	597		2166
07:15-07:30	255	259	514			
07:30-07:45	302	286	588			
07:45-08:00	292	305	597		2157	
08:00-08:15	248	269	517			
08:15-08:30	241	277	517			
08:30-08:45	252	265	516			
08:45-09:00	239	248	487		2037	
12:00-12:15	221	243	465			
12:15-12:30	262	240	503			
12:30-12:45	251	254	504			
12:45-01:00	262	262	525		1996	
1:00 - 1:15	236	280	516			
1:15 - 1:30	275	260	535			
1:30 - 1:45	221	278	500			
1:45 - 2:00	257	261	517		2068	
4:00 - 4:15	258	266	524			
4:15 - 4:30	251	286	537			
4:30 - 4:45	257	294	551			
4:45 - 5:00	266	288	554		2166	
5:00 - 5:15	281	300	581			
5:15 - 5:30	254	281	534			
5:30 - 5:45	245	284	529			
5:45 - 6:00	250	270	520		2164	
Total	6105.85	6482	12588			

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

F.3. Summarized Traffic Volume Analysis @ Dimma Cultural Restaurant.

Station ID :- Section 3	Dimma Cultural Restaurant					
APHV	595 between 5:00 - 5:15					
Time	Direction		Total	Max of 15 minute	Hourly volume	Max of HV
	South bound	North bound				
07:00-07:15	244	253	496	595		2225
07:15-07:30	241	269	510			
07:30-07:45	283	282	565			
07:45-08:00	254	309	563		2134	
08:00-08:15	262	309	571			
08:15-08:30	252	312	564			
08:30-08:45	233	292	525			
08:45-09:00	231	287	518		2177	
12:00-12:15	219	221	440			
12:15-12:30	250	244	494			
12:30-12:45	260	226	486			
12:45-01:00	271	283	554		1974	
1:00 - 1:15	242	267	509			
1:15 - 1:30	259	300	559			
1:30 - 1:45	233	291	523			
1:45 - 2:00	237	257	494		2086	
4:00 - 4:15	266	256	521			
4:15 - 4:30	264	255	519			
4:30 - 4:45	252	269	521			
4:45 - 5:00	253	288	541		2103	
5:00 - 5:15	284	311	595			
5:15 - 5:30	275	301	576			
5:30 - 5:45	248	296	544			
5:45 - 6:00	232	277	509		2225	
Total	6043.8	6654	12698			

Appendix G: - Sample Spot Speed Computation

G.1. Sample Spot Speed Analysis along Bole – Meskel Square.

Analysis of Spot speed @ BM 03: Posted Speed Limit = 50Km/hr.					
Speed (km/hr)	Frequency of vehicles	Cumulative frequency	Cumulative percent	Speed percentile	
27.6	0	0	0.00		
28.4	0	0	0.00		
29.2	0	0	0.00		
30.2	0	0	0.00		
31.1	0	0	0.00		
32.2	0	0	0.00		
33.3	0	0	0.00		
34.5	0	0	0.00		
35.7	0	0	0.00		
37.1	0	0	0.00		
38.6	0	0	0.00		
40.2	18	18	18.00		
41.9	14	32	32.00		
43.9	19	51	51.00		
45.9	15	66	66.00	43.72	50 th%
48.2	10	76	76.00		
50.8	13	89	89.00	50.00	85 th %
53.6	6	95	95.00		
56.8	3	98	98.00		
60.3	2	100	100.00		
64.3	0	100	100.00		
68.9	0	100	100.00		
74.2	0	100	100.00		
80.4	0	100	100.00		
87.7	0	100	100.00		
96.5	0	100	100.00		
107.2	0	100	100.00		
120.6	0	100	100.00		
137.8	0	100	100.00		
160.8	0	100	100.00		
193.0	0	100	100.00		

G.2. Sample Spot Speed Analysis along Mexico Square – German Square.

Analysis of Spot speed @ MG 17; Posted Speed Limit = 50Km/hr.					
Speed (km/hr)	Frequency of vehicles	Cumulative frequency	Cumulative percent	Speed percentile	
27.6	0	0	0.00		
28.4	0	0	0.00		
29.2	0	0	0.00		
30.2	0	0	0.00		
31.1	0	0	0.00		
32.2	0	0	0.00		
33.3	0	0	0.00		
34.5	0	0	0.00		
35.7	0	0	0.00		
37.1	0	0	0.00		
38.6	0	0	0.00		
40.2	16	16	16.00		
41.9	5	21	21.00		
43.9	9	30	30.00		
45.9	2	32	32.00		
48.2	16	48	48.00		
50.8	19	67	67.00	48.5	50th %
53.6	11	78	78.00		
56.8	7	85	85.00	56.8	85th %
60.3	12	97	97.00		
64.3	3	100	100.00		
68.9	0	100	100.00		
74.2	0	100	100.00		
80.4	0	100	100.00		
87.7	0	100	100.00		
96.5	0	100	100.00		
107.2	0	100	100.00		
120.6	0	100	100.00		
137.8	0	100	100.00		
160.8	0	100	100.00		
193.0	0	100	100.00		

G.3. Sample Spot Speed Analysis along Sarbet – Sost kutir mazoria.

Analysis of Spot speed @ SS 07; Posted Spot Speed = 50Km/hr.					
Speed (km/hr)	Frequency of vehicles	Cumulative frequency	Cumulative percent	Speed percentile	
27.6	0	0	0.00		
28.4	0	0	0.00		
29.2	0	0	0.00		
30.2	0	0	0.00		
31.1	0	0	0.00		
32.2	0	0	0.00		
33.3	0	0	0.00		
34.5	0	0	0.00		
35.7	3	3	3.00		
37.1	2	5	5.00		
38.6	0	5	5.00		
40.2	4	9	9.00		
41.9	1	10	10.00		
43.9	14	24	24.00		
45.9	9	33	33.00		
48.2	8	41	41.00		
50.8	13	54	54.00	50.00	50th %
53.6	21	75	75.00		
56.8	9	84	84.00		
60.3	9	93	93.00	57.1	85th %
64.3	5	98	98.00		
68.9	2	100	100.00		
74.2	0	100	100.00		
80.4	0	100	100.00		
87.7	0	100	100.00		
96.5	0	100	100.00		
107.2	0	100	100.00		
120.6	0	100	100.00		
137.8	0	100	100.00		
160.8	0	100	100.00		
193.0	0	100	100.00		

Appendix H: - Output of Negative Binomial Analysis using SPSS.

GET

```
FILE='C:\Users\enok\Desktop\Final Data\SPSS\Model.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
DATASET ACTIVATE DataSet1.
* Generalized Linear Models.
GENLIN AN BY AUTurn (ORDER=ASCENDING) WITH Eighty fifth PS NAP
  /MODEL AUTurn Eighty fifth PS NAP INTERCEPT=YES OFFSET=LnAPHV
  DISTRIBUTION=NEGBIN(MLE) LINK=LOG
  /CRITERIA METHOD=NEWTON SCALE=PEARSON COVB=MODEL MAXITERATIONS=100
  MAXSTEPHALVING=5
  PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(LR) CILEVEL=95
  CITYPE=PROFILE (.0001)
  LIKELIHOOD=FULL
  /EMMEANS TABLES=AUTurn SCALE=ORIGINAL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION (EXPONENTIATED)
  /SAVE MEANPRED STDPEARSONRESID STDDEVIANCERESID.
```

Generalized Linear Models

[DataSet1] C:\Users\enok\Desktop\Final Data\SPSS\Model.sav

Model Information

Dependent Variable	Accident Number by point Weightage / 3 yrs
Probability Distribution	Negative binomial (MLE)
Link Function	Log
Offset Variable	Ln of Average Peak Hour Volume

Case Processing Summary

	N	Percent
Included	20	100.0%
Excluded	0	0.0%
Total	20	100.0%

Categorical Variable Information

			N	Percent
Factor	Availability of U-Turn	No	12	60.0%
		Yes	8	40.0%
		Total	20	100.0%

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Continuous variable information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	Accident Number by point Weightage / 3 yrs	20	23.00	98.00	59.2000	26.34708
Covariate	85th Percentile Spot	20	48.70	67.90	57.9000	5.02426
	Speed (Km/hr)	20	.00	3.00	1.3000	.97872
Offset	Ln of Average Peak Hour	20	7.78	8.49	8.1925	.28364
	Volume					

Goodness of Fit^a

	Value	df	Value/df
Deviance	20.552	15	1.370
Scaled Deviance	15.989	15	
Pearson Chi-Square	19.280	15	1.285
Scaled Pearson Chi-Square	15.000	15	
Log Likelihood ^{b,c}	-80.335		
Adjusted Log Likelihood ^d	-62.500		
Akaike's Information Criterion (AIC)	170.671		
Finite Sample Corrected AIC (AICC)	174.956		
Bayesian Information Criterion (BIC)	175.649		
Consistent AIC (CAIC)	180.649		

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUTurn, Eighty fifth PS, NAP, offset = LnAPHV

- a. Information criteria are in small-is-better form.
- b. The full log likelihood function is displayed and used in computing information criteria.
- c. The log likelihood is based on a scale parameter fixed at 1.
- d. The adjusted log likelihood is based on an estimated scale parameter and is used in the model fitting omnibus test.

Omnibus Test^a

Likelihood Ratio Chi-Square	df	Sig.
22.771	3	.000

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUTurn, Eighty fifth PS, NAP, offset = LnAPHV

- a. Compares the fitted model against the intercept-only model.

*Identification and Countermeasure of Accident Blackspot Locations Using
Statistical Modeling (A case study of Addis Ababa)*

Tests of Model Effects

Source	Type III						
	Likelihood Ratio Chi- Square	df	Sig.	F	df1	df2	Sig.
(Intercept)	35.029	1	.000	35.029	1	15	.000
AUTurn	10.499	1	.001	10.499	1	15	.005
Eighty fifth PS	22.113	1	.000	22.113	1	15	.000
NAP	4.266	1	.039	4.266	1	15	.057

Dependent Variable: Accident Number by point Weightage / 3 yrs

Model: (Intercept), AUTurn, Eighty fifth PS, NAP, offset = LnAPHV

Parameter Estimates

Parameter	B	Std. Error	95% Profile Likelihood Confidence Interval		Hypothesis Test			Exp(B)	95% Profile Likelihood Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi- Square	df	Sig.		Lower	Upper
(Intercept)	-9.754	.8323	-11.442	-8.012	137.352	1	.000	5.806E- 005	1.073E- 005	.000
[AUTurn=0]	-.511	.1359	-.804	-.234	14.117	1	.000	.600	.447	.792
[AUTurn=1]	0 ^a	.	.	.	.	.	.	1	.	.
Eighty fifth PS	.105	.0150	.073	.135	48.829	1	.000	1.110	1.076	1.145
NAP	-.158	.0696	-.300	-.009	5.173	1	.023	.854	.741	.991
(Scale)	1.285 ^b									
(Negative binomial)	.042	.0219	.013	.116						

Dependent Variable: Accident Number by point Weightage / 3 yrs

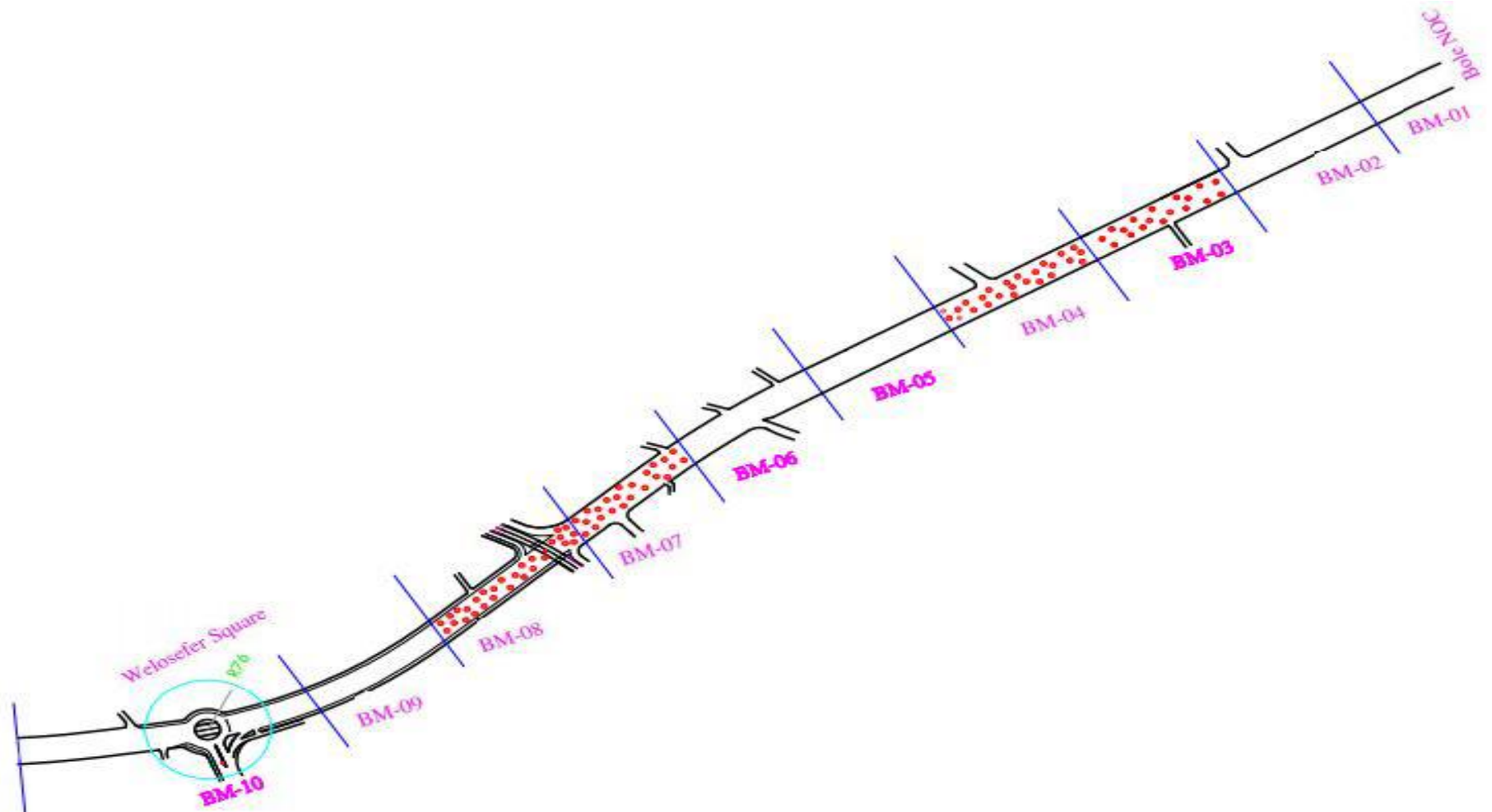
Model: (Intercept), AUTurn, Eighty fifth PS, NAP, offset = LnAPHV

a. Set to zero because this parameter is redundant.

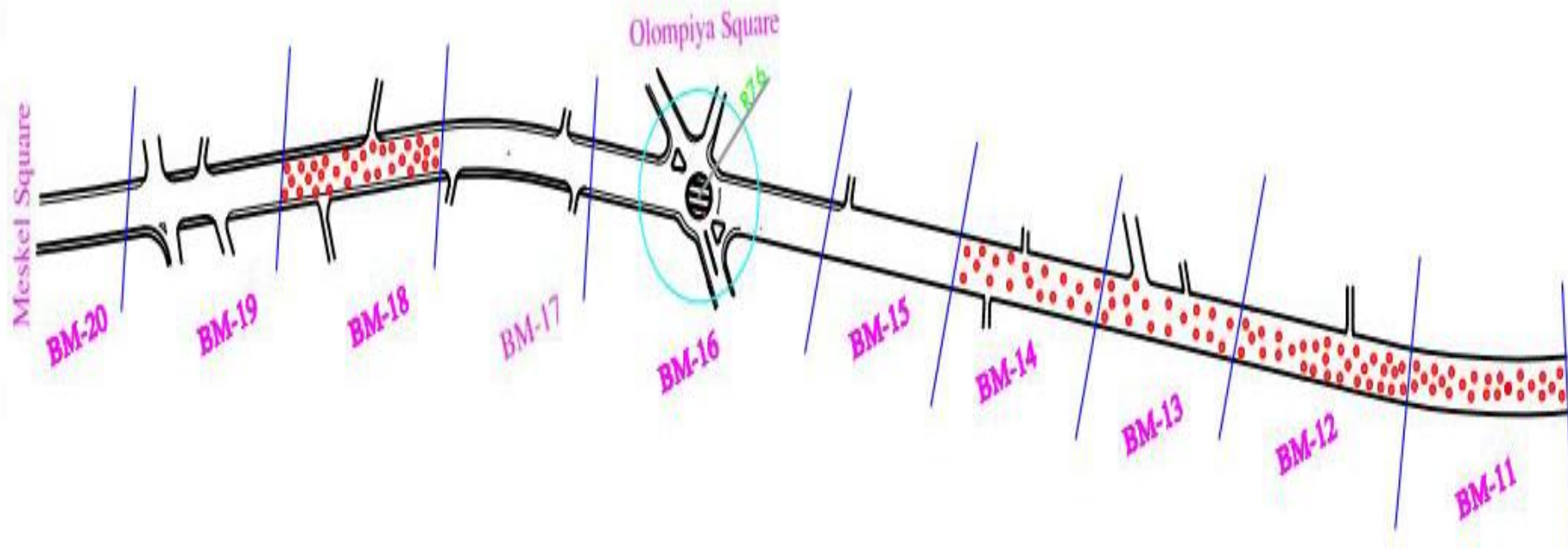
b. Computed based on the Pearson chi-square.

Appendix I: - Pictorial Illustration of Black Spot Locations along the study road networks.

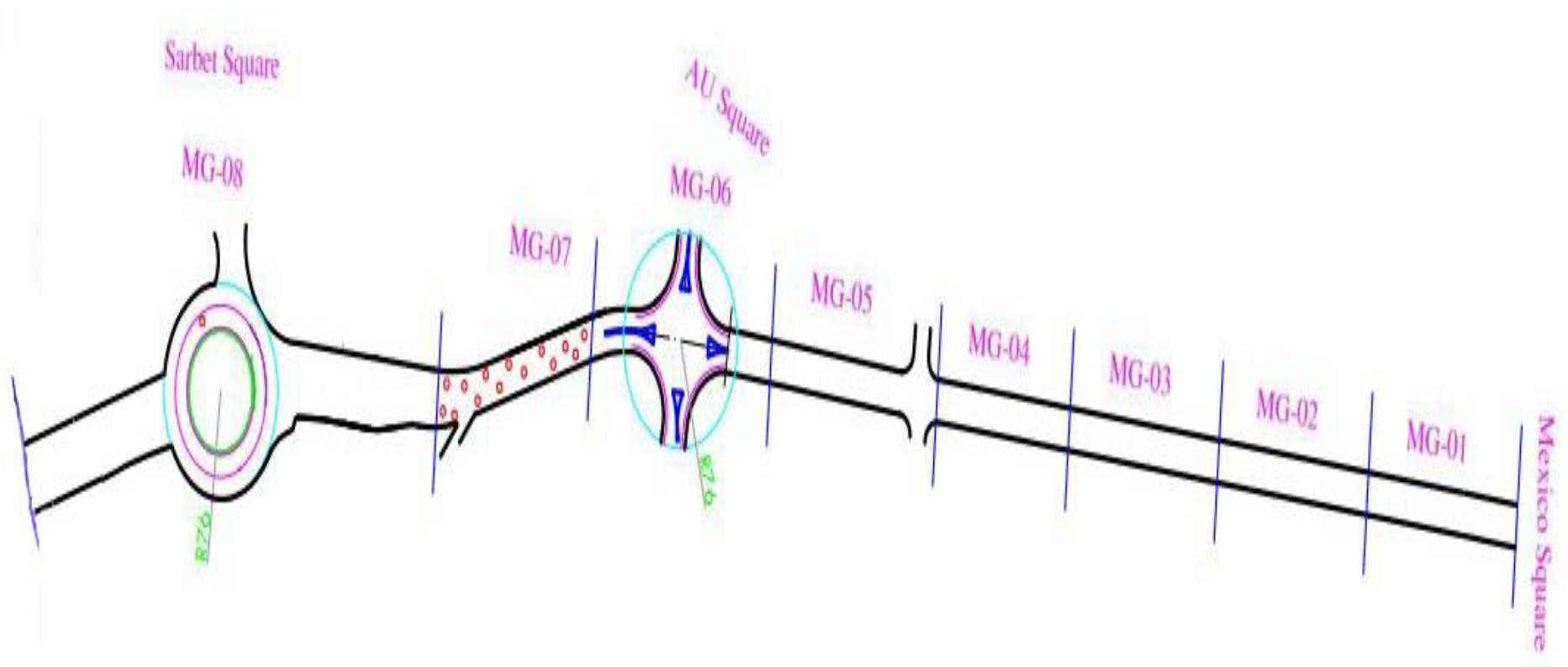
I.1. Black Spot Locations along *Bole to Meskel square*

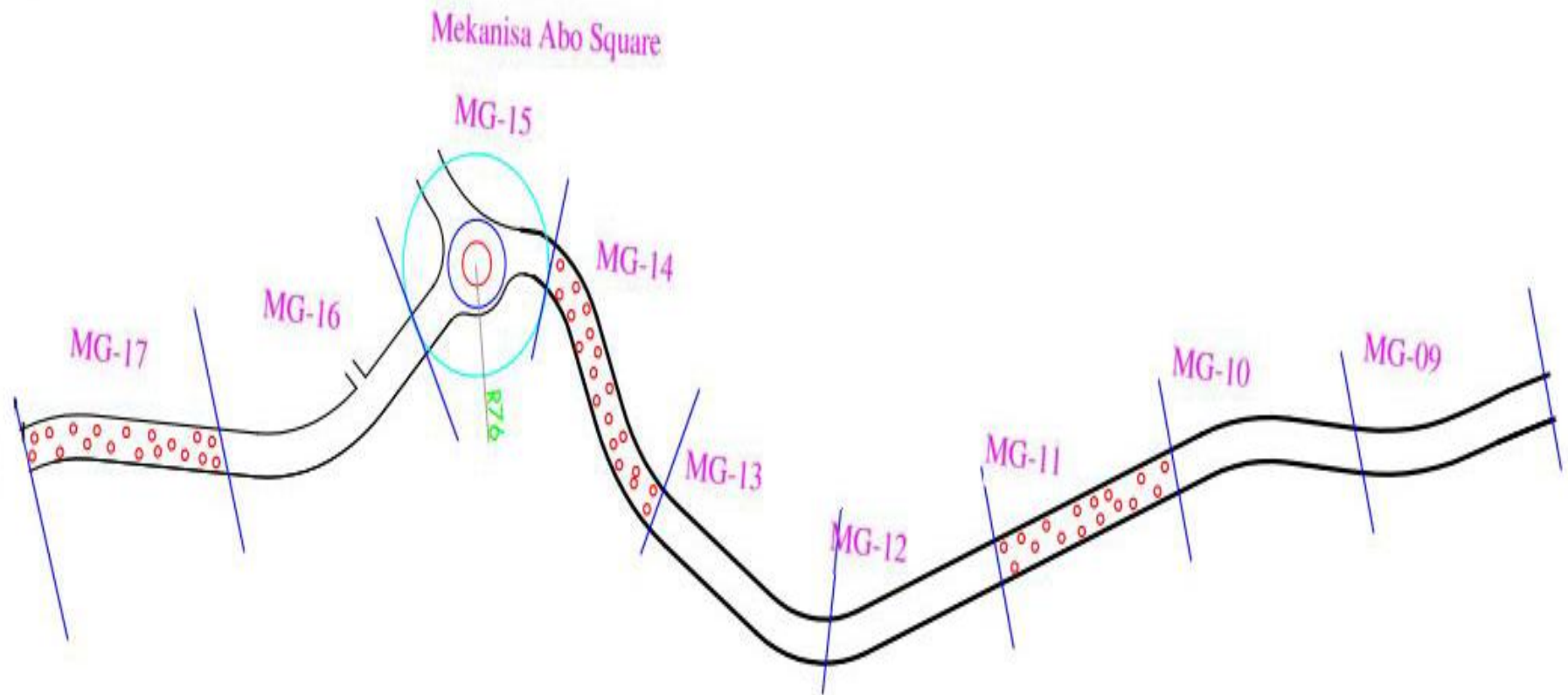


Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

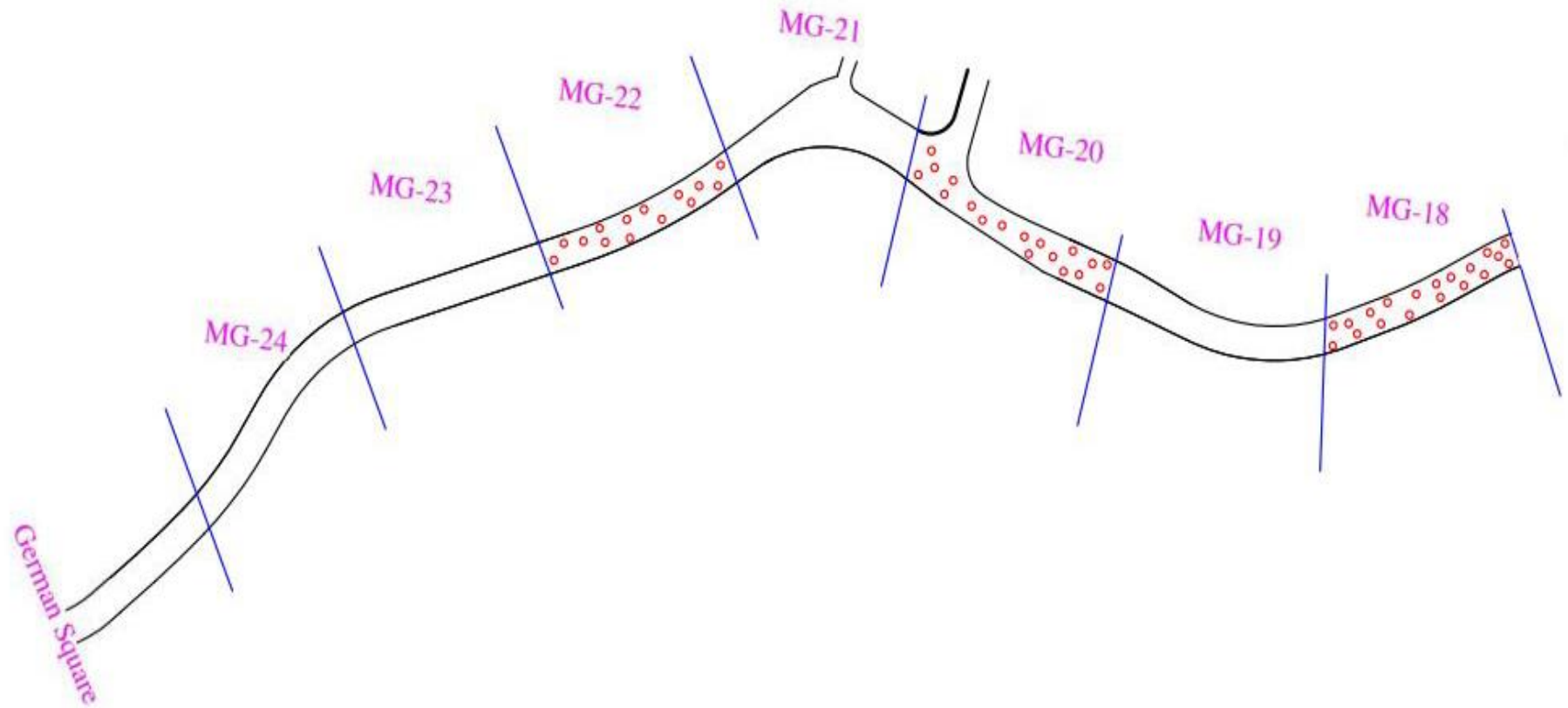


I.2. Black Spot Locations along Mexico to German square

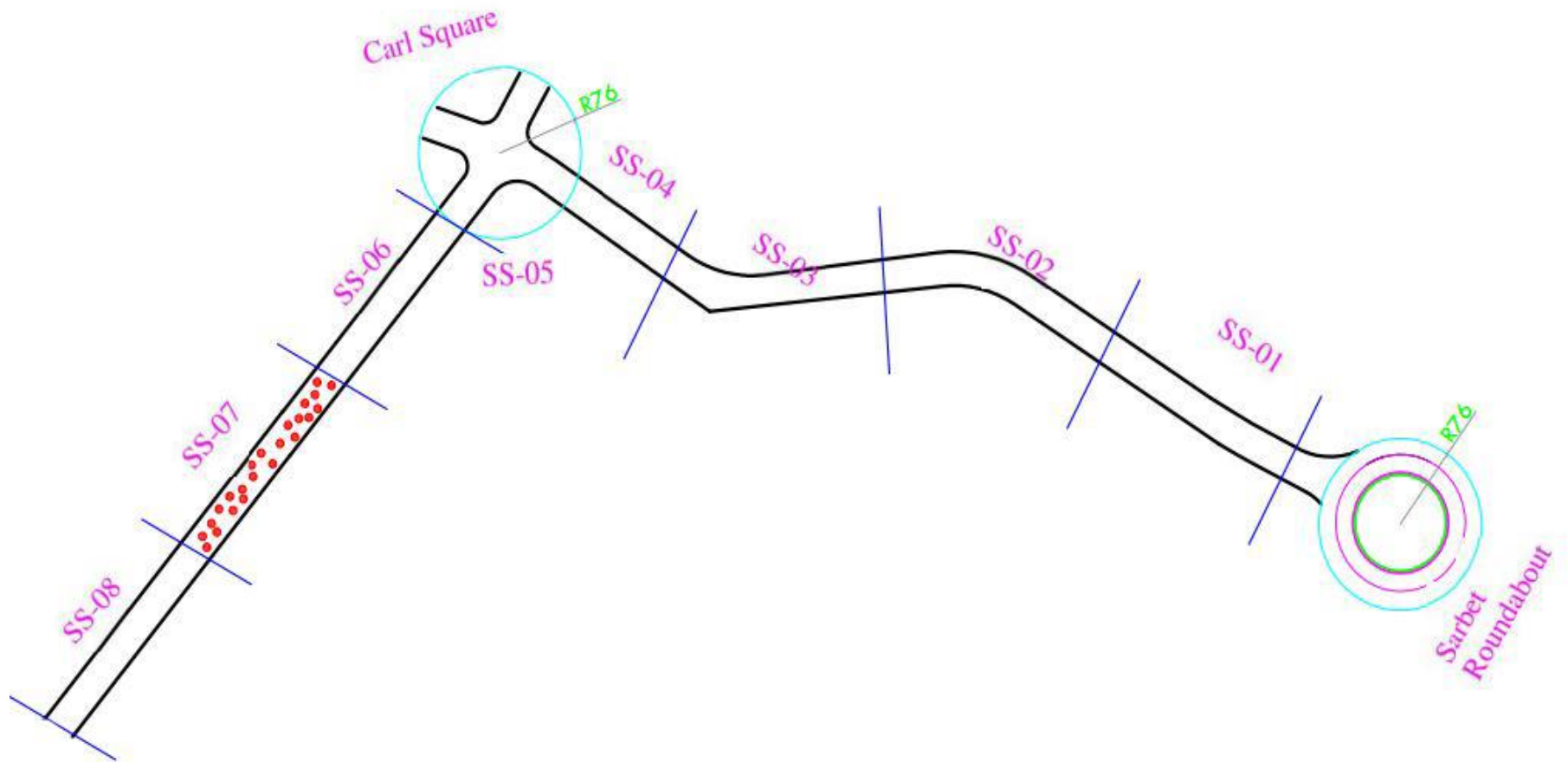


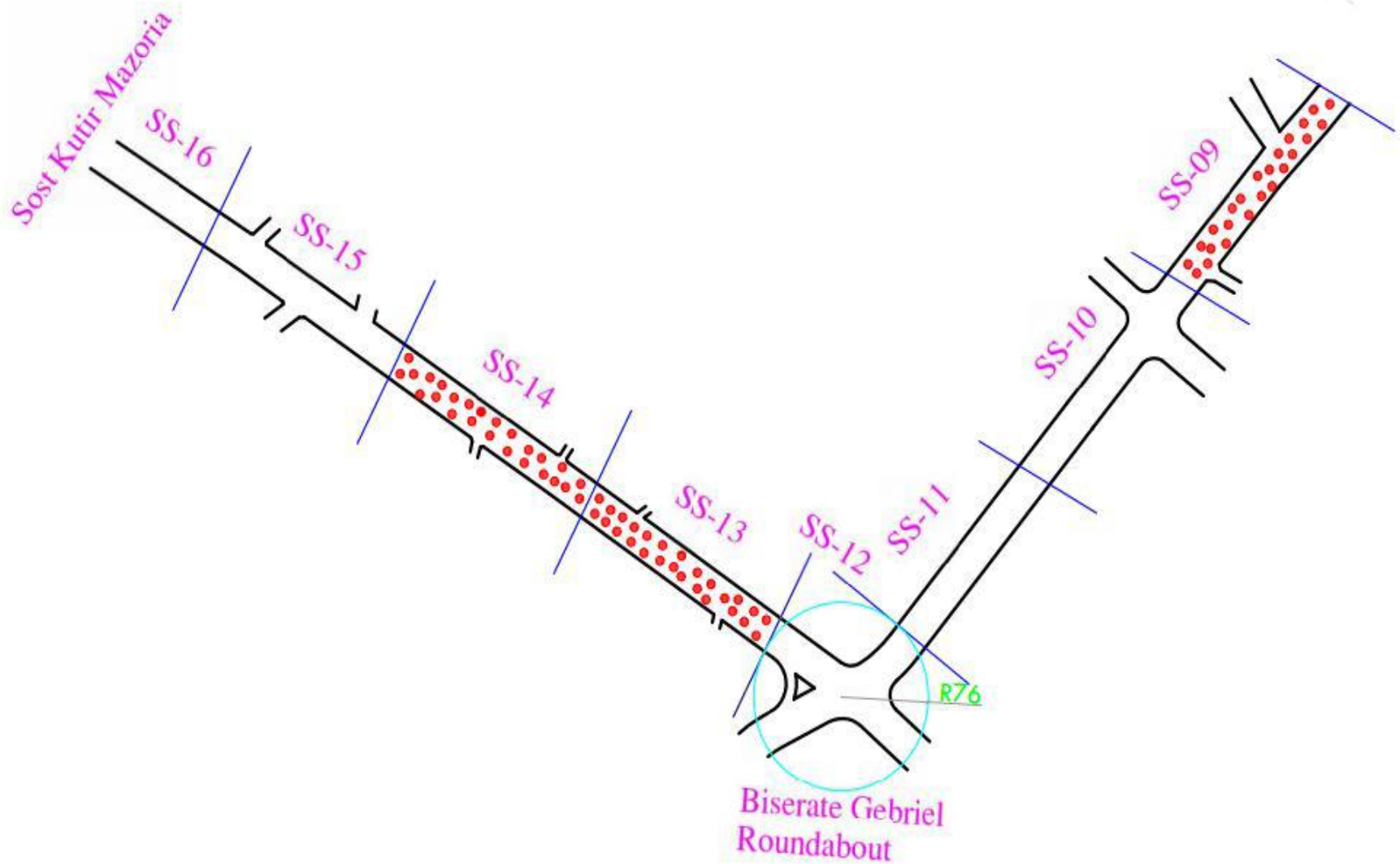


Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)



I.3. Black Spot Locations along Sarbet to Sost Kutir Mazoria





Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Appendix J: - Observed Problems and Countermeasures of the Respective Blackspot Locations.

Station ID	Origin	Destination	Observed problems	Suggested Countermeasures
BM 03	Snap plaza	Senegal residential	<ul style="list-style-type: none"> ✓ Overtaking 	<ul style="list-style-type: none"> ✓ Provide message sign and marking ✓ Improve access geometry.
BM 04	Senegal residential	Garden Court bar and restaurant	<ul style="list-style-type: none"> ✓ Overtaking ✓ Poor message sign 	<ul style="list-style-type: none"> ✓ Provide stop/yield control at the joint of the access road and main arterial street. ✓ Provide warning sign.
BM 07	Werbek House	Mulmul Bakery (Bole)	<ul style="list-style-type: none"> ✓ Over speeding ✓ Message Marking ✓ Sight obstruction 	<ul style="list-style-type: none"> ✓ Provide message sign and marking for the access points (entry or/and exits) to and from the main arterial streets. ✓ Providing speed limit sign. ✓ Relocate pedestrian crossing.
BM 08	Mulmul Bakery (Bole)	Muller Real state	<ul style="list-style-type: none"> ✓ Curve ✓ Over speeding ✓ Overtaking 	<ul style="list-style-type: none"> ✓ Provide warning sign at the adjoining access point. ✓ Police law enforcement. ✓ Provide Speed calming measure ✓ Provide Message sign and marking.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Station ID	Origin	Destination	Observed problems	Suggested Countermeasures
BM 11	Rodeo Restaurant	Sabit Building	<ul style="list-style-type: none"> ✓ Over speeding ✓ Lack of message sign. 	<ul style="list-style-type: none"> ✓ Provide speed limit sign ✓ Provide warning sign at the adjoining access point.
BM 12	Sabit Building	Sangam Indian Restaurant	<ul style="list-style-type: none"> ✓ Local access points ✓ Overtaking ✓ Over speeding 	<ul style="list-style-type: none"> ✓ Provide speed calming measure ✓ Provide message sign and markings
BM 13	Sangam Indian Restaurant	#2 Pelican Pharmacy	<ul style="list-style-type: none"> ✓ Message marking ✓ Over speeding ✓ Overtaking ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Message sign and markings. ✓ Provide speed limit signs. ✓ Employ wider median width.
BM 14	#2 Pelican Pharmacy	Getu Commercial	<ul style="list-style-type: none"> ✓ Over-speeding ✓ Improper location of pedestrian crossing 	<ul style="list-style-type: none"> ✓ Speed calming measure ✓ Relocate pedestrian crossing to the suitable location. ✓ Provide warning sign.
BM 18	Oromia State Council	Sunshine Laundry	<ul style="list-style-type: none"> ✓ Over-speeding ✓ No message marking 	<ul style="list-style-type: none"> ✓ Speed calming measure ✓ Provision of warning message sign.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Station ID	Origin	Destination	Observed problems	Suggested Countermeasures
MG 07	DHL	International Evangelical Church	<ul style="list-style-type: none"> ✓ Over- speeding ✓ Obstructions (tree) ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Speed calming measures ✓ Provision of wider median width ✓ Removing the obstruction features.
MG 11	NIB	Indonesia Embassy	<ul style="list-style-type: none"> ✓ Improper provision of U-turn opening. ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Close/Restrict U- turn movements. ✓ Message sign and markings. ✓ Provide speed limit sign. ✓ Provision of wider median width.
MG 14	Embassy of UAE	Mekane Eyesus Church	<ul style="list-style-type: none"> ✓ Over-speeding ✓ Minimum side distance 	<ul style="list-style-type: none"> ✓ Speed calming measures. ✓ Provision of adequate sight distance.
MG 17	Mekanisa Market	Mekanisa Primary School	<ul style="list-style-type: none"> ✓ Over-speeding ✓ Minimum sight distance ✓ Overtaking 	<ul style="list-style-type: none"> ✓ Speed calming measure. ✓ Increasing the sight distance of the road segment. ✓ Closing the U-turn so that vehicles will turn at Mekanisa abo roundabout.
MG 18	Mekanisa Primary School	Awash wine	<ul style="list-style-type: none"> ✓ Excessive speed ✓ Overtaking 	<ul style="list-style-type: none"> ✓ Provision of speed calming measure Such as rumble strips etc. ✓ Employing stop/yield control.

Identification and Countermeasure of Accident Blackspot Locations Using Statistical Modeling (A case study of Addis Ababa)

Station ID	Origin	Destination	Observed problems	Suggested Countermeasures
MG 20	Ethiopia Areke Factory	D.A Packaging PLC	<ul style="list-style-type: none"> ✓ Excessive speed ✓ Overtaking 	<ul style="list-style-type: none"> ✓ Providing speed calming measures such as Rumble strips etc. ✓ Employing Messaging sign and markings.
MG 22	Joint Language school	Ethiopian Revenue Authority	<ul style="list-style-type: none"> ✓ Excessive speed ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Provide speed limit sign ✓ Provide speed calming measure ✓ Provide wider median width
SS 07	Africana Bar and Restaurant	Tivoli Restaurant	<ul style="list-style-type: none"> ✓ Excessive speed ✓ Lack of messaging sign ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Provide message sign and marking ✓ Employ speed limit sign ✓ Provide wider median width
SS 09	INSA	St. Biserate Gebriel church	<ul style="list-style-type: none"> ✓ Smaller median width ✓ Message sign and marking. 	<ul style="list-style-type: none"> ✓ Employing message marking and sign. ✓ Provide wider median width.
SS 13	EPHRAM	Norwegian Residence	<ul style="list-style-type: none"> ✓ Excessive speed ✓ U-turn ✓ Smaller median width 	<ul style="list-style-type: none"> ✓ Providing speed limit signs and markings. ✓ Improving the median width to a wider level.
SS 14	Norwegian Residence	Dimma Cultural Restaurant	<ul style="list-style-type: none"> ✓ Smaller median width ✓ Excessive speed 	<ul style="list-style-type: none"> ✓ Employ stop/yield control at the joint of minor road. ✓ Provide speed calming measures