



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
**INVESTIGATION OF HOTSPOT LOCATION AND EXCESSIVE
SPEEDING IN ADDIS ABABA, ETHIOPIA.**

BY

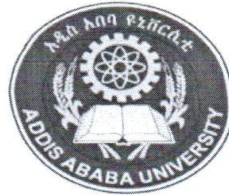
ELIAS LETA DABALO

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for Degree of Masters of Science in Civil Engineering (Road and Transportation Engineering).

Advisor: Getu Segni Tulu (PhD).

January, 2020 G.C.

Addis Ababa, Ethiopia.



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

M.Sc. Thesis on
INVESTIGATION OF HOTSPOT LOCATION AND EXCESSIVE SPEEDING
IN ADDIS ABABA, ETHIOPIA.

By

ELIAS LETA DABALO

JANUARY, 2020 G.C

Approved by Board of Examiners

Dr. Getu Segni Tulu

Advisor

Signature _____ Date _____

Dr. Bikila Teklu

Internal examiner

Signature _____ Date 01/02/2020

Mr. Wondewossen Tadesse

External examiner

Signature _____ Date 10-02-2020

Dr. ing. Mebruk Mohammed

Chairman

Signature _____ Date _____

**Mebruk Mohammed (Dr.-Ing.)
Dean, School of Civil &
Environmental Engineering**



Declaration

I declare that this thesis entitled “**INVESTIGATION OF HOT SPOT LOCATION AND EXCESSIVE SPEEDING IN ADDIS ABABA, ETHIOPIA.**” is my original work. This thesis has not been presented in any other university for assessment and award of any degree or diploma, and all sources of material used for the thesis have been duly acknowledged.

Candidate:

Name: Elias Leta Dabalo

Signature: -----

Place: Addis Ababa University, Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Date of submission: January, 2020 G.C

Table of Content

Declaration II

Table of Content..... III

List of Table..... VII

List of Figures..... VIII

List of Abbreviations X

Acknowledgment..... XI

Abstract..... XII

Chapter -One..... 1

1. Introduction 1

1.1. General background 1

1.2. Problem of statement 3

1.3. The objective of the study..... 4

 1.3.1. General objective. 4

 1.3.2. Specific objective..... 4

1.4. Research question..... 5

1.5. The scope of the study 5

1.6. Significance of the Study..... 5

1.7. The structure of the thesis 6

Chapter Two..... 8

2. Literature Review 8

2.1. Definition of speed and speed type..... 8

 2.1.1. Operating speed. 8

 2.1.2. Design speed 8

 2.1.3. Speeding or excessive speeding..... 9

2.1.4.	Speed limit	9
2.2.	Speed and road safety	10
2.3.	Factors influencing the speed of the vehicle.....	12
2.3.1.	Drivers related factors influencing the speed of a vehicle	12
2.3.2.	Road and vehicle -related factors on the speed of a vehicle	13
2.4.	Speed and its impact on the environment	14
2.4.1.	Impact of speeding on air pollution	15
2.4.2.	Impact of speed on the noise.....	16
2.5.	Speed management.....	16
2.5.1.	Setting a speed limit.....	17
2.5.2.	Speed enforcement.....	17
2.5.3.	Education and publicity campaign on speed.....	18
2.5.4.	Traffic calming method.....	19
2.6.	Road traffic crashes	19
2.6.1.	The major factors influencing the pedestrian crash	19
2.6.2.	Traffic crash in Addis Ababa city and its' risk factors	22
2.7.	Impact of speed on the pedestrian crash	23
2.8.	Road traffic crash hotspot investigation	25
2.8.1.	Non-spatial approach hotspot investigation.....	25
2.8.2.	Spatial approach hotspot investigation	26
2.9.	Gaps and summary of the reviewed research.....	27
Chapter -Three.....		28
3.	Methodology and data collection.....	28
3.1.	Introduction	28
3.2.	Study area.	28

3.3.	Study design and source of data	29
3.4.	Data base	30
3.5.	Data collection and description.....	30
3.5.1.	Road traffic crashes data collection and description.....	30
3.6.	Traffic crash hotspot location identification in the city using ArcGIS.	31
3.6.1.	Severity index of road traffic crash.....	35
3.7.	Data collection and description of speed violation	35
Chapter- Four.....		38
4.	Data analysis, result and discussion.....	38
4.1.	Introduction	38
4.2.	Descriptive analysis of road traffic crash in Addis Ababa city.....	39
4.2.1.	Annual Distribution of traffic crash in the Addis Ababa city	39
4.2.2.	Distribution of road traffic crashes by temporal variables.....	40
4.2.3.	Distribution of location of traffic crash in Addis Ababa city on a map.....	49
4.2.4.	Distribution of road traffic crashes hotspots location	53
4.3.	Speed violation analysis	82
4.3.1.	Distribution of driver age involved in exceeding posted speed.....	82
4.3.2.	Distribution of driver involved in exceeding the speed limit by experience	83
4.3.3.	Distribution of driver involved in exceeding the speed limit by gender.....	85
4.3.4.	Distribution of vehicle types involved in speeding in Addis Ababa city	87
4.3.5.	The extent of Speeding of drivers' relative to the posted speed limit	88
4.3.6.	The extent of Speeding of drivers per day of the week	89
4.4.	Excessive speeding and hotspot locations in the city.....	93
Chapter-Five.....		95
5.	Conclusion and Recommendation.....	95

5.1. Conclusion..... 95

5.2. Recommendation..... 97

5.3. Limitations of this study..... 100

5.4. Proposed future work..... 101

References..... 102

Appendices..... 106

List of Table

Table 4-1 Summary of chi-square value of temporal variable with traffic crash 41

Table 4-2 Summary of chi-square test value under excessive speeding..... 87

Table 4-3 Positive mean speed deviation analysis by day of the week 89

List of Figures

Figure 2-1 Crash rate versus deviation from average travel speed (Solomon, 1964).....	11
Figure 2-2 Speed limit violations per age group (Harrington, 1970)	13
Figure 2-3 Pollutant emission factors for the average vehicle type distribution in the C-32 freeway near Barcelona, Spain. Note: Different units for each pollutant	16
Figure 2-4 the key factors influencing pedestrian traffic crashes (Charles Zegeer, 2010)	20
Figure 3-1 Addis Ababa city map (www.google.com December, 1st 2017/2018)	28
Figure 4-1 The trend of road traffic crashes in the Addis Ababa city from 2007 to 2011.	40
Figure 4-2 The trend of fatal traffic crashes in the Addis Ababa city from 2007 to 2011.	40
Figure 4-3 Distribution of traffic crashes per year and a day in a week	42
Figure 4-4 Distribution of traffic crashes per year and hour and the average of five years	44
Figure 4-5 Distribution of fatal traffic crash per year per hour and its average (2007-2009).	44
Figure 4-6 Variation of injury crashes by time of a day per year	46
Figure 4-7 Causes of a road traffic crash as identified by Addis Ababa police (2007-2011).....	47
Figure 4-8 Causes of a fatal traffic crash as identified by Addis Ababa police.....	48
Figure 4-9 distribution of vehicle types involved in traffic crashes in Addis Ababa city.	49
Figure 4-10 spatial distribution of total road traffic crash in Addis Ababa city in 2007	50
Figure 4-11 spatial distribution of total road traffic crash in Addis Ababa city in 2008	51
Figure 4-12 spatial distribution of total road traffic crash in Addis Ababa city in 2009	52
Figure 4-13 spatial autocorrelations by a function of distance for fatal traffic crash of 2007.....	54
Figure 4-14 Getis-Ord G_i^* based hotspot analysis of fatal crash in 2007	55
Figure 4-15 Kernel Density Estimation based hotspot analysis of fatal crash in 2007	56
Figure 4-16 Kernel Density Estimation based hotspot analysis of injury crash in 2007	58
Figure 4-17 Getis-Ord G_i^* based hotspot analysis of injury traffic crash in 2007	59
Figure 4-18 Getis-Ord G_i^* based hotspot analysis of non-injury traffic crash in 2007	61
Figure 4-19 Kernel Density Estimation based hotspot analysis of non-injury crash in 2007.....	62
Figure 4-20 Getis-Ord G_i^* based fatal crash hotspot location analysis in 2008	64
Figure 4-21 Kernel density Estimation based hotspot analysis of fatal crash in 2008	66
Figure 4-22 Getis-Ord G_i^* based hotspot analysis of injury traffic crash in 2008.....	68
Figure 4-23 Kernel Density Estimation based hotspot analysis of injury crash in 2008.....	69

Figure 4-24 Getis-Ord G_i^* based hotspot analysis of non- injury crash in 2008	71
Figure 4-25 Kernel Density Estimation based hotspot analysis of non-injury crash in 2008.....	72
Figure 4-26 Getis-Ord G_i^* based hotspot analysis of fatal crash in 2009	74
Figure 4-27 Kernel density estimation based hotspot analysis of fatal crash in 2009	75
Figure 4-28 Getis-Ord G_i^* based hotspot analysis of injury crash in 2009.....	77
Figure 4-29 Kernel density estimation based hotspot analysis of injury crash in 2009	78
Figure 4-30 Getis-Ord G_i^* based hotspot analysis of non-injury crash in 2009	80
Figure 4-31 Kernel density estimation based hotspot analysis of non-injury crash in 2009	81
Figure 4-32 Distribution of driver age involved in posted speed limit violation.....	83
Figure 4-33 Distribution of female and male speeder by experience group.....	84
Figure 4-34 Male and Female speeder age distribution.....	86
Figure 4-35 The excessive speeding engagement by gender of the driver	86
Figure 4-36 Distribution of vehicles types engaged in excessive speeding.....	87
Figure 4-37 The extent of speeding distribution above the speed limit.....	88
Figure 4-38 The extent of driver speed above 30kmphr and 40kmphr posted speed	89
Figure 4-39 The extent of driver speed above 50kmphr and 80kmphr posted speed.....	90
Figure 4-40 The extent of speeding by the age of the driver	90
Figure 4-41 The extent of speeding by vehicle types	91
Figure 4-42 The extent of speeding by the posted speed limit of the city	91
Figure 4-43 The extent of speeding by gender of the driver.....	92

List of Abbreviations

AACTPM	Addis Ababa City Transport Program and Management,
AASHTO	American Association of State Highway and Transportation Officials
E.C	Ethiopian Calendar
ERA	Ethiopian Road Authority
G.C	Gregorian Calendar.
ISA	Incremental Spatial Analysis.
KDE	Kernel Density Estimation.
SPSS	Statistical Package for the Social Sciences
USA	United States of America
WHO	World Health Organization
UNECA	United Nations Economic Commission for Africa
OECD	Organization for Economic Co-Operation and Development
UAE	United Arab Emirates

Acknowledgment

First and foremost, I thank the Almighty God for giving me strength, knowledge, ability, patience and opportunity to undertake this research study and complete it. Without his showers of blessings, this achievement would not have been possible.

I acknowledge my advisor **Dr. Getu Segni Tulu** for not only being my research advisor but also being very patient and understanding during every trying time of this work and for his assistance in data collection. I extend my deep and sincere gratitude for providing constructive suggestions, valuable comments and guidance for this thesis till the end.

I express my appreciation to the University of **Mizan Tepi** for its financial support, which made it possible for me to continue and complete my studies.

Last but not least, my parents, my sister Hawi Leta, my brother Lalisa Leta, my father Leta Dabalo and my mother Tsehay Dhasa for whom I dedicate my work. I am grateful for the prayers, unconditional love, continuous support, encouragement and constantly reassuring me that this study will reach a stage of completion.

Abstract

Road traffic crash is a serious problem in the world and highly prominent in developing countries. Road traffic crash cannot be totally stop, but using appropriate engineering measures and road safety management and improvement the traffic crash rate can be decrease. The road safety improvements are supposed to be implemented to the hotspot location of traffic crashes where they have the most significance and on the other hand, excessive speeding is also one of the road safety problems. Thus, this study aimed at investigation of hotspot location and excessive speeding in Addis Ababa city. To meet the objective of the research the researcher has given attention to collect traffic crash data and excessive speeding data from Addis Ababa Police Commission. The hotspot location identification was based on the ArcGIS software using Kernel Density Estimation and Getis-Ord G_i^* tools in the software. Hence, the results of a study regarding excessive speeding showed the existence of huge disparity among drivers' demography by their gender, age & driving experience levels, and vehicle types engaged in speeding and variation of the extent of speeding above the posted speed limit among posted speed limit. Comparing gender, male drivers were the most frequently engaged in excessive speeding than female drivers in the city. Moreover, the results confirmed that young drivers under the age categories from 25 to 40 regardless of their gender and those drivers less than 5 years driving experience are highly involved in excessive speeding. Based on vehicle type's automobile, pickup, and mini-bus are the first three mostly involved in excessive speeding. More than 69% of speeders in city were driving by more than 10kmph above speed limit. The extent of speeding of those divers engaged in speed violation decreases as the posted speed limit increases. Furtherly, this study confirmed that the significant growth of traffic crashes in the city annually. The major causes of traffic crashes revealed in this study are following too closely (25.6%), failure to give-way for other vehicle (21.3%) & pedestrians (10.1%), improper overtaking (8.7%) and improper parking and moving from (8.2%), over speeding (7.6%) etc. The other finding of this study is the investigation of a hotspot location. The hotspot location of fatal traffic crashes identified is Megenagna intersection, Sebetegna, Asra Simint to Atena Tera and Zenebework along the ring road, and Ayer Tena along Jimma road where high vehicular and pedestrian movement and excessive speeding were expected. Finally, the hotspot location of injury traffic crashes identified in the study was Mexico to Leghar to Stadium, to Urael along LRT route, Auto

bis Tera to Atekilt Tera route, Ayer Tena to Miachel Adebabai to German Adebabai to Haile Garment route.

Chapter -One

1. Introduction

1.1. General background

The road is one of land transportation, which includes the use of motor vehicles (cars, Lorries, buses, bicycles, and truck) and animals, walking and cycling that provides movement of goods and peoples from place to place within a short period of time through enabling access to the market, recreation, health care, and education. However, the growth rate of modes of road transportation like car, bus, truck and trains in the city has also a negative impact on the human health in the form of a road traffic crash, environmental pollution (respiratory illness and other) and noise, which reduces the activity of people in their daily life highly. Among the negative impact of transportation on a human being, directly and indirectly, especially due to modes of land transportation is a road traffic crash. A road traffic crash is one of the growing global and national public health issues endangering and destabilizing life of humankind.

According to world health organization global road safety report (WHO 2018) 1.35 million people have lost their life by road traffic crashes per year on the world's roads, with more than 50 million sustaining serious injuries and living with long-term uncomfortable health consequences (disabled) due to road traffic crashes. Even though only 53% of a registered vehicle in low and middle-income countries around 92% of death occurs in those countries from the total death due to road traffic crashes and vulnerable road users such as a pedestrian, motorists and cyclists have shared half of the fatalities (WHO 2013). In addition to tremendously suffering the life of human being, road traffic crash drives the life of one family or nation into the poverty by revealing them for costing including medical cost, funeral cost, loss of family and cost of rehabilitation and finally world health organization global road safety report in 2015. According to the world health organization report in 2015 road traffic crash held the ninth rank of a global cause of death across all age groups and predicted that in 2030 traffic road injuries will be the seventh leading cause of death.

In developing countries, road traffic crash is a major health, economic and development problem like African countries. Even if only 4% motorized vehicle in Africa more than 10% of the total road traffic crashes in the world occurs in African countries. The majority of affected body in the

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

continent with a road traffic crashes were pedestrians, which is beyond 40% of total traffic crash in Africa. This is due to many reasons like human behavior and immaturity on road traffic crashes are the principal cause of road traffic crash in Africa, which covers more than 85% as contributing factor of traffic road crashes in the continent (Greg 2010). Ethiopia is one of the African countries extremely hit in a road traffic crash and has a high rate of road traffic crashes according to the world health organization report of 2015. Every year many lives are lost and the huge property has destroyed in Ethiopia due to road traffic crashes. According to (Abegaz T 2019) study, the rate of death due to a road traffic crash in Ethiopia in 2016/2017 was 4,922 per 100,000 vehicles in the country. Consequently, Addis Ababa is the capital city of Ethiopia the majority of traffic crashes in the country shared by the city.

In Addis Ababa according to (Tariku Hailu 2017) which has based on the 2010-2014 road traffic crash data concluded that 14,263 persons sustained different levels of severity injuries. Among these road traffic crashes occurred in the city 1,911 were fatal whereas, the rest were serious and minor injuries. Most fatal (79%) and 76% of serious injuries were males and pedestrians shared about 87% fatal crash in the city. Generally, road traffic crashes strongly hit the national economy as well as a household by killing the economically active age group those supporting their families and society as a whole, due to the many risk factors of road traffic crashes. Those major risk factors of road traffic crashes are: speeding, drinking and driving, and inadequate visibility are some of the problems for the occurrence of traffic crash and roadside object and non-use of seat belt, non-use of motorcycle helmet and child restraint non-use in motor vehicle is the risk factors influencing the degree of injury severity according to (WHO 2015). Proposing and installing traffic regulation is one of countermeasure approach to reduce road traffic crashes frequencies and severity, but ignoring to traffic regulation by a driver is among the human behavior factor that leads to road traffic crashes (Petridou E. 2000). Speeding is one of the ignoring traffic regulations and considered as the critical factor that contributes the most to risk and severity, and has high contribution to the mortality related to traffic crashes. A speed-related traffic crash is a complex, which is influenced by different factors. Among the factors' contributing to speed-related traffic crashes: drivers' characteristics (demography and psychological factors) is the main actor (Svenson 2012).

1.2. Problem of statement

The burden of road traffic crashes is highly increasing, particularly in low and middle-income countries, where rates of fatal crashes are more than twice those in high-income countries (WHO 2015). In economic terms, road traffic crash affects the countries' economies at a national and individual level particularly by affecting the economically active age group of one country. For instance, according to the world health organization report on the status of road safety, the cost of road traffic death and injuries in low and middle-income countries were estimated up to 5% of GDP (Gross Domestic Product) (WHO 2015).

In the case of Ethiopia, the issue of traffic crash has been worsened as the rates of motorization and mobility increased, which creates an increment of traffic flow and conflict between pedestrians and vehicles because of insufficient and poor infrastructure in urban streets particularly. According to the Ethiopian federal traffic police commission of the 2011 E.C report, 5,118 people have lost their life in road traffic crashes annually in Ethiopia. Accordingly, the Addis Ababa city has shared the majority of traffic crashes throughout the country. For instance, from the total road traffic crashes of 15,082 in Ethiopia during 2007/8, about 8,169 (54%) and out of 9,301 injuries in the country, about 2,071 (22%) have occurred in Addis Ababa city (UNECA 2009). Further study, on the traffic, crashes in Addis Ababa, Ethiopia revealed that on average more than one person has lost their lives daily on the road network of Addis Ababa city (Jiregna 2016). The main risk factors for the occurrence and degree of severity in road traffic crashes on the world's road are speeding, drug-driving, distracted-driving, non-use of safety seatbelt and motorcycle helmet problem, drinking and driving (WHO 2015). Especially, the risk factors of a road traffic crash in developing countries are partially due to the rapid rate of motorization that has occurred without a parallel investment in road safety strategies and land use planning in the country (Bekibele 2007). In Ethiopia, the major risk factors of road traffic crashes as identified by traffic police are the failure to give-way for pedestrians, over speeding, failure to respect right-hand rule by pedestrian and failure to give-way for other vehicles (Tariku Hailu 2017). From the listed risk factor of road traffic crashes, excessive speeding is the main risk factor that contributes highly to the road traffic crashes in Ethiopia (UNECA 2009). According to the review on the relationship between speed and road traffic crashes by (Letty. A 2005) Speeding not only affects the outcome of road traffic crashes, but it also related to the

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

probability of being involved in road traffic crashes. In addition, speeding is also the core of the disturbance of environments by engaging in air pollution and traffic noise (Mansour H. Hosseinlou 2015). In the same manner, on the road network of Addis Ababa city, excessive speeding is suspected as a major risk factor for road traffic crashes happening daily. Considering the above all problem this study investigates the excessive speeding in Addis Ababa city during an off-peak hour on the different road networks of a city at a different posted speed limit and investigates the hotspot location of road traffic crashes in the city.

Therefore, understanding the road traffic crashes and influence of excessive speeding in road traffic crashes, identifying hotspot location of road traffic crashes and investigation of excessive speeding in the city has highly important for the following. a) To put direction, remedial solution for traffic crashes. b) To develop road safety strategy to reduce road traffic crashes in the city and important for further investigation on the causes of highly disclosed location (hotspot area) by road traffic crashes in Addis Ababa city. In this research, it has tried to investigate hotspot location of traffic crashes in Addis Ababa city using ArcGIS software and assessment of excessive speeding in the city.

1.3. The objective of the study.

1.3.1. General objective.

The main objective of this study is the identification of road traffic crashes hotspot location and assessment of excessive speeding on the road network of the Addis Ababa city.

1.3.2. Specific objective.

1. Assessment of excessive speeding (extent of speeding above the posted speed limit) and identifying the link between drivers' demographic related factors and vehicle types with speed violation in Addis Ababa city during an off-peak hour.
2. Investigation of hotspot location of traffic crash in the city from 2007 to 2009 E.C using ArcGIS software in Addis Ababa city.
3. To know the trend of traffic crashes by temporal variation from 2007 to 2011 E.C.
4. To know the causes of traffic crashes and the association between vehicle type and traffic crash in the city.

1.4. Research question

1. Is there any excessive speeding during an off-peak hour on the street in the city?
2. By whom the speed violation occurred? By how much they are driving above the posted speed limit? What are the drivers 'demographic characteristics' and vehicle types' that are highly engaged in speed violations (excessive speeding)?
3. Where is the hotspot location of traffic crashes from 2007 to 2009 E.C in the city per severity types of road traffic crashes?
4. What is the temporal trend of road traffic crashes in Addis Ababa City?
5. What are the causes of road traffic crash in the city?

1.5. The scope of the study

The main target of the study is to investigate the excessive speeding in 2010 and hotspot location of road traffic crashes from 2007 to 2009 E.C in the Addis Ababa city.

Therefore, the main contents of this study can be stated as follows

- ❖ The study on excessive speed was covered the whole sub-city in Addis Ababa, it could be helpful to understand about excessive speeding who violate and by how much speed, drivers traveling above the posted speed limit in the city.
- ❖ This study considers only three years of road traffic crashes (2007-2009 E.C) the researcher took from the Addis Ababa city program and management office, to address the black spot or hotspot location in Addis Ababa city with the help of ArcGIS software and google. The latest data was not digitalized.
- ❖ Finally, the study also considers the traffic crashes from 2007 to 2011 E.C to analyze the trend of traffic crashes by temporal variation (time of the day, day of the week and year), causes of traffic crash and the association between vehicle types with traffic crash.

1.6. Significance of the Study

It is expected that the results of this study will have the following importance;

Theoretical Significance:

- ❖ Helps road safety experts to know the hotspot location of fatal, injury and non-injury traffic crashes in the city.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- ❖ It helps road safety experts to know the trend of traffic crashes and fatal traffic crashes in the city by the time of the day and annual variation.
- ❖ Helps to find how excessive speeding are associated with drivers', posted speed limit and vehicles' characteristics,
- ❖ It helps the road safety experts to know the extent of speeding above the posted limit in the city.

Practical Significance:

- ❖ By identifying the most common hotspot location for each type of traffic crashes, trend and variation of traffic crash with time variation, road safety management and road safety engineers can make interventions towards minimizing traffic crashes.
- ❖ Identifying hotspot location of traffic crash helps road safety management for further study to identify the major cause of traffic crash in the city.
- ❖ After identifying the extent of the speed of driver above the posted speed limit and the differences in excessive speeding by vehicle types', posted speed limit and drivers' characteristics the road safety management can make interventions to minimize the extent and amount of excessive speeding in the city to minimize speeding- related traffic crashes in the city.

1.7. The structure of the thesis

This study has been prepared in five main chapters to address the problem of the statement and to achieve the aim of the study. Chapter one discusses the general background of the study, the problem of the statement, the main objective and specific objective of the study and finally, it includes the research question which should have to be answered in the study.

Chapter two demonstrates the review of journals, thesis, and related literature on the topic of the study, like methodology, techniques of data collection, a conceptual, theoretical and analytical framework to shape the study, etc.

Chapter three talks about the methodology of the study how to attain the objective of the study that includes data collection methods used, the study area and study design in detail discussed

Chapter four focused on the data collection analysis and the result of the study using different software like ArcGIS, SPSS, Microsoft excel, and google map and finally the presentation of the result.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Chapter five discusses the result of the study, conclusion, the limitation of the study and recommendations for the concerned body related to the study and further study.

Chapter Two

2. Literature Review

This chapter reviews journals, a thesis of masters of Science degree and Philosophical doctorate degree on the speeding, factors influencing the speed, speeding-related traffic crashes, and influence of speeding on the environment and also the approach used to investigate hotspot location of road traffic crashes analysis with the help of ArcGIS software.

2.1. Definition of speed and speed type.

Speed is the rate of movement of vehicles or the distance covered per unit time it takes to complete it and expressed in km/hr. It is one of the basic components in the transportation engineering to measure time-saving, to determine the level of service, to evaluate the performance of the road operation, for the investigation of the road safety issue and it affects more directly geometric design of highway (Fitzpatrick K 2003). Many scholars and textbooks define various aspects of speed such as: operating speed, speed design, speeding and speed limit as described below.

2.1.1. Operating speed.

Operating speed is defined as the speed at which drivers operating their vehicle under the free-flow condition and favorable condition and the actual traveling speed on the road segment (AASHTO. 2001). Furtherly in statistics, the 85th percentile of observed (assessed) speed from the site while investigation most frequently used to measure the operating speed of the vehicle at a specific time, location and geometric characters according to (Fitzpatrick. K 1995), (Fitzpatrick .K 2000) and (AASHTO. 2001) study.

2.1.2. Design speed

The geometric design is a process of proper selection of roadway components to attain the desired level of road safety, mobility, accessibility for non-motorized vehicles and pedestrian and efficiency of road. The traveling speeds of the vehicle are affected by geometric elements of highway and street such as horizontal curve, superelevation, vertical curve and cross-section of the road segment. Therefore, designing the geometric elements of the road with inappropriate speed resulting in an uncomfortable and unsafe geometric element of road. In general, design speed is the cornerstone of geometric element design. When we come to the definition and the

way of design speed selection there are numerous studies let us see some of them. According to ERA (Ethiopian Road Authority) manual design speed is the selected speed used to determine the different component of geometric design elements of roadways (stopping sight distance, minimum curve radius, and length of vertical curve of the alignment) depending on the purpose of the road, traffic volume and topography of the ground the road alignment passing through (ERA 2013).

AASHTO manual design defines the design speed as “a selected and logical speed depending on many factors such as: topography, expected operating speed, the adjacent land use and functional road classification of highway to determine the geometric features of roadway such as curvature, superelevation, and sight distance” and also the design speed should be assumed logically in order to attain a desired level of mobility, accessibility and efficiency of highway or streets within the boundary of aesthetics, environmental quality, economic and political impact (AASHTO 2004).

2.1.3. Speeding or excessive speeding

Speeding was defined in a number of ways by different studies. Speeding is one of the traffic rule violations exposing to road traffic crashes. Speeding is an excessive speed which means that driving above the posted speed limit and also defined as inappropriate speed which means that traveling at speed limit of the road but, unsuitable for prevailing road, weather and traffic condition, which reveals vehicle for the road traffic crashes (WHO 2017).

2.1.4. Speed limit

A speed limit is a maximum or minimum speed posted on the section of highway and street to inform those drivers of the highest speed believed to be safe and reasonable under a friendly road condition and traffic flow condition. A speed limit is also the maximum speed decided through law and regulation of the nationwide or locally and posted to inform the drivers in order to operate below the posted speed limit shown on the speed limit sign for the purpose of different things such as politics, fuel consumption, and road safety. The 85th percentile of operating speed of a vehicle is greater than the posted speed limit of the road segment and 50th percentile of a speed of a vehicle is very close to the posted speed limit but there is strong relationship between speed limit and 85th operating speed of vehicle according to study by (Fitzpatrick K 2003).

2.2. Speed and road safety

Speed has a positive effect regarding mobility by reducing the transport time to reach the destination but, in another way, it influences negatively the road safety. The speed of a vehicle is commonly known as the main contributing factor of a road crash in the world. Especially in the developing country and closely related to the geometric design of the road. In the first case, speed influences the occurrence of a road crash and the injury severity or the degree of injury. According to (Letty. A 2005) speed affects the types of severity of traffic crashes and it is also a factor for the rate of traffic crashes (frequency of crash occurrence) because as travel speed increases the reaction time of the driver is reduced and also due the high speed of a vehicle the distance required to stop the vehicle before the collision with another vehicle or pedestrian or to protect overturning on the curve becomes increases. This paper also discussed the increment of a crash rate due to the high speed of the vehicle and due to speed variance between vehicles on the road section. Traffic crash because of the speed of the vehicle and its outcome is directly related to the kinetic energy. High speed of vehicle generates high kinetic energy, which results in a high level of traffic injury. Road safety is related to the dozen of the cause but in case of operating speed, high-speed change is very sensitive to a road traffic crash and associated with the high road safety problem (Elvik 2004). Not only excessive speed but also, the speed variation from the mean speed of vehicle revealed through different researchers.

According to (Solomon 1964) the speed dispersion or variation is the measure of speed distribution on the road segment and which, has a high influence on the road traffic crash and road traffic crash frequency. The study noted that the crash frequency was varied when operating speed of vehicles asymptote to the mean speed the speed of traffic flow and as the speed variation increases the crash rate also increases. Solomon has developed the U-shaped curve on the relationships between speed deviations from the average mean speed versus the crash rate. In another study, the variation of speed has an impact on the crash rate. According to the paper reported by (OECD 2018) on the international transport forum, the high-speed variance between vehicles also have an effect on the crash frequency even though the exact relationship of probability crash frequency and speed variation not known.

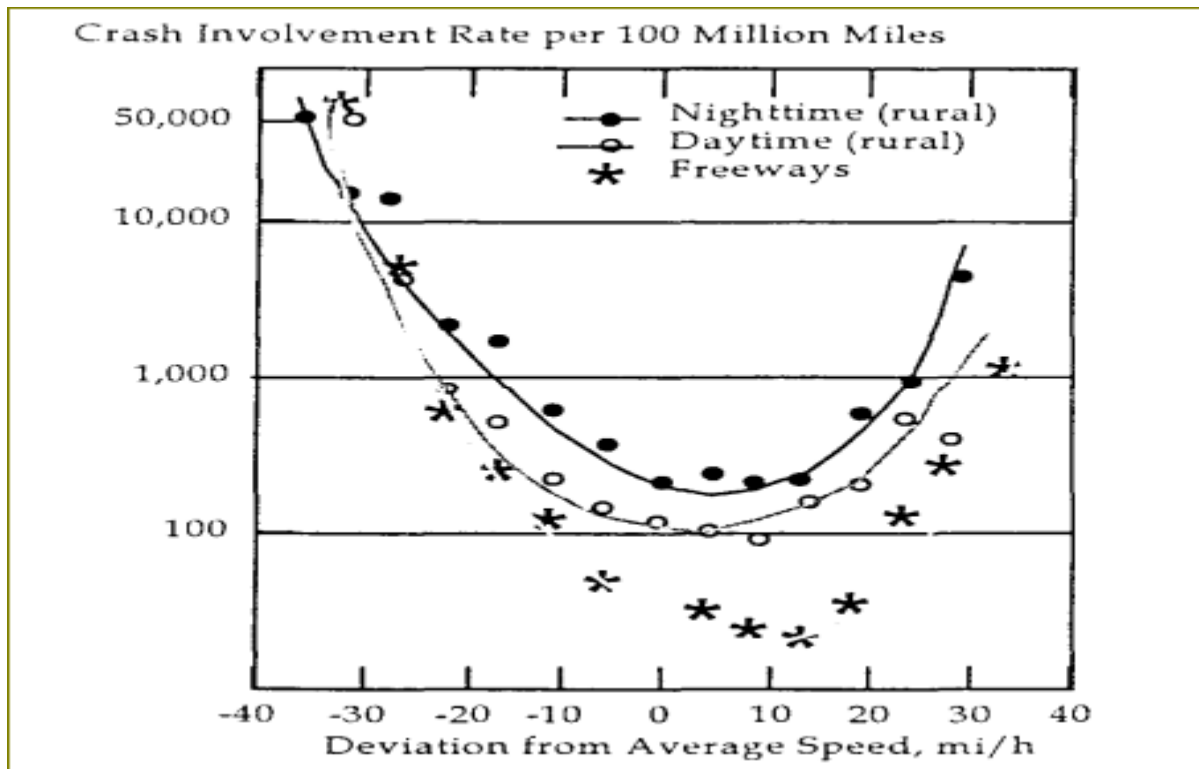


Figure 2-1 Crash rate versus deviation from average travel speed (Solomon 1964)

In addition, there are many empirical relationships between speed and the probability of road crash severity before and after speed management not only on their deviation. The probability of a number of crash after change in speed equals to the number of crash before speed change times the square of the ratio of speed after and speed of vehicle before speed management. The probability of fatal crash is proportional to the fourth power of speed ratio and the probability of serious injury is proportional to the third power of speed ratio (Nilsson 2004).

The survival probability of Pedestrians at collision with the speed of 30km/hr. or below is 90%, but less than a 50% chance of surviving under the speed of 45 km/h or above regardless of many other factors because a human being has no capacity of cushion in a road traffic crash (WHO 2017). In Abu Dhabi, the United Arab Emirates more than 16% of a total crash and 26% of fatal crashes in 2014 were due to speeding-related crashes resulted from younger drivers less than 45 years old (Hany M. Hassan 2016). In New Zealand, the combination of speeding and alcohol contributes 17% of fatal crashes and speeding alone contributed to 12% (Ministry of Transport 2014).

2.3. Factors influencing the speed of the vehicle

There are several factors influencing the speed of the vehicle too fast or too slow. According to the World health organization report on global road safety problems and risk factors, the following are the main factors of influencing speeding (WHO 2017).

1. Drivers related factors (Age, Sex, driving experience, Alcohol level, etc.)
2. Road and vehicle-related factor (vehicle power, type, weight, the volume of traffic) and (horizontal curve, tangent length, a number of lanes, lane width number of access, gradient, median type and availability of median and shoulder width).
3. Traffic and Road environment (land use, pedestrian volume, and accessibility of pedestrian crossing)

2.3.1. Drivers related factors influencing the speed of a vehicle

Human behavior has a great role in the operating speed of vehicle and road traffic crash because speed and any type of driving error are controlled with the aid of human beings. Drivers related factors are like age, sex, and the reaction time of the driver, ownership of a vehicle, education level, driving experience of driver, income, attitude and amount of alcohol consumption by drivers some of the factors influencing the speed of the vehicle. (Fildes 1991) reviewed in his paper on the driver-related speed factor the mean speed of young drivers, out of state vehicles, buses and latest model passenger vehicles were exceeding the speed limit and in addition he found that younger drivers, drivers without passengers, drivers of new cars, drivers traveling for business purposes and high mileage drivers were more likely to drive faster than average speeds and exceed the posted speed limit of the roadway. Based on a study of speed selection behavior of Korean drivers, (Kang 1998) concluded that male drivers with higher income tended to drive faster and experienced drivers drive at a higher speed than others. Trip distance and frequency of use of a road were also found as an important factor for speed selection behavior. As the age of the driver increases the percentage of vehicles participating in speed violation decreases by both genders according to the study of (Harrington 1970). In addition, Harrington has identified male drivers more highly participated in speed violations than female drivers.

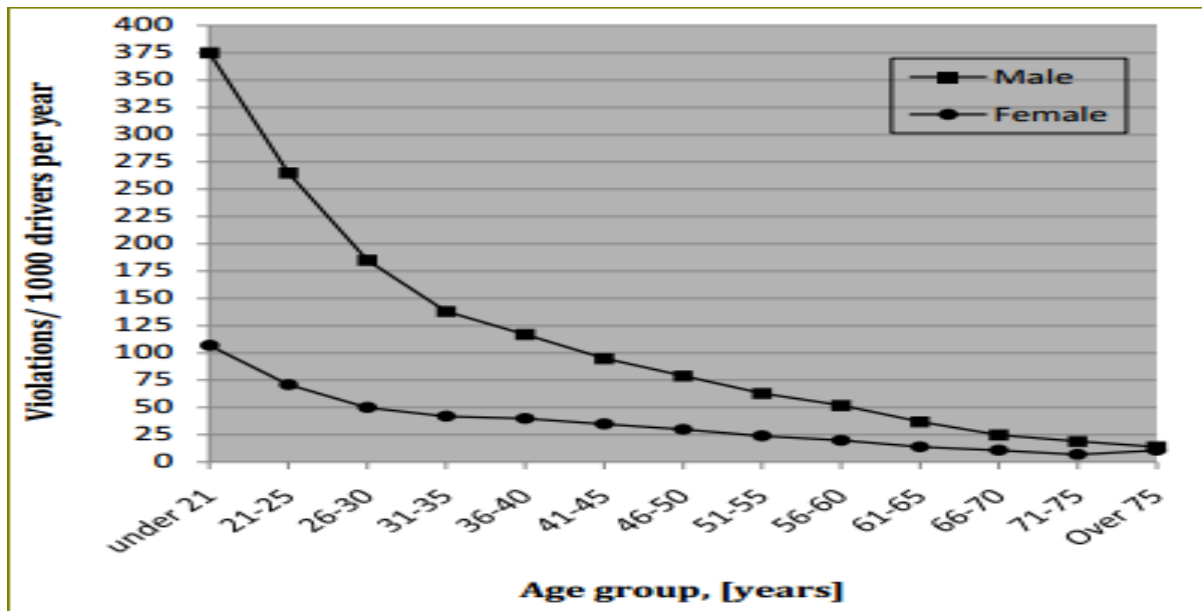


Figure 2-2 Speed limit violations per age group (Harrington 1970)

2.3.2. Road and vehicle -related factors on the speed of a vehicle

The main factors influencing the operating speed of a vehicle on the urban tangent road are the degree of the horizontal curve, the number of lanes, posted speed limit, presence of crosswalk, access density, types of median and lane width some of them (Mariangela .Z 2018). The study investigated by collecting speed data in tangent sections, using 200 vehicles equipped with GPS by the researcher (Jun Wang 2006) brought out that the roadside density, driveway density, intersection density, sidewalk presence, and parking presence are negatively associated with operating speed on an urban streets while a number of lanes, curb presence, and commercial and residential land uses are positively associated with operating speed and also the researcher determined that the availability of poles and trees has significant influence on the drivers operating speed of a vehicle.

Highway Capacity Manual (HCM) (200) discussed briefly on the factors influencing the traveling speed and indicated that the speed of vehicle operating on the urban street is highly influenced by road environment, interactions between vehicles, percentage of trucks and bus, traffic control, adjustment land use and traffic density on the road segment. The another study by (Zamanov 2012) on the influence of road geometry on the speed of vehicle under 200 vehicles per hour traffic flow on urban streets shows that the number of lane width, median width,

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

tangent length, and barrier or guardrail used as traffic flow separation from pedestrian walk on both sides of road has positive relationship with the percentage of vehicle violating the posted speed limit in urban road which, means that as tangent length and number of lanes increases the speed violation percentage increases. Furtherly this study also revealed that speed violation during the night time decreases when there is street lighting on the road, few drivers operate above the posted speed. In addition, the researcher also concluded that the frequency of violation of traffic rules (like red-light running and speed violation) extremely influenced by driver's characters such as age, sex, experience and, vehicle types.

Generally, the geometric factors influencing the traveling speed of urban roads are summarized as bellows from different journals.

1. Horizontal curve
2. Number of lanes
3. Lane width
4. Number of access on the road segment
5. Length of a tangent.
6. The surface condition of the road
7. Posted speed limit.

The drivers' related factors influencing the speed of vehicle operating on urban road summed up from journals and graduate thesis are: Age, Experience, Gender, Education Level, Socioeconomic and drinking and driving are some of the factors.

2.4. Speed and its impact on the environment

In addition to road traffic crash, excessive speed has a significant negative impact on the environment, which needs to be addressed and recognized, while speed limit choice. Excessive speed principally increases the air pollutant gases, greenhouse gases, as well as fuel consumption and noise on the environment. The result of this unwanted noise and air pollution brings the unwanted cost to the country (Elizabeth 2012).

The other main health problem of developing country cities due to transportation is air pollution due to vehicle gas emission and traffic noise. When a vehicle operates on the road, it consumes fuel that released as the pollutant compound to the air. The main pollutants of air due to the speed of the vehicle are an oxide of nitrogen (NO_x), carbon monoxide (CO) and hydrocarbon

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

(HC). At low speed and high speed of traffic flow, the emission rate of those pollutants is high but the emission rate of pollutants is low between 25km/hr. and 55km/hr. speed of vehicle irrespective of any other factor and also the noise increased by 10db when the speed of the vehicle becomes double (Elizabeth 2012).

2.4.1. Impact of speeding on air pollution

The release of emission by a vehicle on the urban roads depends on many factors, like vehicles related factors, traffic flow, traffic density and nature of the road. The types of vehicle, speed of a vehicle, age of vehicle, nature, and condition of emission control equipment of vehicle are some of the crucial factors influencing the emission rate of vehicles related factors. The emission produced by road traffic contains a different amount of pollutants and quantities at different speeds of the vehicle. The main air pollutants from the due to road traffic emissions are (OECD, 2006):

1. Carbon monoxide(CO)
2. Nitrogen oxides(NO_x)
3. Hydrocarbon(HC)

According to the study of the Organization for Economic Co-operation and Development (OECD) the production process of those listed above pollutants is very complex and depends on different conditions as detailed above. The speed at the emission of vehicle minimized or optimum speed is different for each type of emission. For example, carbon dioxide (CO₂) and carbon monoxide (CO) depends on the amount of fuel consumption (at a low travel speed of vehicle less than 15km/h), and nitrous oxide is produced under high steady traveling speed of the vehicle. The optimum travel speed of a vehicle to minimize the emission or to optimize the pollutant emissions should be within the range of 40km/h and 90km/h according to this study detailed.

Furtherly the study also approved the fuel consumption of vehicles also depends on the travel speed of road traffic vehicles. At low speed less than 20km/h the fuel consumption of vehicle increased significantly, which means that the travel speed of vehicle affects the economic resource of the country (cost of travel time, cost of fuel and cost for environmental protection) and the travel speed of vehicle with 90km/h saves 23% of fuel relative the 110km/h travel speed. In general optimum traveling speed of vehicle have the pillar role on the environment, road

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

safety and quality of life of human being (as whole speed has the fundamental role in the economy of the country). The optimum speed of vehicle modeled by (Soriguera 2013) based on the emission rate factor of CO₂, NO_x and fine particulate matter (less than 10µm) (PM10) because of a vehicle is described in Figure 2-3 below in a clear way.

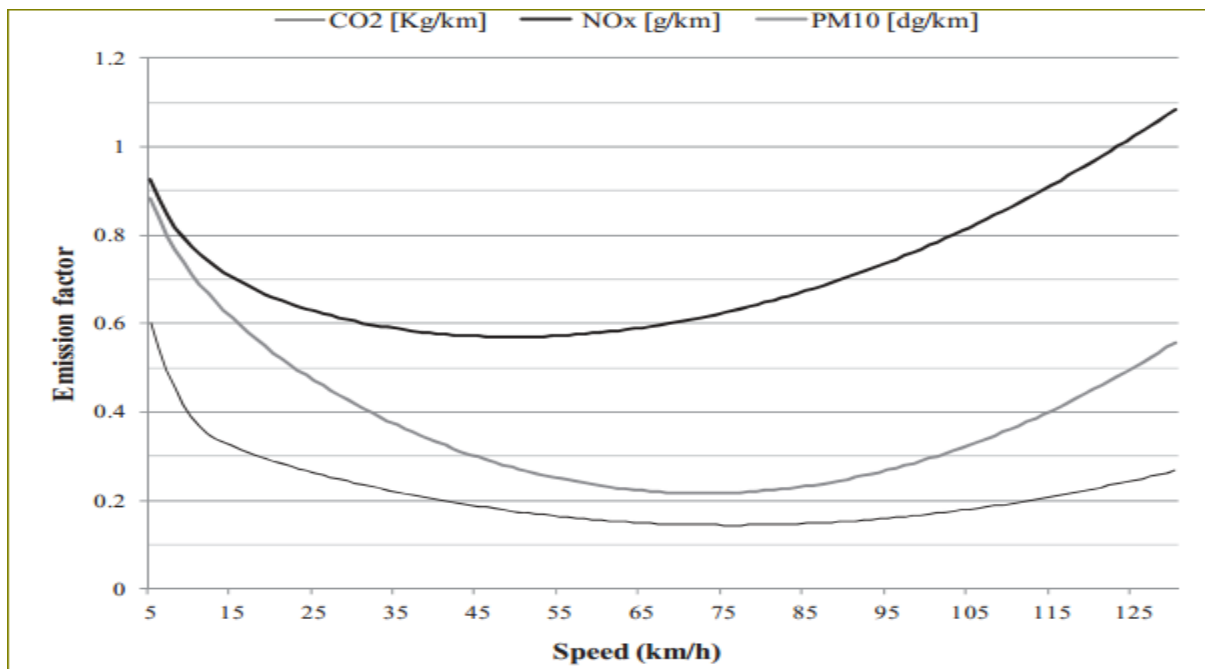


Figure 2-3 Pollutant emission factors for the average vehicle type distribution in the C-32 freeway near Barcelona, Spain. Note: Different units for each pollutant

2.4.2. Impact of speed on the noise

Another impact of speeding on the environment is environmental noise. Noise means unwanted sound. The traffic noise produced is the combination of engine (power unit) noise and rolling noise (the unwanted sound between tire and road interaction). Traffic noise also depends on the many factors like age of the vehicle, the roughness of road and slope, speed of vehicle and acceleration and deceleration of vehicle due to speed-reducing devices such as road hump. The tire-road interaction noise increases as the speed of vehicle increases, when the speed of vehicle becomes double the tire-road interaction noise become increased in 12dB (A) (OECD. 2006).

2.5. Speed management

Speeding is a highly complicated problem, which is interconnected with road user behavior, vehicle character, road geometry, and characteristics, posted speed limits, and enforcement

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

strategies. Speeding has a significant role in the occurrence of a road traffic crash, environmental pollution and traffic noise in an urban and rural area. In order to solve those problems, it is mandatory to manage the speed. Speed management means the way of reducing the negative impact of excessive speed or inappropriate speed on the humankind directly and indirectly.

Some of speed management approaches are:

1. Engineering measurement (setting speed limit, traffic calming and properly designing the road (designing self-enforcing road geometry),
2. Enforcement (enforcement through radar and video camera recording the speed of the vehicle),
3. Training driver and publicity campaign on the consequence of speeding.

2.5.1. Setting a speed limit

Setting an appropriate speed limit which is based on the research or by considering the impact of the speed on road traffic crashes were one means of speed management. When setting the speed limit of the urban street it is mandatory to take into account the impact of speed on the environment because of the speed of vehicle influence the emission rate, fuel consumption and noise in the city. Setting the speed limit depends on an engineering study such as land use (local environment), traffic crash, road category, mobility and road geometry. Generally, there are two approaches to set the speed limit according to different studies.

1. Setting the speed limit at the 85th percentile of operating speed of the vehicle and modifying it through time depending on the accident history, road geometry and land use (Fildes 1991).
2. Setting speed limit using a computer software program considering different factors such as accident history, number of the lane, road function, pedestrian, and non-motorized activity.

Setting the speed limit was not enough because most of the drivers were not ready to obey the traffic rule especially posted speed limits. Therefore, speed enforcement technique was mandatory to make effective the posted speed limit.

2.5.2. Speed enforcement

Speed limit setting considers different factors as described above but setting an appropriate speed limit was insufficient to manage the speed of vehicle because there are drivers who do not obey

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

the speed limit and driving above the posted speed limit of a road segment. Speed violation and speed variation from the mean speed different from country to country. In Ghana, more than 95% of vehicles traveled above the posted speed of 50km/h in the built area after 24 hours of continuously speed measurement at Atwidie and Adansi town, which are located 62km and 70km respectively from second-largest city Ghana, Kumasi city (Afukaar 2007). In this study, the mean speed of all vehicle types traveling through the studied site was with the speed of 87kmph, which means that 37km/h above the posted speed limit 50km/h. This study revealed not only the violation of speed but also confirmed that speed dispersion of vehicles from the mean speed of traveling speed has exposure for road traffic crash in those small towns. According to this study, the speed dispersion from the mean speed of the vehicle was highly revealed by private car with 18km/h speed variation.

Finally, speed enforcement is one of the speed management to ensure the effectiveness of the posted speed limit. Speed enforcement is based on negative principles to make drivers try to complain about the posted limit in order to avoid penalty coming on them. Speed enforcement is a way of changing the attitudes of the driver through penalizing. There different tools of speed enforcement.

Those are:

1. Manual speed enforcement using radar and Laser gun with the help of traffic police commission.
2. Speed camera installation.

2.5.3. Education and publicity campaign on speed

Other methods of speed management tactics are training drivers, educating the road user on the impact of speeding and campaigning the significance of speed on road traffic crash and remedial things through media. Educating and training the driver were raised as essential to deliver information about the risk of speeding or inappropriate speed how and why speed limits according to different literature. The study of (Vaa.T 2009) on the campaigning of the risk of excess and inappropriate speed of the vehicle through media such as radio, television or newspaper and message sending using meta-analysis showed that overall speed campaign reduced 16% of speeding of vehicle.

2.5.4. Traffic calming method

Traffic calming of speed management is the traditional speed management system in the urban street through self-enforcing of road. Horizontal and vertical deflection schemes are some of among speed calming techniques used. Those traffic calming roadways are speed hump, cushions, diverters, mini traffic circles, full or partial road closure. In addition to this the modern and safest one of the traffic calming techniques is striping which is effective without affecting emergency service vehicle while traveling and highway drainage with less cost with respect to other types of traffic calming techniques to construct and striping can reduce the speed of vehicle by 3km/h to 11km/h (Robert Kahn 2011).

According to the study by (Mountain 2005) on the “Are speed enforcement cameras more effective than other speed management measures? The impact of speed management measures on 30 mph roads” has shown that the vertical deflection speed management reduces 44% of a personal injury crash, horizontal deflection reduces 29% of a personal injury crash and installing speed camera reduced 22% of a personal injury crash. Depending on their result they have concluded that vertical deflection speed management techniques were effective than speed camera speed management and horizontal deflection.

2.6. Road traffic crashes

Even though all road users are affected by the road traffic crash, pedestrians are the most vulnerable road users by road traffic crash than vehicle occupants throughout the world. This is very common in low-income and middle-income countries due to many reasons such as lack of separation pedestrian from the other road user, traffic mix and fast-moving motorized vehicle are some of the factors raised problem (WHO 2018).

2.6.1. The major factors influencing the pedestrian crash

There are different factors raised as a cause of injury severity of the pedestrian-vehicle crash in either urban or rural roads. The summary of the pedestrian-vehicle crash factors is described by the figure-2-4 as bellow. According to (Charles Zegeer 2010) the key factors of pedestrian-vehicle crashes divided into five main categories. Charles Zegeer and his colleagues reviewed different international and national articles published in Transportation Research, Accident Analysis and Prevention and related journals to develop a framework of pedestrian-vehicle crash

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

factors depending 2000-2010 pedestrian safety studies and they had presented to Federal Highway Administration (FHWA) to develop a pedestrian safety strategic plan.

Those main factors are:

1. Driver related factor
2. Pedestrian-related factor
3. Road and environment-related factor
4. Vehicle-related factor
5. Demographics/social/policy factors.

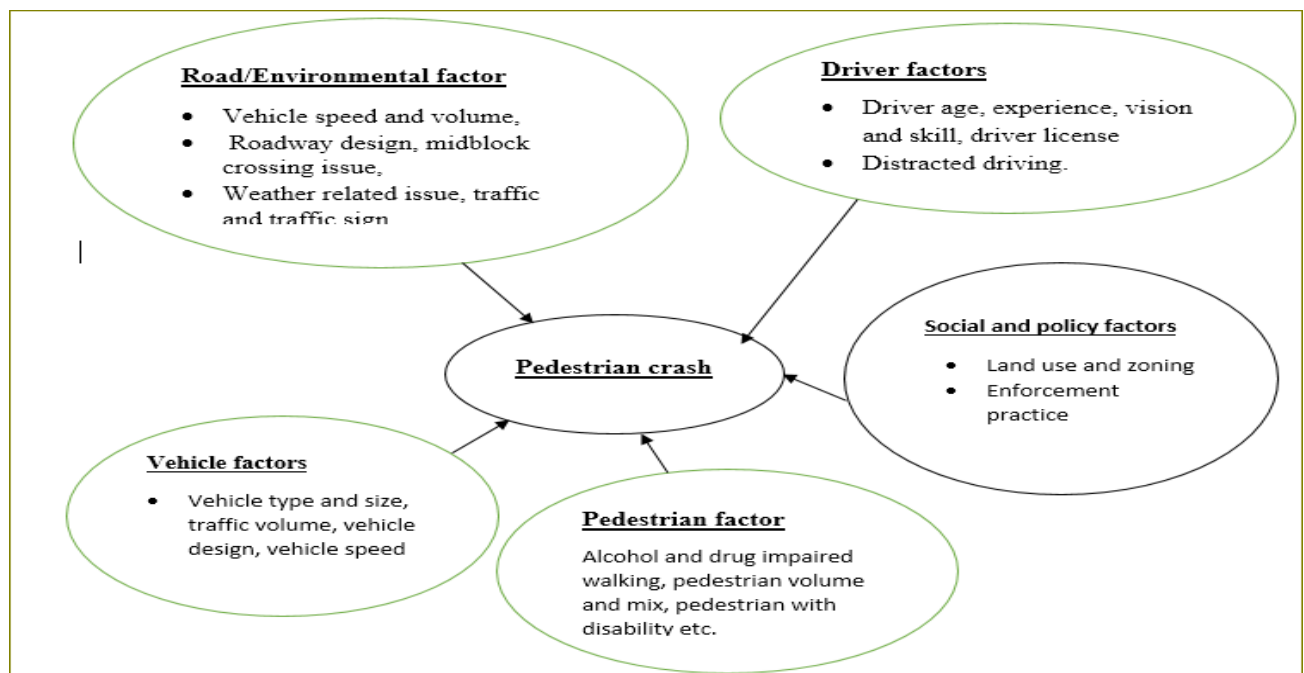


Figure 2-4 the key factors influencing pedestrian traffic crashes (Charles Zegeer 2010)

1. Driver-related factors of a pedestrian crash.

The principal factors of driver-related factors that revealed pedestrians for pedestrian crashes include driver age, experience, education level, gender, driving distractions, speeding and driver insobriety (intoxication).

A. Driver Age and Gender

Different studies have analyzed the relationship of driver age to the crash rates and there are numerous studies identified the relationship between the pedestrian crash and drivers' age

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

specifically. The role of driver age and gender in motor vehicle fatal crash by (Deogratias 2010) concluded that the younger driver and the elderly driver were highly participated in fatal crashes. They have shared 83.1% of total fatal crashes based on three years fatal crash report of 2001 to 2003. he has also confirmed that the exposure of driver age and gender operating error (per mile driving error exposure) on the fatality related crashes such as excessive speed, run-off-road, failure to keep in the proper lane and operating in erratic, reckless and careless as the main contributing factor of young and middle-age driver operating error. The elderly driver and young driver accounted for only 6.4% of a total mile driven in 2001 through 2003 but they shared the majority of fatal crashes in the USA, Ohio State. In another study, on injury crashes of pedestrian the age group of (25-54) drivers highly involved in the pedestrian crash of the city according to the study (Getu.T 2017). They have shared about 76.6% of total pedestrian injury, 18.8% of fatality, 45.8% of serious injury and 35.4% of slight injury in the city were attributed in those age groups of driver (25 through 54 age group) based on the reported pedestrian crash data of over three years period (2009-2012) by traffic police commission. In his study, he has also confirmed that the most participatory one in terms of the gender category of the driver was a male driver with a percentage of 71.3% of total pedestrian injury and the rest one was contributed by a female driver (28.7%).

Due to the driving distraction related to cell phone and others like cell texting, talking on hand-holding telephone, interacting with passengers, singing, drinking, eating, and looking outside the road traffic crash occurred in the Virginia, Blacksburg, USA the majority of driver participated in the crashes were a teenage and young driver rather than middle-age driver (Feng Guo 2017). In the study of Feng,et al and his colleagues, the road traffic crash occurred due to driving distraction by the teenage driver (16-20 age group) who shared the majority of the road traffic crash.

B. Influence of driver experience and education level on pedestrian crash

The other human behavior influencing, the pedestrian crash occurrence is the driver skill due experience and education. In the study by (Yazan 2016) young drivers less than 30 years old were highly participated in the traffic road crash by sharing more than 60% of total traffic crashes in the city due the less responsibility and highly experienced driver more than 5year contributes around 65% total crash and higher education level of driver holding at least a

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

bachelor of degree were highly involved in the road traffic crash with an account 47% of total crash in Saudi Arabia. In contrary to the study of (Yazan 2016) inexperienced and young drivers (25-36 age group) are highly involved in a road traffic crash by sharing 42.3% of a total pedestrian crash due to speeding and carelessness in Ghana during 2005-2007 (Adonteng 2011).

2.6.2. Traffic crash in Addis Ababa city and its' risk factors

The study by (Jiregna 2016) based on the report data from police commission of three years (2013-2015) revealed that on average 391 peoples per year have lost their life in Addis Ababa city irrespective of under-reporting of a traffic crash. He has confirmed also more 86 percent of a fatal crash in the city is pedestrian and the major contributing factors of traffic crashes in Addis Ababa city are speeding, pedestrian accessibility and drinking and driving. This study concluded the majority of fatalities are caused by excessive speed hitting a pedestrian at the mid-block of the road where there is no intersection and occurred on the ring road and major roads of the city. Findings further (Getu.T 2017) on pedestrian crash of three years (2009-2012 G.C) data on the pedestrian crash in Addis Ababa city (6208 pedestrian crash) collected from Addis Ababa police commission on traffic accident report indicates that more than 48% of pedestrian crash were productive age group (24-54) and this study reveals also the majority of pedestrian crash happened under the posted speed limit of more than and equals to 60km/hr. which reflects that higher speed incidence the road traffic crash on the road segment and increases the probability of death. In terms of the location of a pedestrian traffic crash, the mid-block pedestrian crash held the first rank in more than 77.7% of a pedestrian traffic crash out of the total pedestrian traffic crash. In this study, the factors contributing to the pedestrian crash were identified in detailed those influencing factors are driver experience, a land-use area, types of vehicle in a collision, driver relationship with a vehicle, posted speed limit and road condition.

According to the study by (Tariku Hailu 2017) on the road traffic crash in Addis Ababa, Ethiopia empirical finding of road crash on the data of road traffic crash between 2010 and 2014 the speeding-related traffic crash in Addis Ababa city covers 3.5% of total crash and 87% of serious injury, 83% of fatal crash, 82% and 83% of minor crash occurs on the straight road section. In this study, the main cause of traffic crash in the city are a driver's not yielding right of way to

pedestrian and the problem of not yielding right of way vehicles to each other are leading factors of a road traffic crash.

2.7. Impact of speed on the pedestrian crash

Pedestrian crashes were commonly known as road traffic crashes in the developing country especially in highly affecting the economic product age group of the country. In the developing country, the majority of road traffic crashes vulnerable were pedestrian because lower-income countries used walking modes of transportation relative to a higher-income country which exposed them to vehicle-pedestrian crashes. The pedestrian crash injuries influenced through different factors like vehicle type, the speed of the vehicle, the age of pedestrian, pedestrian socio-economic status, driver age and experience and different factors as described above. Speed increases the pedestrian crash injuries and the frequency of pedestrian crash happening when the speed of the vehicle was not properly installed and controlled. Different studies show that the speed of the vehicle generates the kinetic energy that directly fails on the body of a pedestrian which has no capacity of energy absorption to resist the impact of the collision.

According the (Tefft 2013) on the impact of speed on the pedestrian risk injuries and death in USA using speed of collision and types of pedestrian crash occurred based on the police reported road traffic injuries using the logistic regression modelling, the pedestrian crash included in the modeling was only 315 pedestrian crash selected at different speed of vehicle during the collision and finally he found that the probability of risk severity and probability of death of pedestrian increases as the speed of vehicle increases and also the probability of risk significantly related to the pedestrian age which, means that the risk of pedestrian crash of older pedestrian relative to the younger pedestrian was high. In this study, he/she has developed the impact of speed versus the risk of severity and probability of death as described in figure-1 below. The study considers the pedestrian age, body mass index, height and different types of vehicles participated in the collision and developed the graph of the impact of speed versus pedestrian risk of severity and probability of death.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

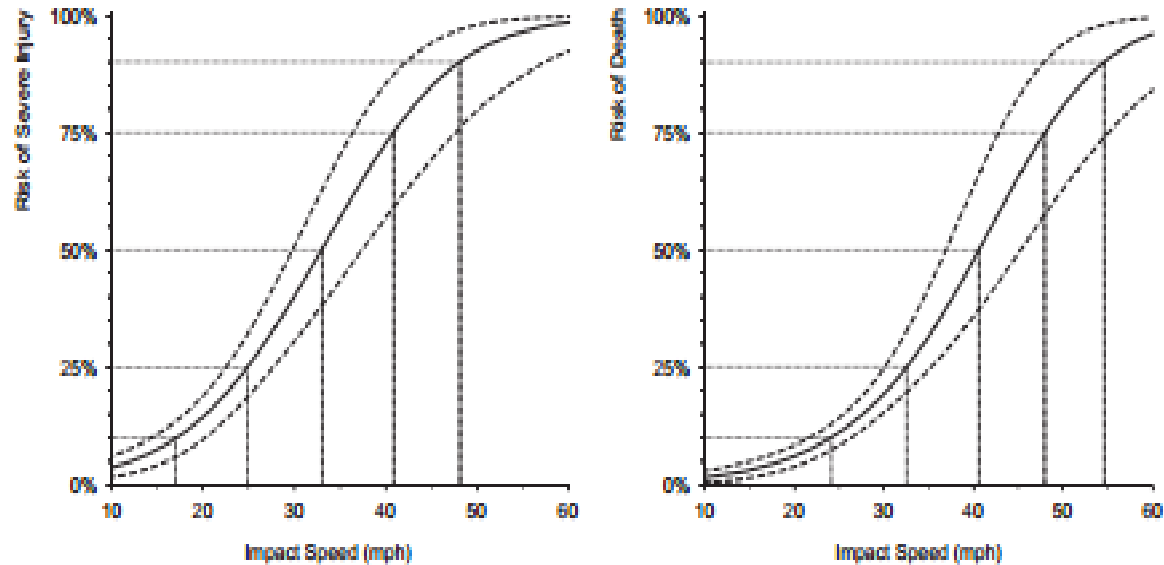


Figure 2-5 Pedestrian risk of severity and risk of death in relation to the impact of speed

In another study in China on the Investigation of passenger car-pedestrian crash as the speed of the vehicle increases the probability of death and severity injury and slight injuries increases. The study includes only passenger cars involved in the pedestrian crash and only 184 pedestrian crashes gathered from three provinces of China (Beijing, Shanxi, and Chongqing) between 2006 and 2008.

The output of the research revealed that the probability of death is very less under the speed of 30 km/h 38% slight and 62% serious injury occurred without any pedestrian fatalities from 34 pedestrian crashes. When the impact of speed of vehicle between 30km/h and 39km/h the percentage of slight injuries, serious and fatalities shared 63%, 32.6%, and 4.4% respectively from the 46 pedestrian crash. When the speed of vehicle becomes between 40-49 km/h the percentage of slight, serious and fatalities of pedestrian were 34%, 49%, and 17% respectively from the total pedestrian crash of 41. When the impact of speed becomes above 80km/h the pedestrian totally fails under serious injury or death. In this study, he/she also revealed that the role of gender, age and first contact between vehicle and pedestrian has a pillar in the types of severe injury of a pedestrian in addition to the impact of speed (Hui Zhao 2010).

2.8. Road traffic crash hotspot investigation

Road traffic crash cannot be totally prevented but by using appropriate engineering measurement, road safety improvement and management, the traffic crash rate can be decreased. The road safety improvements are supposed to be implemented to the traffic crashes hotspot location where they have the most significance. To do that the prerequisite for the management of road traffic safety and reduction of traffic crash rate were the systematic collection of data on traffic crashes that will enable the identification and determination of the place or section where there are high frequency of road traffic crashes. The definitions of hotspot were different from country to country, but there is a common understanding that the hotspots or dangerous sites are generally defined as an area where traffic crash density highly occurred (Tessa K. Anderson 2006). Identifying the hotspot location of traffic crash has a great role in the reduction of a traffic crash. There are many simple and straightforward non-spatial approaches to identify hotspots as an Accident Rate (AR), Accident Frequency (AF) and Relative Severity Index (RSI) used in many parts of the world by the department of transportation with the help of excel (Harirforoush 2017). There are also spatial approaches to identify hotspot road traffic crash using GIS like a Kernel Density Estimation (KDE), K-means, Nearest Neighbor Method (NNM), Point Cluster Method and Getis-Ord G_i^* : hotspot analysis. GIS is a computer-based system for storing, querying, and displaying geographic point data and its' pattern on the map and analyzing and identifying hotspots or black spots with the help of spatial statistics and spatial analyst tools and also, GIS analysis takes a few time and less tedious to analyze the collected data.

2.8.1. Non-spatial approach hotspot investigation

1. Traffic Crash frequency

Accident frequency is the oldest and simplest approach used to identify and summarizes the number of traffic crashes for each location, and ranks them in descending order of their frequency. Those locations with higher than predetermined number of traffic crashes are classified as a high -frequency location or site (AASHTO, 2010). In order to compare segments of different lengths, the total number of traffic crashes is divided by the segment length and the time period. The result is a value showing crashes per year per kilometer. It does not consider the traffic volume exposure on the traffic crashes.

2. Traffic Crash Rate

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

The crash rate method of hotspot identification focused upon the average crash frequency in, which it normalizes the frequency of crashes with the exposure, as measured by traffic volume. It is calculated by dividing the total crash frequency for a period of time by the estimated average annual daily traffic (AADT) of vehicles entering from all approaches in that time period. Crash rate provides an improved standard for comparison between different sites. As with average crash frequency, a crash rate for an intersection undergoing a safety assessment may be compared to similar intersections (signalized, same number of legs, same range in AADT).

3. Equivalent Property Damage Only Method (EPDO)

The EPDO method crash frequency measure weights crashes according to severity (fatal, injury, and property damage only) to develop a combined frequency and severity score for each site. The weighting factors are based on property damage only (PDO) crash costs. An EPDO value summarizes the traffic crash costs and severity

4. Relative Severity Index Method

Under this method, monetary traffic crash costs is assigned to each traffic crash severity and the total cost of all traffic crashes is calculated for each site. An average traffic crash cost per site is then compared to an overall average traffic crash cost for the site's reference population. The overall average traffic crash cost is an average of the total costs at all sites in the reference population. The resulting Relative Severity Index (RSI) performance measure shows whether a site experiences higher traffic crash costs than the average for other sites with similar characteristics. Strengths of this method include the simplicity of the analysis and the consideration of collision type and traffic crash severity. Weaknesses include lack of traffic volume considerations. This type of analysis can also overemphasize locations with a small number of severe crashes depending on weighting factors, and it can prioritize low-volume, low-collision sites (Mohammed Fayaz 2018).

2.8.2. Spatial approach hotspot investigation

This study focuses on the most popular method used for spatial analysis of hotspot traffic crash analysis Kernel Density Estimation (KDE) and Getis-Ord G_i^* : hotspot analysis (Jayvant Choudhary 2016). Even though, they are the most common methods in spatial analysis of hotspot traffic crash especially Kernel Density Estimation has its own weakness. The major weakness of Kernel Density Estimation is an inability of analyzed data to be tested the significance and

difficulty of obtaining a reasonable value of searching radius and grid size as input to analyze the hotspot location of traffic crash (Williamson D. 1999).

2.9. Gaps and summary of the reviewed research

Most of the previous research on the speeding of the vehicle has focused on the three methods of data collection approach.

1. Self-reporting speeding assessment.
2. Using speed enforcement records (Camera).
3. Using Global Position System in Vehicle methods.

Self-reporting speeding survey methods are limited to some selected driver and over and under-reporting of the speeding and speed enforcement approach using installed camera has limited to no full information about the driver. Using the GPS in-vehicle speeding assessment approach relied on a few numbers of vehicle for a long period of time to evaluate the same driver, which is the most advanced, expensive and reliable than others. However, in this study the only available and selected approach used to assess the excessive speeding is secondary data, which was recorded by traffic police while speeding enforcement during off-peak hour in the city with the help of Radar and Laser gun instrument.

On the other hand, in case of road traffic crashes, the gaps were identifying the black spot or hotspot using the location or area and road types based on the number of traffic crashes occurred around that location still today in our country manually. However, in this study, the density of traffic crashes hotspot locations identified through ArcGIS version 10.3.1 software based on Easting and Northing location of road traffic crashes collected data by the concerned body with the help of Google map.

Chapter -Three

3. Methodology and data collection

3.1. Introduction

This chapter focused on data collection process and analysis of the collected data. The aim of this study was two things: a) to assess excessive speeding and to identify the main contributing factor of excessive speeding related to vehicle type, posted speed limit and driver related. b) to identify the hotspot location of road traffic crash in the city using ArcGIS software to help decision-makers for taking appropriate measures in order to prevent and reduce road traffic crash happening in the city. In general, this paper focuses mainly on two sources of data in order to achieve its objective.

3.2. Study area.

This research was conducted in Addis Ababa, Ethiopia where road traffic crashes were highly visible and excessive speeding is suspected on the road network of the city. This study covers the whole city.



Figure 3-1 Map of Addis Ababa capital city of Ethiopia (www.google.com December, 1st 2017/2018)

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Addis Ababa is the capital city of Ethiopia; headquarter of United Nations Economic Commissions for Africa and headquarter of African Union. In Addis Ababa city, there is the high population of a government institution and there is no separation of commercial land use from a residential area. Addis Ababa has five-entrance way that connects to different parts of the regional states of Ethiopia and horn of Africa country through railway and trunk road. Addis Ababa city has undergone numerous changes and development within a few years ago, in spite of all that the city has different challenges and problems on the road traffic emission, and road traffic crashes. To solve the problem that faced the city, Addis Ababa city administration has been divided into ten (10) sub-city in order to improve the public service for society, to address the problem in the city and to administrate the city easily.

3.3. Study design and source of data

This study, depends on secondary data of recorded speed violation for the duration of three months in 2010 E.C, five years road traffic crash (2007-2011) E.C and three years (2007-2009 E.C) of traffic crash location on the streets of Addis Ababa city were incorporated in this study to answer the problem of the study and to achieve the aim of the study. The questions raised in this studies, are ‘who violate the posted speed limit?’, ‘To what extent the drivers operate their vehicle above the posted speed limit?’ and where is a hotspot location of road traffic crashes in the city geographically with the help of ArcGIS software?’

Generally, to answer the research question the main source of the data used in the study were:

1. Recorded data on the speed violation by Addis Ababa police commission.
2. Recorded data on road traffic crashes from 2007 to 2011 E.C in the Addis Ababa city.
3. Recorded data on the road traffic crash location from 2007-2009 E.C in the city by National Road Traffic Safety Council of Ethiopia.

The three types of data used in this study to answer the problem of the study from different sources such as the first data is speed violation data gathered by Addis Ababa Sub-city Police Commission and the second one is location of traffic crash, which gathered by National Road Traffic Safety Council of Ethiopia.

3.4. Data base

The database approach of the gathered data was in Microsoft Excel format which, was collected through researcher from ten sub-cities of Addis Ababa traffic police commission office in the form of a paper format recorded speed violation data and road traffic crashes in excel format.

3.5. Data collection and description

3.5.1. Road traffic crashes data collection and description

Road traffic crash data in Addis Ababa city collected by two bodies. The first concerned body to gather traffic crash is Addis Ababa sub-city traffic Police Commission, and the second one is Addis Ababa traffic police commission. Addis Ababa traffic police commission has the responsibility to collect fatal crash data information in the city. The 10 (ten) sub-city are responsible to gather the information (driver information, Passenger or pedestrian information, location, weather condition, and road geometry information) regarding on serious injury, slight injury and property damage in their own sub-city in detail and the whole gathered data is documented in paper form except fatal crash data in the city.

The data gathered in the city through two bodies and documented in paper form are converted into the excel format by each sub-city and reported for Addis Ababa police commission. The researcher took the data for this study (location of road traffic crash from 2007 to 2009 E.C) collected by National road traffic safety council of Ethiopia under the European Union project in excel format. They have collected location of road traffic crash in the city based on the police commission traffic crash report using GPS(Easting and Northing) and as well as road traffic crash data from 2007 to 2011E.C from Addis Ababa police commission for the analysis. Addis Ababa city Traffic program Management office is the one doing on traffic management problem in the city cooperating with Addis Ababa traffic police commission. Among its duties traffic rule violation, road marking and sign problem, drinking and driving, causes of road traffic crash and proving the measurement (solution) based on the research using the data that comes from traffic police commission and the data they have collected by their own office. The main information incorporated, while investigation of traffic crash are: vehicle information (vehicle type and plate number), driver information (age, gender, experience and education level), weather condition (bad or good), land use, road condition (median types, straight or curve and

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

slope) and types of road traffic crash (fatal, serious, slight and property damage) with detail information of injured person. However, for this study only location, time-related, vehicle types engaged in traffic crash and causes of traffic crash data was used for analysis.

According to (Tariku Hailu 2017) which has based on the interview of traffic police and World Health Organization Report in 2013, the definition for each of road traffic crashes severity is as follows.

1. A fatal traffic crash is the one in which one or more persons are killed as a result of traffic crashes at a time of traffic crash or any other time within the 30 days.
2. Serious injury is the one in which there are no deaths but one or more road user(s) (pedestrian, passenger and drivers) suffered severe cuts, bleeding, breaks and any other damage, which requires them to be treated as “in-patient “in the hospital.
3. A slight injury is another injury defined as when one or more road users like pedestrian, passenger or drivers suffered minor cuts, scratches and any other minor damage that needs road user(s) to be treated in hospital as an “outpatient”.
4. Non- injury (property damage) is any vehicle crash other than injury crash, which, occurs between the vehicle and real object such as animal, roadside object and traffic control device.

3.6. Traffic crash hotspot location identification in the city using ArcGIS.

ArcGIS spatial analysis is used to analyze and pilot geographically the location where the road traffic crashes occurred and to assess specific patterns of distribution through map visualization (Rudolphine Nyoni 2018). ArcGIS software version 10.3.1 was used to perform spatial statistical analysis and generation of road traffic crash density in the Addis Ababa city on a map. In this study, the collected road traffic crashes location data (Easting and Northing) were used to identify hotspot or black spot site and it was conducted with the help of Kernel Density Estimation (KDE) and Hotspot analysis: Getis-Ord G_i^* tools in ArcGIS software.

1. Kernel density estimation (KDE)

The kernel density method is one of the most important spatial analysis tools and the non-parametric estimator used to analyze the density of the point data on ArcGIS using bandwidth or searching radius and cell size as an input parameter by creating surface value (Bham 2011). It calculates the density of traffic crashes within a specific bandwidth (searching radius) around

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

each location of a traffic crash in the study area to generate a smoothed surface. KDE uses a kernel function to assign a weight to each point surrounding the center proportional to its distance to the central event. In other words, the surface value is highest at the point location (i.e., the center) and drops smoothly to a value of zero at the radius of the circle (bandwidth). Finally, it generates a smooth continuous density surface by adding up the individual kernels in the study area.

According to (Silverman 1986) the general formula of Kernel Density Estimator of density value at a location of X, Y coordinate within the searching radius of 'h' is given as follows in a mathematical expression.

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \dots \dots \dots (1)$$

Where n, is the total number of traffic crashes, 'h' is searching radius or bin width, which controls the size of neighborhood around the x. K is the kernel value, which controls the weights of Xi events, from the center x based on the proximity. f(x) is the density value at the location of x, and '(x-xi)' is the distance between the center of traffic crash and the neighbor traffic crash.

While using kernel density estimation (KDE) searching radius and cell size are the two parameters affects the outcome of the hotspot location of a traffic crash. Selecting an appropriate bandwidth is a critical step in Kernel Density Estimation to determine the hotspot location of road traffic crashes. The bandwidth determines the amount of smoothing of the traffic crash pattern; it defines the radius of the circle centered on each grid cell, containing the points that contribute to the density calculation. A high value of bandwidth will come up in a large amount of smoothing and low-density values. In contrast, a small bandwidth will result in less smoothing and using a very small value of bandwidth makes the map similar to the original point location pattern in appearance (Williamson D. 1999). In general, Williamson and his colleagues have discussed different methods available on the selection of appropriate bandwidth and they recommended one best approach to analyze the hotspot location of a road traffic crash. The first approach to determine the bandwidth is the division of shortest side the extent of point events displayed on the GIS which is usually 1/30th of shortest side extent of events. The second method defines bandwidth as the following equation (Bailey 1995)

$$r = 0.68N^{-0.2} \dots \dots \dots (2)$$

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Where r is the bandwidth and N is the total number of point observations

The third method which, was recommended by (Williamson D. 1999) is the Average K^{th} Nearest neighbor distance method. The formula of average k^{th} nearest neighbor distance is given as follows by Williamson.

$$r = \frac{\sum_{i=1}^n \sum_{j=1}^k d_{ij}}{kn} \dots\dots\dots (3)$$

Where r is bandwidth or average k^{th} nearest neighbor, n is the total number of points, k defines the number of nearest neighbor points chosen by analyst and d_{ij} is the distance between point i , and its j^{th} neighbor. This approach enables the observer to evaluate the local probability of traffic crash occurrence and degree of danger of a zone. The average k^{th} nearest neighbor considers the relative distribution and the spacing of traffic crashes location data from each other across the study area not the size of the extent or the number of points in the study area, due this it is used for searching radius determination for this study. Based on the above reasons Williamson and his colleagues recommended the Average k^{th} nearest neighbor distance as a bandwidth of KDE.

Another parameter used in KDE is cell sizes. Cell size has little impact on the mapping output of ability to predict a spatial pattern of point data and usually, it affects the visual appeal of hotspots, which means that varying the cell size has no significant difference like bandwidth (CHAINEY 2013). Like bandwidth, there are no fast and hard rules to determine the cell size. Since it is subjective but using half of the bandwidth size for grid cell size is recommended by (Anderson 2009). For this study, average k^{th} nearest neighbor method is selected for the determination of bandwidth of KDE and half of bandwidth size for grid cell size for the analysis of traffic crash hotspot location identification study in the Addis Ababa city for each of a traffic crash severity and per each year. The average k^{th} nearest neighbor looks at the distance between points and their distribution in the dataset. The distance between each point and its k^{th} nearest neighbor is calculated and then averaged. This calculation was conducted in the ArcGIS software with the help of Calculate Distance band tools from Neighbor Count Tool in the Spatial Statistics toolbox.

2. Hotspot analysis: Getis-Ord G_i^* Statistics.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Getis-Ord G_i^* statistics is another most important methods of local spatial traffic crash analysis used to identify statically significant hotspot (clusters of high value) and cold spot (clusters of low value) locations relative to its neighboring features (Zeyang Cheng 2018). Getis-Ord G_i^* generates z-score (standard deviation) and p-value (statistical probability) associated with it for each event. Highly clustered patterns have a higher positive z-score and lower p-value (hotspot area) but, a highly dispersed pattern has a lower negative z-score and a lower p-value (cold spot area) (Chien-Yuan Chen 2018). To identify the hotspot location using Getis-Ord G_i^* statistics for gathered data of traffic crashes, which has displayed on the ArcGIS software threshold distance or searching radius is necessary. The Incremental Spatial Autocorrelation (ISA) tool under spatial statistics is used for the calculation of threshold or bandwidth distance for hotspot analysis Getis-Ord G_i^* statistics in ArcGIS software. ISA tools in ArcGIS software generates the z-score versus threshold distance graphs. The appropriate threshold distance for identification of hotspot location is occurred at the first peak value of Z-score or at the maximum z-score (Jayvant Choudhary 2016). Before, going to run Getis-Ord G_i^* statistics analyses tools, the following steps were taken to determine the appropriate distance threshold (d) or bandwidth: integrate the point data displayed on ArcGIS, collect events within the XY tolerance distance, and calculate threshold distance for hotspot analysis: Getis-Ord G_i^* and kernel density estimation (Isha . A 2017). The integrated tool is used to snaps all the features within XY tolerance distance (100m was used in this study). The changed data obtained after the use of the integrating tool is used as an input file in the collective events tool. Collective events result gives the count “I count or the number of traffic crashes within the XY tolerance distance” of traffic crashes at each unique location. The tool, collective events is then used to convert traffic crash points to weighted points required to perform the Getis-Ord G_i^* hotspot analysis. The general mathematical expression formula of Z score generated by hotspot analysis: Getis- Ord G_i^* is expressed by the following equation:

$$Z(G_i^*) = \frac{\sum_{j=1}^n x_j * w_{i,j}(d) - \bar{X} \sum_{j=1}^n w_{i,j}(d)}{S \sqrt{\frac{n \sum_{j=1}^n (w_{ij}^2) - [\sum_{j=1}^n w_{ij}(d)]^2}{n-1}}} \dots\dots\dots (4)$$

$$\bar{X} = \frac{\sum_{j=1}^n x_j}{n} ; S^2 = \frac{\sum_{j=1}^n (x_j)^2}{n} - (\bar{X})^2 \dots\dots\dots (5)$$

Where, d is the threshold distance or searching radius of traffic crashes location, and $w_{ij}(d)$ is the weight matrix for each traffic crash locations that has only 1.0 or 0.0 values. $w_{ij}=1.0$ if j location of traffic crashes is within threshold distance (d) with respect to i , traffic crash location and $w_{ij} = 0.0$ if its beyond that searching radius from i . S^2 is the variance of traffic crashes, x_j is the attribute value for feature j or the number of traffic crashes collected at the j location on the map after integration of the traffic crashes within 100m radius and $Z(G_i^*)$ is the z-score of each feature which means that p-value or the confidence interval.

3.6.1. Severity index of road traffic crash

To determine whether high density or low density of traffic crashes exists in a country or city, it is mandatory to assign weights to each type of road traffic crashes data because all severity have no equal cost. The occurrence of traffic crashes is sometimes used to evaluate the safety issue at a location and it is highly believed that the more severe traffic crashes have greater weights in identifying an unsafe location based on costs (Truong 2011). This study identified the hotspot location for each of traffic crash severity separately so that, a weighting factor is not included in the analysis of hotspot location of traffic crashes on the road network of a city.

The main criteria focused under this study is only the frequency of traffic crashes per severity in the city because to consider the exposure like the traffic volume and severity index is impossible due to the following things.

- a. Since the study covers the whole parts of the city, it is impossible to get traffic volume (AADT) for every street and intersection in the city, pedestrian volume and consider it as the exposure to identify the hotspot locations.
- b. There is no determined the standard severity index of traffic crash for our country.

3.7. Data collection and description of speed violation

Road traffic rule violation means driving by violating posted traffic signs, road marking, red-light running, and priority for pedestrian and violating posted speed limit are some of the violations influencing the road traffic crashes. From the listed traffic violation, only excessive speeding traffic rule violation has discussed and assessed in this paper. The type of data used is the secondary data of excessive speeding recorded by the police commission and traffic control of Addis Ababa city for investigation and analysis. The data of traffic rule violation were

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

collected through two bodies: Addis Ababa sub-city traffic police commission and Addis Ababa Traffic Control in the city. Those two concerned bodies collected excessive speeding data during the enforcement of vehicle speeding at an off-peak hour to reduce the road traffic crash in the city due to the speeding of the vehicle. They collected the excessive speeding data continuously during an off-peak hour daily in good weather conditions and the place where road traffic crashes were frequently happened in the city. Addis Ababa sub-city traffic police commission and traffic control investigate the excessive speeding in the city during off-peak hour at the morning time (4:00- 6:00) and afternoon (8:00-10:00) local time in each sub-city at least using one radar gun daily and records those drivers violate the posted speed limit on the road segment during good weather condition. The Addis Ababa sub-city police commission has the responsibility of enforcement doing and recording the detail information about the driver, vehicle and road and environment in their respective sub-city while investigation. Traffic control is the supervisor doing on the traffic offense and records the details of all information related to vehicle, driver, and road in the city.

Speeding investigation through Traffic police commission is one way of excessive speeding enforcement begun in the city with the cooperation of the Addis Ababa Transport Program Management Office to reduce the road traffic crash related to excessive speeding of the vehicle in the city. The researcher has gathered the speed violation data recorded by Addis Ababa traffic police commission from ten (10) sub-city and Addis Ababa traffic control office in paper format and converted the data in to excel format. The gathered data by the city has no detail information about the driver, road segment and vehicle types. The speed violation data documented by traffic police commission contains only driver characters (age, sex, and experience), vehicle information (only vehicle types and plate number), posted speed limit and name of road segment investigated, time of the day and day of the week. The speed enforcement in each sub-city by traffic police commission and traffic control was done at different road types and posted speed limits. During enforcement in the city by ten (10) sub-city traffic police commission and traffic control officers, they have collected 26580 (twenty-six thousand and five hundred and eighty) speed violation data within not more than two or three months. However, all gathered data has no full information on the driver, time of the day, day of a week and road types.

Generally, the methods used for the analysis of the gathered data contain two-phase.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- A. Analysis of road traffic crashes characteristics, plotting the location of a traffic crash in the city on the map and identifying the hotspots using Kernel Density Estimation and Getis-Ord G_i^* : hotspot analysis and googles maps.
- B. Analysis of recorded posted speed limit violation in the city using Microsoft excel software and SPSS program.

Chapter- Four

4. Data analysis, result and discussion

4.1. Introduction

This chapter focuses preliminary: a) on the investigation of road traffic crashes hotspot location. b) assessment of excessive speeding and descriptive analysis of traffic crashes by time variation (time of day, day of the week and annual variation) such as: the number of fatal traffic crashes and the number of people injured (slight injury and serious injury) by road traffic crashes on the road network of Addis Ababa city. The detailed analysis of the road traffic crash data using descriptive statistics based on the temporal variation and displaying the density of the road traffic crash on the map accordingly their category of traffic crashes severity (fatal, injury and non-injury) is elaborated under this chapter. Finally, analysis of excessive speeding in Addis Ababa city during an off-peak hour also discussed in this chapter in detail. This study, considers the road traffic crash data of five consecutive years from 2007 to 2011 E.C which, is the latest data at a time for traffic crash analysis and 2007-2009 traffic crash location for hotspot analysis and too speed violation data of three month in 2010 E.C which was gathered during an off-peak hour of traffic flow by Addis Ababa police commission. In the analysis of the traffic crash collected data the number of traffic crash were used as dependent variable and day of the week, time of the day, vehicle types, causes of traffic crashes and driver demography involved in the traffic crash are used as explanatory variable and in case of speed violation analysis, the number of drivers involved in the speed violation and penalized by traffic police were used as response variable and age of driver, sex of driver and experience of driver, vehicle type, posted speed limit are used as independent variable. The software used for the analysis of the collected traffic crash location data (2007-2009 E.C) in the study was ArcGIS version 10.3.1 software to display the density of traffic crash (to identify the hot spot location of traffic crash) in the city on the map and Microsoft excel for the descriptive statistical analysis of the speed violation and traffic crashes in the city and finally testing the result of analysis speeding with the help of Microsoft excel through SPSS program. The collected data of traffic crash location, types, day of the week and speed violation data including age, gender, and experience of driver and vehicle types were organized on excel. The road traffic crash location collected data were exported and plotted on

the ArcGIS to visualize the geographical distribution and hotspot location of the traffic crashes in the city.

4.2. Descriptive analysis of road traffic crash in Addis Ababa city

According to the Addis Ababa police commission report data, 128,223 road traffic crashes and 2,235 fatal traffic crashes, which have killed 2,454 peoples occurred in the city from 2007 to 2011 E.C (within five years). This means on average around 25,645 traffic crashes per year and 70 road traffic crashes per day occurs in the city and also annually on average 447 fatal traffic crash(490 peoples died), which means 1.34 per day has lost their lives in the city.

4.2.1. Annual Distribution of traffic crash in the Addis Ababa city

Figure-4-1 shows the trend of a road traffic crash in Addis Ababa city from 2007 to 2011 E.C. This figure shows that the number of traffic crashes in the city gradually increased annually with an equation of $Y = 2365.3X + 18549$, $R^2 = 0.9516$. Where $X=1$, in the year 2007 and increases by one for one year increase from 2007 (e.g., in 2008, $X=2$) and Y is the number of traffic crashes. This finding shows that every year the number of road traffic crashes is increased by 2365 in the city. In the same fashion, the trend of road traffic fatal crash for the past 5 years is shown in figure 4-2. It is tried to determine the equation for the number of fatal crashes in the future based on the graph assuming nothing new will be done to reverse the growth rate $Y = 10.4X + 415.8$, $R^2 = 0.6996$. Where $X=1$, in the year 2007 and increases by one for one year increase from 2007 (e.g., in 2008, $X=2$) and Y is the number of fatal traffic crashes. According to this trend, the number of fatal traffic crashes is increasing by 10 for every successive year.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

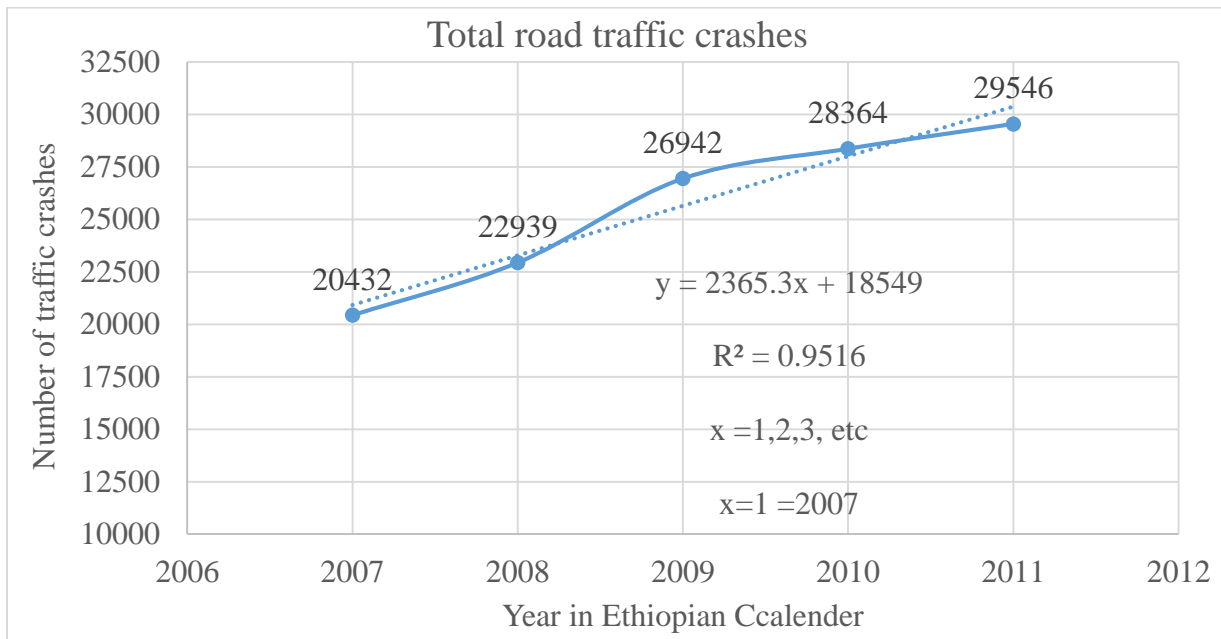


Figure 4-1 The trend of road traffic crashes in the Addis Ababa city from 2007 to 2011.

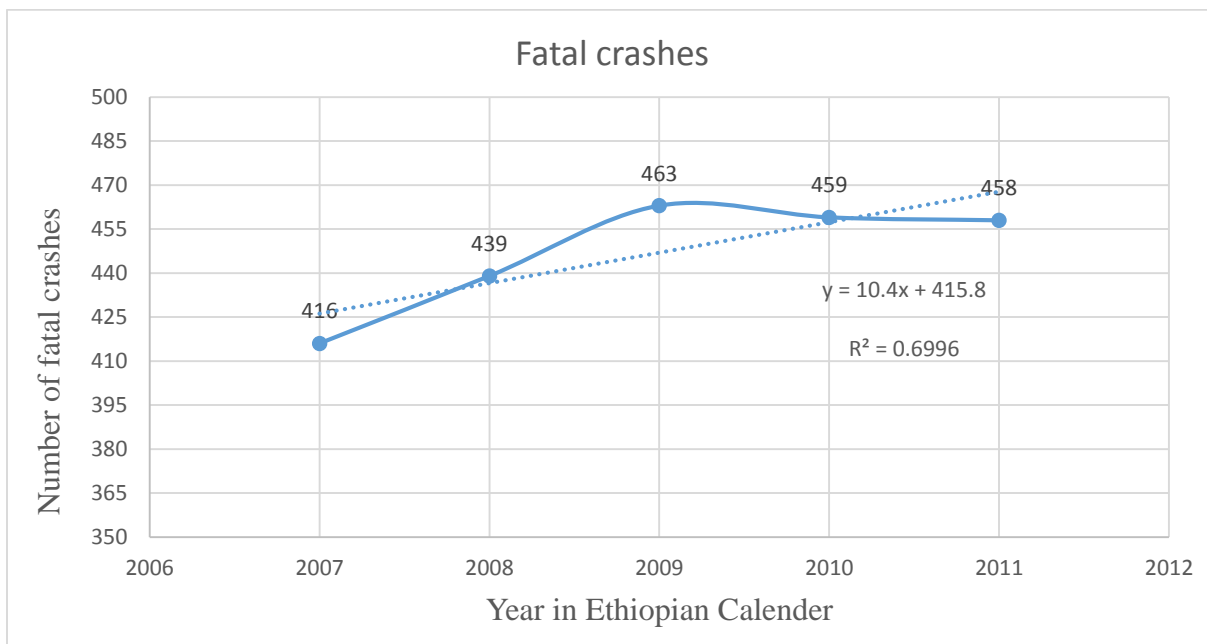


Figure 4-2 The trend of fatal traffic crashes in the Addis Ababa city from 2007 to 2011.

4.2.2. Distribution of road traffic crashes by temporal variables.

The distribution of traffic crashes by a temporal variable means time-related the distribution of traffic crashes such as hours of day and days of a week. The number of traffic crashes in relation to the hours and days were analyzed with the help of Microsoft Excel and SPSS program (Chi-

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

square for the significance of variation between two or more categorized variables). Table 4.1 shows that the summary of chi-square test values of a traffic crash at a 95% confidence interval ($\chi^2_{critical}$) and the calculated Chi-square test value using SPSS (χ^2_{test}). The null (Ho) hypothesis formed to check the significant variation between the number of traffic crashes and temporal variables such as hours of the day, days of the week, monthly and seasonally are as bellows:

Ho: (Hours): There is no variation in the number of road traffic crashes by hours a day.

Ho: (Days): There is no variation in a number of road traffic crashes by days in a week.

Finally, for a determination of critical chi-square test value from the Chi-square table the two variables used are $\alpha = 0.05$ (95%) (Confidence interval) and degree of freedom (df) = n-1 where n is the number of categorical data in the analysis (Simon P. Washington 2003).

Table 4-1 Summary of chi-square value of temporal variable with traffic crash

Variable	Significance level (α)	Degree of freedom (df)	$\chi^2_{critical}$	χ^2_{test}	p-value	H ₀ (reject or fail to reject)
Hours	0.05	23 & 3	35.17&7.8	4,044 &3,290	0.00	Reject
Days in a week	0.05	6	12.59	225	0.00	Reject

A. Road traffic crash distribution by the day in a week

In the analysis of traffic crashes in weekdays at the significance level of $\alpha = 0.05$ with the degree of freedom 6 the $\chi^2_{critical}$ which is read from the chi-square distribution table is 12.59 and the calculated χ^2_{test} in SPSS software is 225 with the p-value of 0.00, which is less than p-value of 0.05. Since the value of the calculated χ^2_{test} is greater than $\chi^2_{critical}$ value at the significance level of 0.05 the null hypothesis is rejected. It indicates that there is a variation of a number of traffic crashes in the days of a week. Figure 4-3 and its legend shows that the traffic crash distribution by days in a week occurred in the past five years (2007-2011) and the average of those five years traffic crashes by the days in a week in the Addis Ababa city. This figure illustrates that the distribution of total traffic crashes by the day in a week per year is almost holds the same pattern. By using the representative of five traffic crash data, which means the average of traffic crashes per days in a week the number of traffic crashes gradually decreases from Monday to Wednesday, then it starts to increase slowly from Wednesday to Thursday and slowly decreased to Saturday and finally it declines to the minimum traffic crash on Sunday. According to this

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

figure, the highest number of road traffic crashes occurred on Monday and Tuesday in the city and the less number of a traffic crashes occurred in the city on a Sunday. Monday is a starting of workdays. People do not want to stay at home on Mondays. As a result, the streets in Addis Ababa are congested on Mondays particularly during rush hours when compared with other workdays. Therefore, a higher number of traffic crashes expected on Mondays. Sunday had small road traffic crashes relative to other days. This may be because of resting day, low movements of vehicles, passengers, and pedestrians on weekends relative to the weekday in the city.

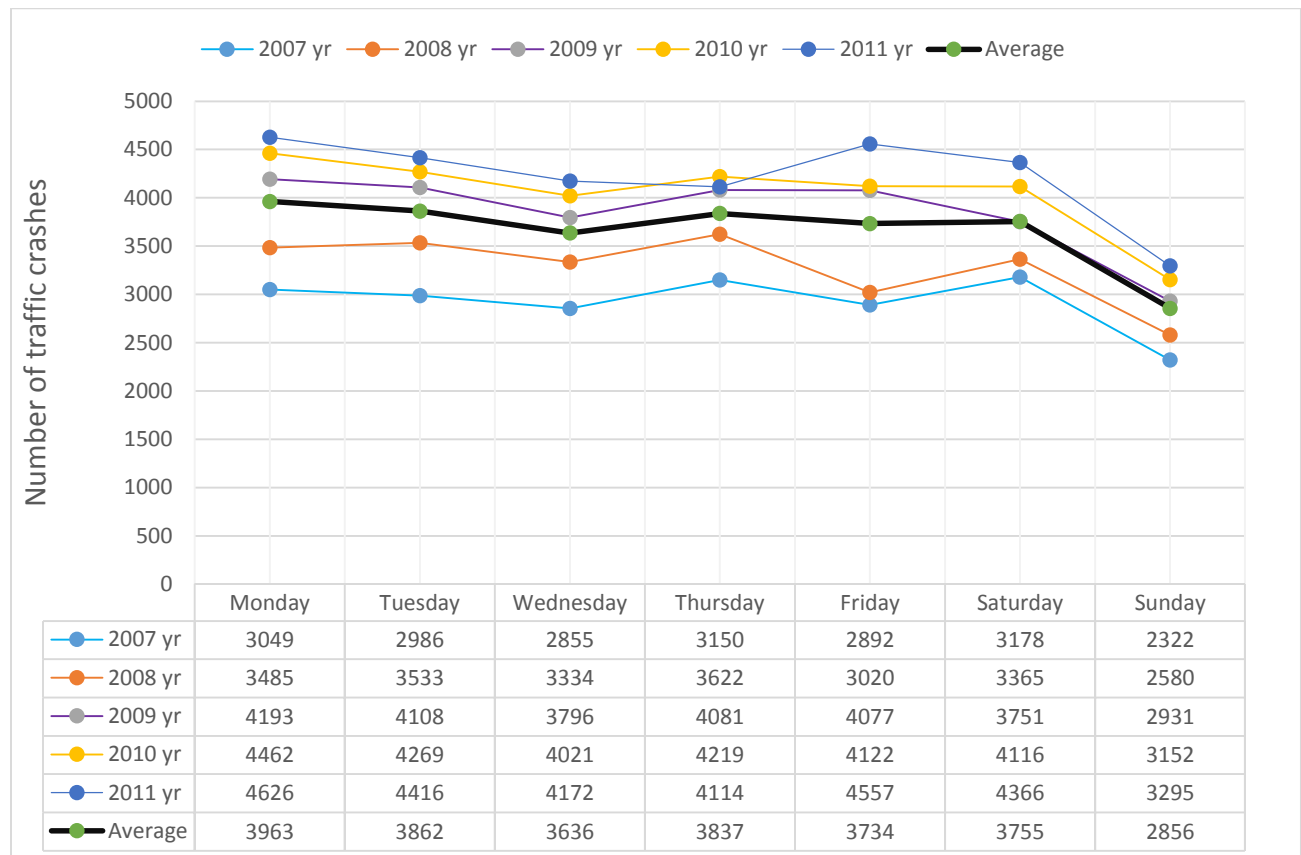


Figure 4-3 Distribution of traffic crashes per year and a day in a week

B. Distribution of road traffic crash by the time of day.

In case of analysis of traffic crash by the hours in a day at a significance level of $\alpha=0.05$ with a degree of freedom 23 the $\chi^2_{critical}$ which is read from the chi-square distribution table is 35.17 χ^2_{test} which was calculated by the SPSS program is 4,044. Since the value of χ^2_{test} is greater than the value of $\chi^2_{critical}$ at the significance level of $\alpha=0.05$ the null hypothesis is rejected and the alternative hypothesis fails to reject. Thus, there is a significant variation of a number of traffic

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

crashes per year (2007-2011) by the time of the day. Distribution of traffic crashes varies throughout the time of the day due to the variation of traffic flow on the road segment. Figure 4-4 shows that road traffic crashes in the city rapidly increased from 6:00 am to 8:00 am it may be due to the increment of traffic flow rapidly during morning time. The highest number of traffic crashes occurred in the city during the daytime (6:00 am-6:00 pm), which has shared 67% of total traffic crashes. These times coincide with the period when people are more active and mobile from place to place in the city for their daily life. In addition, analysis of traffic crashes by the time of a day under the four categories of six (6) hour time block is statically significant ($\chi^2_{\text{critical}}=7.81 < \chi^2_{\text{test}}=3,290$) shows that the highest (34%) percentage of traffic crashes occurred in the 12:00 pm-6:00 pm time block (afternoon). These hours are the busiest as there is a heavy rush of commuters from schools, offices, factories, business places, to home, etc. to home. Between 6:00 am-12:00 pm (morning) time category 33% of road traffic crashes occurred in the city that may be because of heavy vehicular movement and pedestrian from home to school, office and factories and 21% in the 6:00 pm-12:00 am time category and the lowest 12% traffic crashes occurred in the 12:00 am-6:00 am time category. Based on the single hour contribution, the highest (6.21%) percentage of traffic crashes were observed in the 11:00 am-12:00 pm time block, followed by (6.01%) in the 9:00 am-10:00 am time block according to the figure below.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

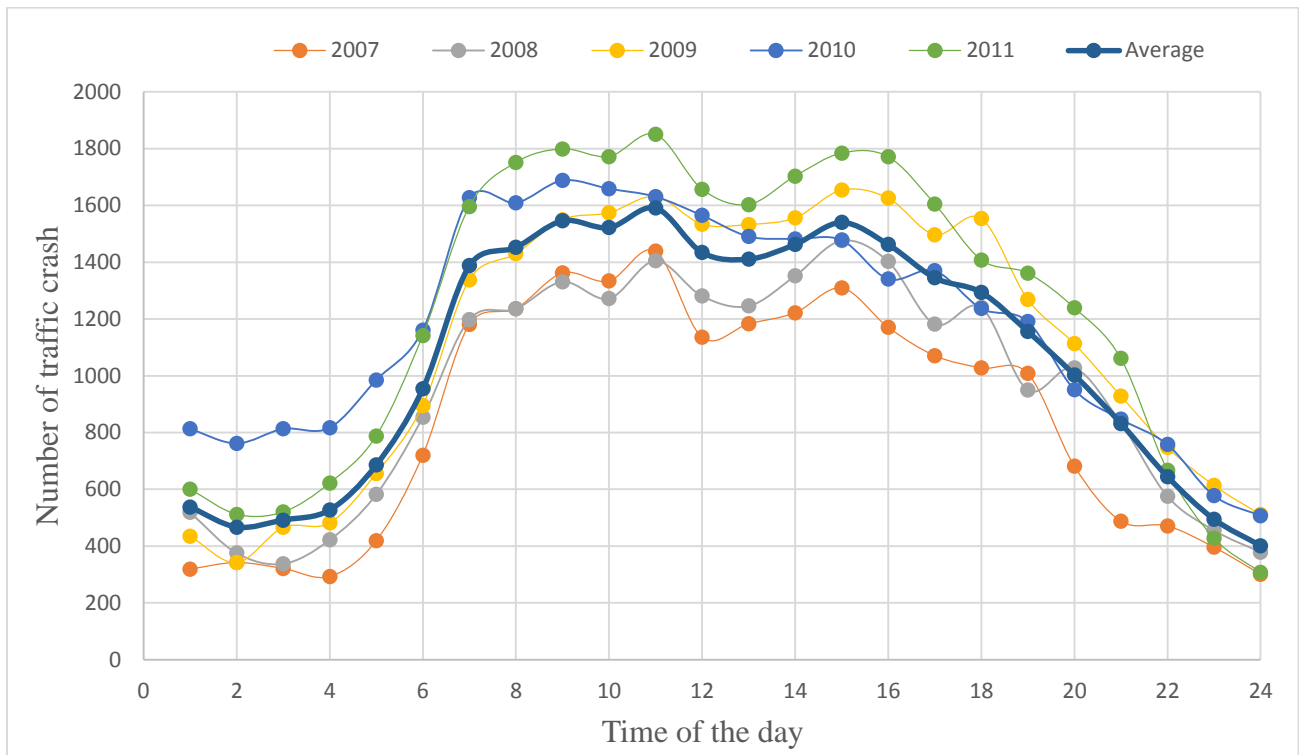


Figure 4-4 Distribution of road traffic crashes per year and hour and the average of five years

c. Distribution of fatal crashes by time of a day and year

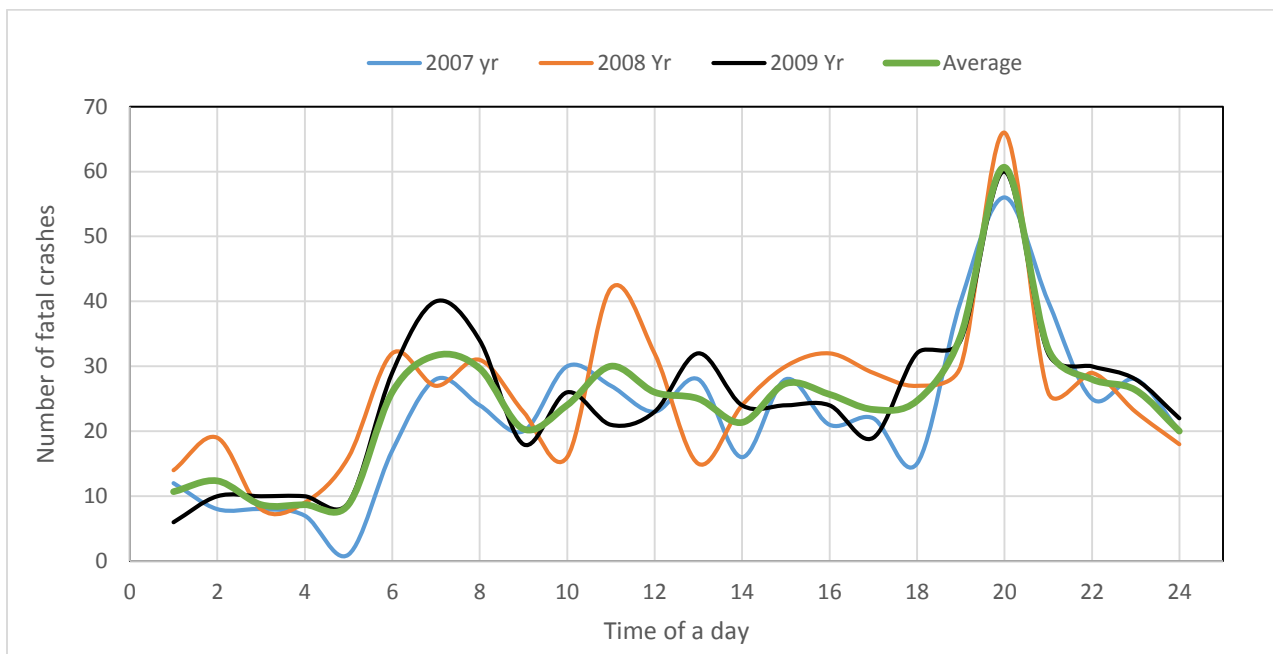


Figure 4-5 Distribution of fatal traffic crash per year per hour and their average (2007-2009).

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

As illustrated by the figure 4-5 above, the distribution pattern of fatal traffic crashes per year and hour in the city from 2007 and 2009 is the same but, in somehow the distribution of fatal crash per hour in 2008 has a little bit different from 2007 and 2009 fatal traffic crash distribution pattern. To get the best pattern of fatal traffic crashes per hour of the day the average of three years (2007-2009 E.C) of fatal crashes was used. The most frequent fatal crash observed in city were between 6:00am to 7:00 am (5.3%), 10:00am to 11:00am (5.2%) during daylight hour and 4:00pm to 5:00pm (4.6%) and 7:00pm to 8:00pm(10.3%) during the night time based on the single hour contribution. Under the categories of 6 hour time interval (four categories 0:00am-6:00am, 6:00am-12:00pm, 12:00pm-6:00pm and 6:00pm-0:00am) (Rudolphine Nyoni 2018) the time block categories. The highest number of fatal crashes recorded in the city (34.2%) of fatal crashes from 2007-2009 E.C occurred in the 6:00pm-12:00am time block followed, by 27.3% in the 6:00-12:00 time block, 25% in the 12:00pm-6:00pm time block. The lowest (13%) fatal traffic crashes happened in the 12:00am-6:00am time block and with around 0.5% of fatal crashes has no recorded time. The time block 6:00 pm-12:00 am is the dominant period in which fatal crashes occurred in the city. This finding is in line with (Rudolphine Nyoni 2018) and (Mavis Agyakwah 2018) in South Africa and Ghana. Some of the contributable factors of high rate of road traffic fatal crashes within 18:00-24:00 time block are: work-related stress and fatigue, invisibility of pedestrian to a driver due to lack of enough lightings at pedestrian crossings, rushing to home daily to eat and to spend time with families of commuters (Rudolphine Nyoni 2018).

d. Distribution of injury crashes by time of day per year.

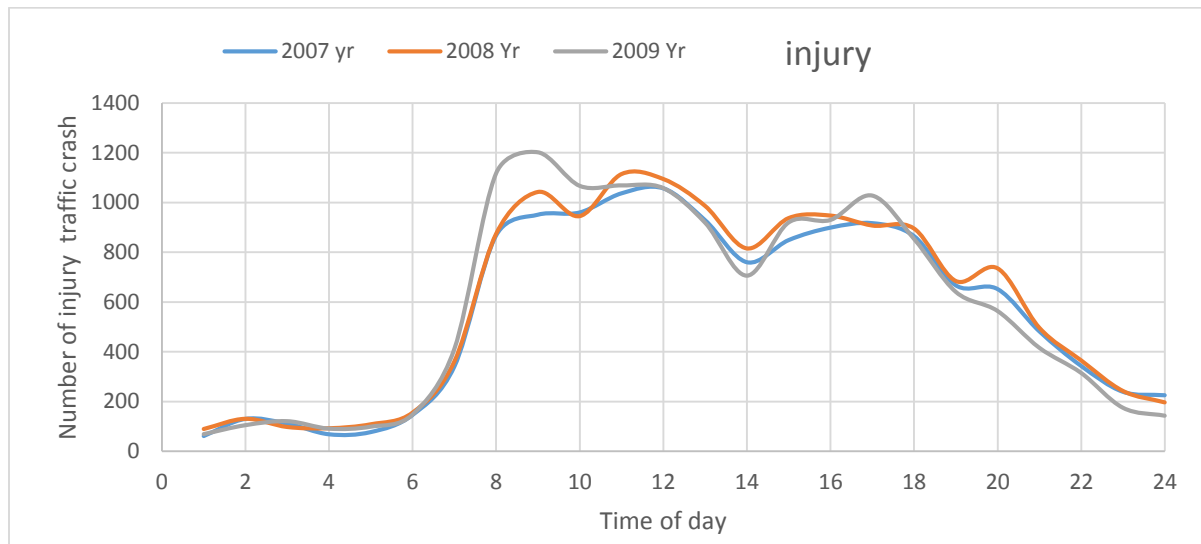


Figure 4-6 Variation of injury crashes by time of a day per year

The figure 4-6 above shows that the distribution diagram of injury (serious and slight injury) per year and hour. All annual trends of injury traffic per hour are almost the same pattern. According to this figure, the number of injury crashes rapidly increased between 5:00 am and 9:00 am. Different times of a day have different traffic crash risk factors depending on the activity of the people, the traffic situation, the condition of road users and work time rules, etc. During day times people are active on the streets. Hence, the conflict between road users is expected that might result in a traffic crash. In the afternoon and night times, the mental and physical ability of people decreases as a result of work in the morning and/or drug consumption. A time on which employees be on the streets depends on the work time rule of the city. Those all factors result in traffic crashes in the city. The distribution pattern of the injury traffic crashes in the city were highly related to the vehicular movement and pedestrian activity in the city distribution pattern.

C. Causes of a road traffic crash in Addis Ababa city as identified by police

According to this analysis based on the police reports under this study, more than 90 percent of the traffic crashes are caused by human errors (influence of alcohol or drug, failure to respect right hand rule, failure to give-way for vehicles, failure to give-way for pedestrians, following too closely, improper overtaking, improper turning, over speeding, failure to respect traffic signs and police, driving with fatigue, driving without attention and improper parking/moving from

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

parking). Figure 4.7 shows the causes of road traffic crashes in the Addis Ababa city as identified during a police investigation. Accordingly, most causes of traffic crashes in order of their rank are following too closely (25.57%), failure to give-way for other vehicle (21.29%), failure to give-way for pedestrians (10.10%), improper overtaking (8.68%), improper parking and moving from (8.24%), over speeding (7.63%) and failure to respect right hand rule driving (5.57%). However, according to figure 4-8 most causes of fatal crashes in Addis Ababa city is a failure to give way for pedestrians, which have shared around 62% of a fatal crash, driving following too closely (8.02%) and over speeding (5.43%).

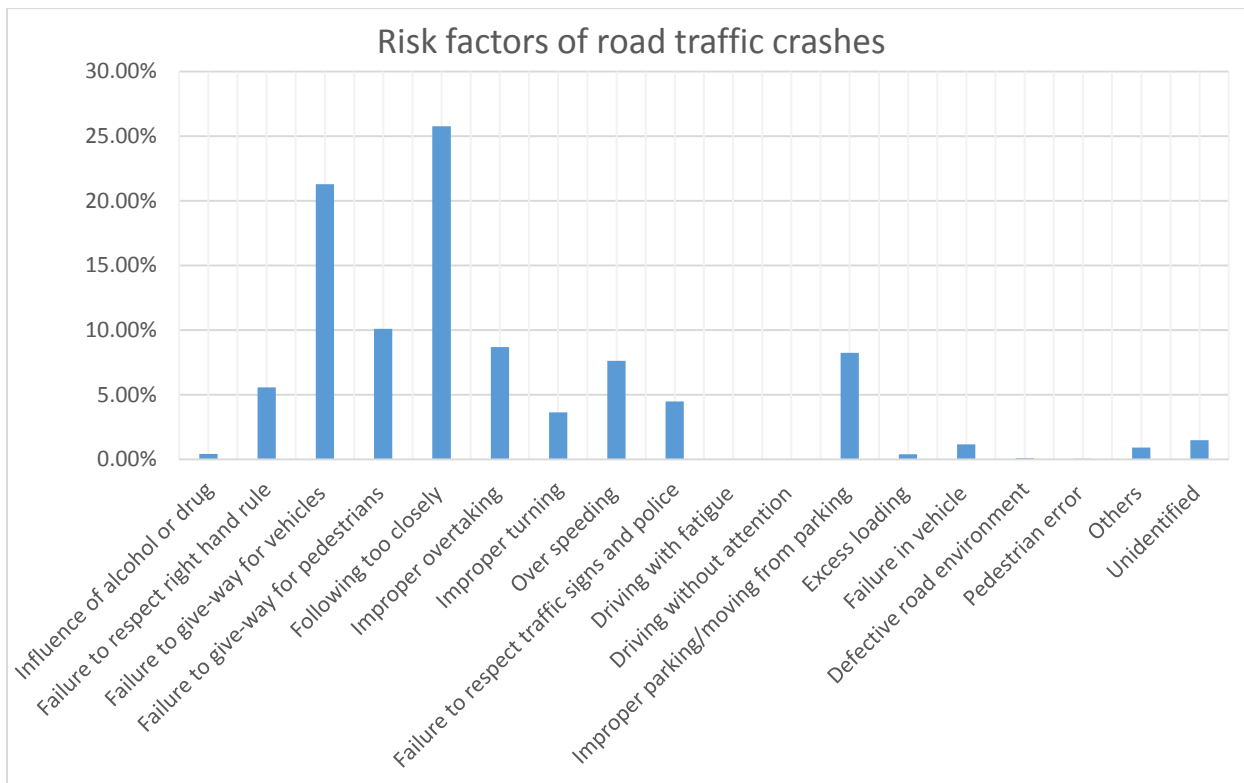


Figure 4-7 Causes of a road traffic crash as identified by Addis Ababa police (2007-2011)

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

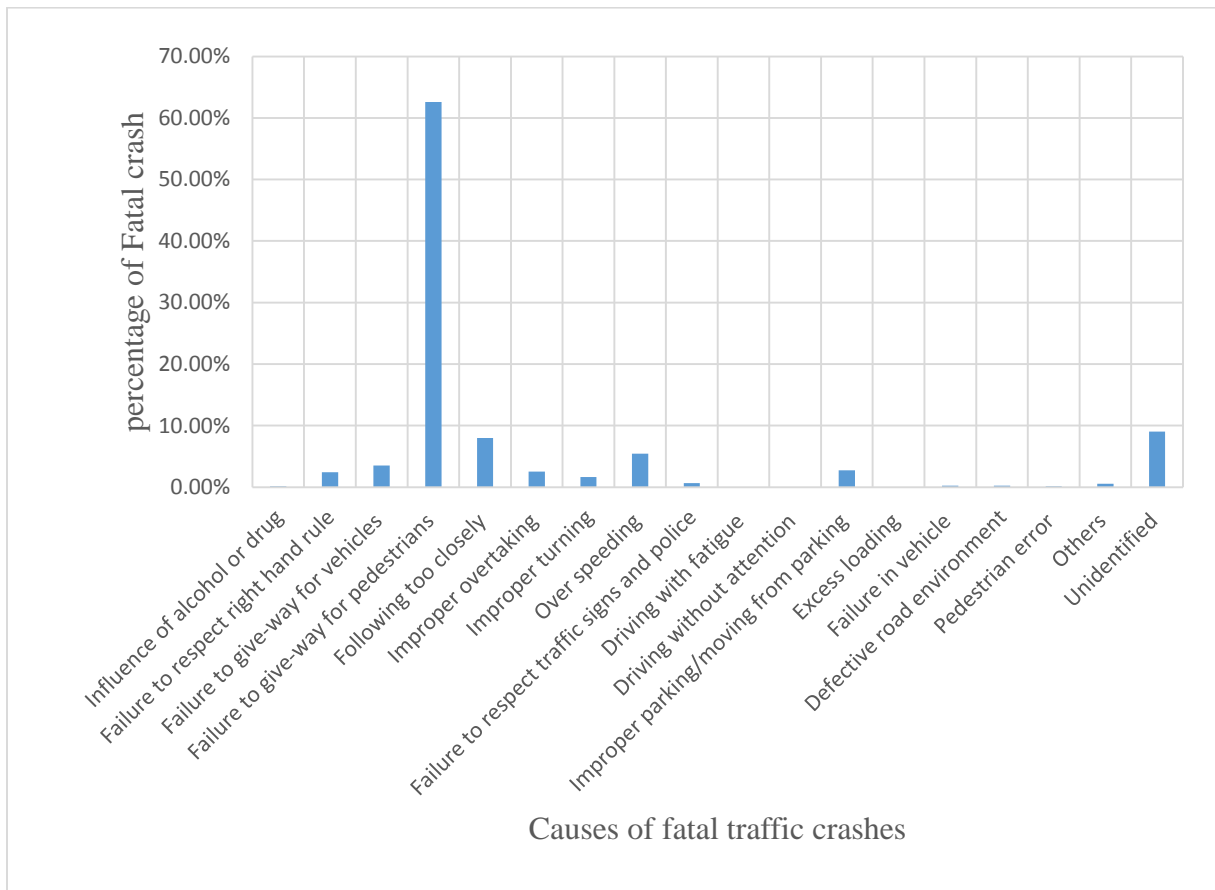


Figure 4-8 Causes of a fatal traffic crash as identified by Addis Ababa police.

D. Road traffic crashes occurred by vehicle types

Figure 4-9 below shows that the average of five year road traffic crashes occurred (2007-2011 E.C) by vehicle types: 2WD, automobile, station wagon, pick up <=10 quintal, truck 11-40 quintal (small truck), truck 41-100 quintal (medium truck), truck with trailer, taxi, minibus up to 12 seats, mid bus 13-45 seats, large bus >46 seats and botte. This analysis result confirms that based on the average of five year traffic crash data, most of the traffic crashes were occurred by automobile, taxi, pick up <=10 quintal, mini-bus, station wagon, truck 11-40 quintal (small truck), medium truck and medium bus (13 to 45 seats) (41-100 quintal) with the percentage of traffic crashes 21.4%, 19.5%, 14.5%, 13%, 8.2%, 6.5%, 4.8% and 4.5% respectively.

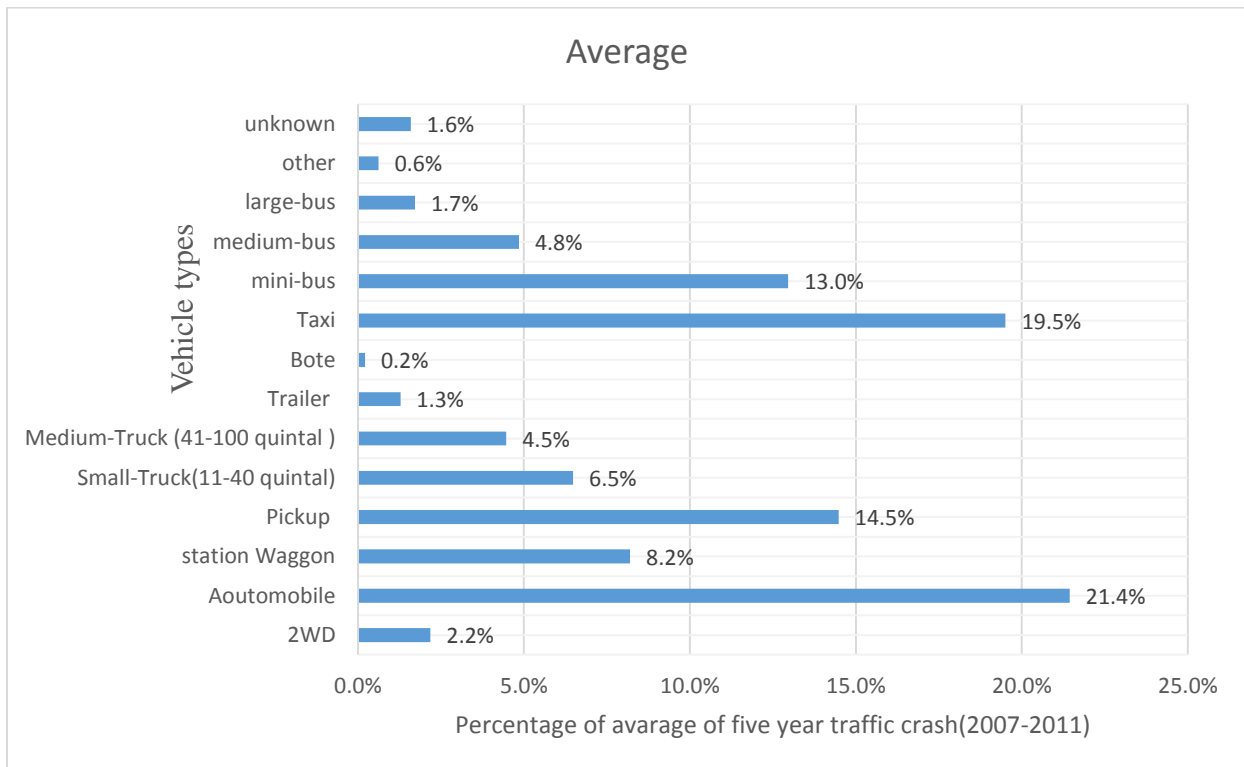


Figure 4-9 distribution of vehicle types involved in road traffic crashes in Addis Ababa city.

4.2.3. Distribution of location of traffic crash in Addis Ababa city on a map.

This section looks at the distribution of road traffic crashes locations in the city on the map. The XY coordinates of road traffic crash in the city from 2007 to 2009 E.C were gathered and displayed on the map using ArcGIS version 10.3.1 software. This study considers only the spatial parts of traffic crashes in the Addis Ababa city. Spatial distribution of total road traffic crashes is plotted on the map and presented in figure 4-10, figure 4-11 and figure 4-12 for each year (2007 to 2009 E.C). Further analysis on road traffic crashes hotspots locations were carried out by Kernel Density Estimation and Getis-Ord Gi* hotspot analysis for each category of traffic crashes and per each year and the results of them presented as follows.

1. Distribution of road traffic crash in Addis Ababa city on the map in 2007

Figure 4-10 bellow and its legends show that the distribution of total road traffic crashes in Addis Ababa city in 2007 E.C. According to this figure and its legend, the distribution and density of traffic crash in the city within a 100m XY tolerance distance were collected and differentiated by the dot color as follows. The red color location shows that the location where the number of

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

traffic crashes between 146 and 195 occurred in the city within the XY tolerance distance of 100m and the yellow color location shows that 98 to 146 range of road traffic crashes occurs in the city per year per 100m radius. A high number of traffic crashes within a searching radius of 100m occurred around the intersection, on the Principal Arterial road and ring road of the city according to the figure bellows. Under this study, the following assumption used to determine the range of traffic crash frequency.

Based on the assumption of Prioritizing Improvements

1. Urgent - immediate attention needed
2. High - improve in the near future
3. Medium - improve as priority allows
4. Low - improve when other work is done to road Priority

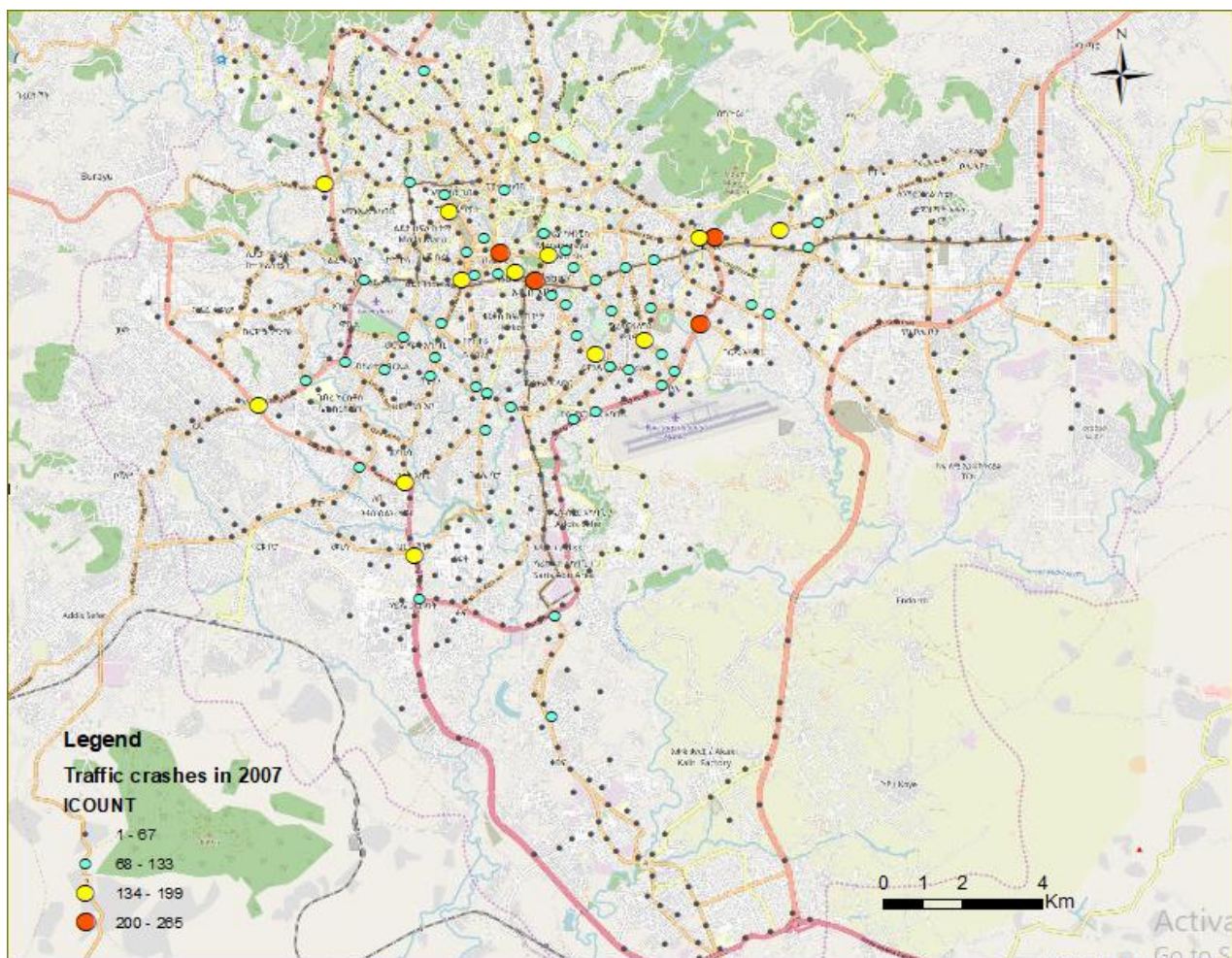


Figure 4-10 spatial distribution of total road traffic crash in Addis Ababa city in 2007

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

2. Distribution of road traffic crash in Addis Ababa city on the map in 2008

The figure 4-11 and its legend shows that the distribution of road traffic crash in Addis Ababa city in 2008 E.C with the help of google map and ArcGIS 10.3.1 software. According to this figure, a high number of traffic crashes within a 100m XY tolerance distance were observed around the intersection and on the ring road and principal arterial streets of the city in the same fashion as road traffic crash distribution in 2007 E.C.

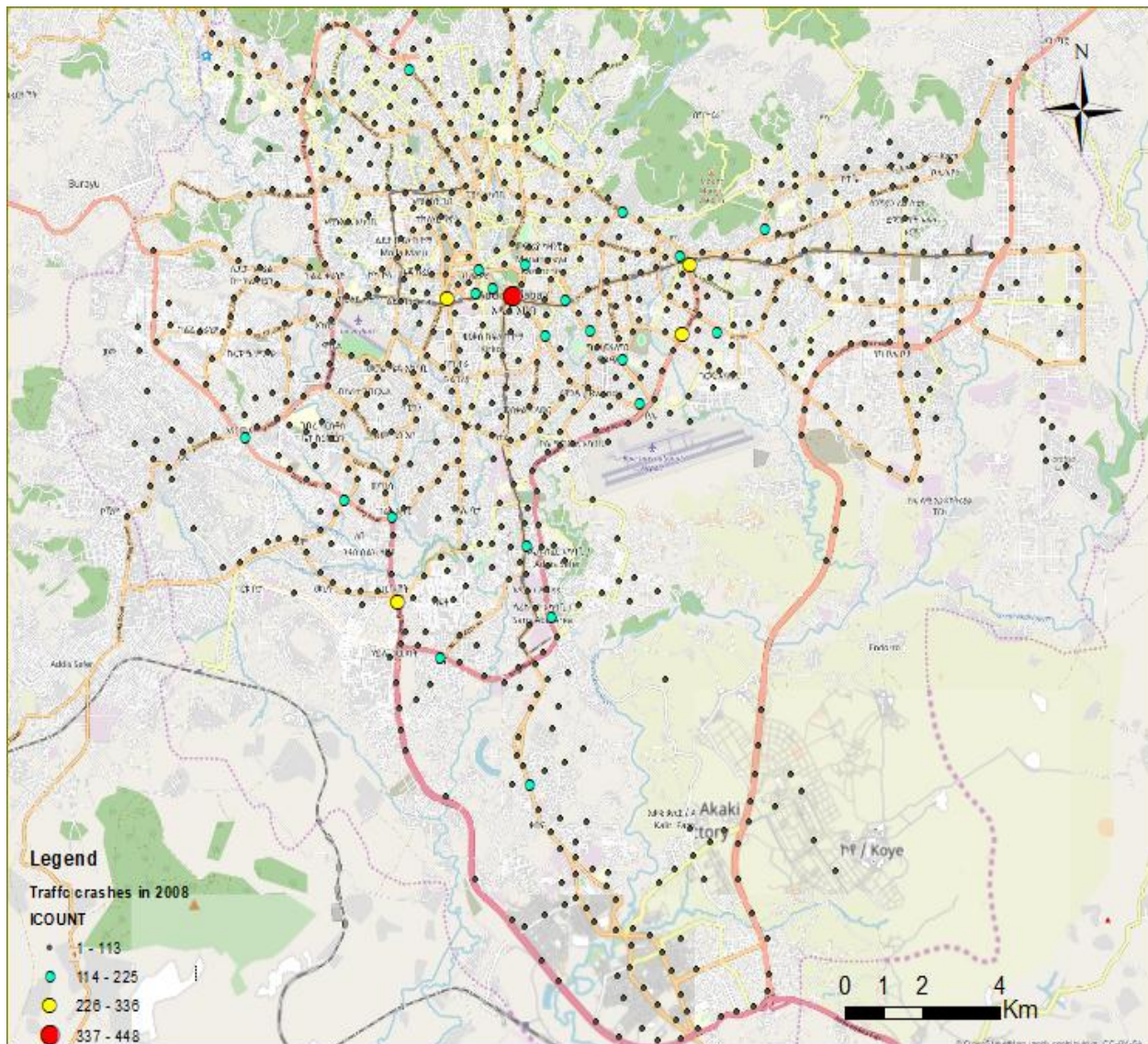


Figure 4-11 spatial distribution of total road traffic crash in Addis Ababa city in 2008

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

3. Distribution of road traffic crash in Addis Ababa city on the map in 2009

Again Figure 4-12 and its legend shows that the distribution of road traffic crashes and number of road traffic crashes occurred in Addis Ababa city in 2009 E.C. This figure revealed that each red, yellow, black and other dot color shows the location of traffic crashes in the city not a number of traffic crashes but, number of traffic crashes at each location within the 100m XY tolerance distance were put with help of its legend for each and every dot color (e.g. red dot 238 to 317 range of traffic crashes within 100m XY tolerance distance).

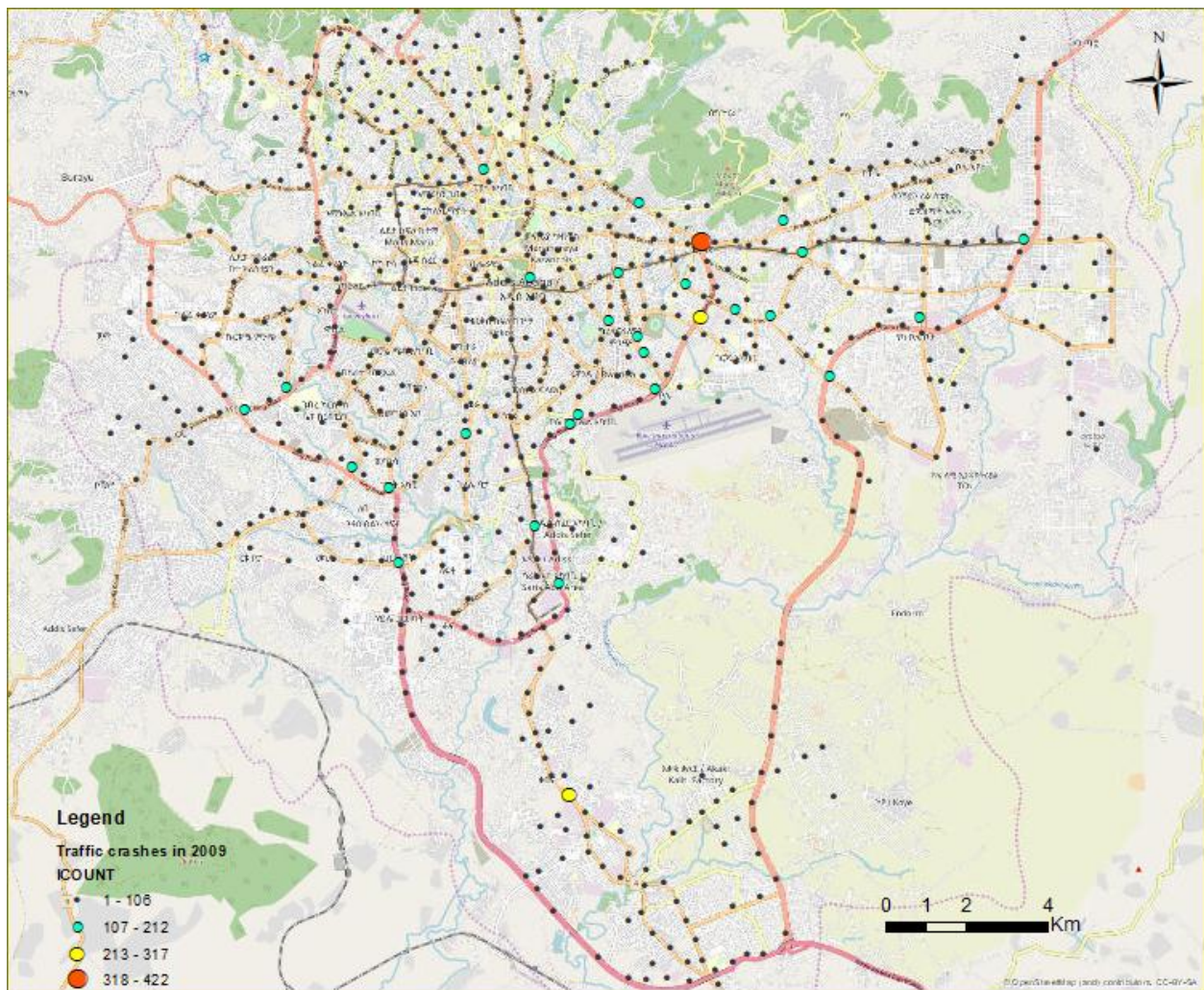


Figure 4-12 spatial distribution of total road traffic crash in Addis Ababa city in 2009

4.2.4. Distribution of road traffic crashes hotspots location

Under this topic, its' tried to identify the hotspot location of traffic crashes in the city. Prior to run Getis-Ord G_i^* :hotspot analysis and Kernel Density Estimation tool of hotspot location identification, road traffic crashes data were passed through integration, collection of events, calculation distance function (nearest neighbor distance) and incremental spatial autocorrelation analysis (ISA) tool to obtain the appropriate bandwidth for further analysis of collected data. In this study, 100m XY tolerance distance is used to convert a displayed data on the map by integration tool to the weighted data (I count). The output obtained using 100m XY tolerance distance in integrating toolbox and finally collected by collect events toolbox of ArcGIS software for each type of road traffic crashes such as fatal traffic crash, injury traffic crashes, and non-injury traffic crashes of 2007 to 2009 E.C separately. I Count (weighted data) obtained after execution of collect events tool is further used in KDE and Getis-Ord G_i^* hotspot analysis as an input to identify hotspot location and detailed as follows.

4.2.4.1. Distribution of hotspot location of road traffic crashes in 2007

A. Distribution of road traffic fatal crash hotspot location in 2007

For 2007 E.C fatal traffic crashes occurred in Addis Ababa city the minimum nearest neighbor distance of 250m, an average nearest neighbor distance of 500m and maximum nearest neighbor distance of 2200m including at least one neighbor fatal traffic crash were obtained, using calculation distance function toolbox after integrating and collection event analysis within 100m XY tolerance distance (Appendix-A). The maximum and average neighbor distance were used in Incremental Spatial Autocorrelation (ISA) tool as beginning and incremental distance input value respectively, to identify the first peak z-score at which clustering occurred in the data so that the corresponding distance at the first peak z-score is used as threshold in hotspot analysis by Getis-Ord G_i^* hotspot analysis. Using those two values as input in ISA either the maximum or the first peak value of Z-core did not occur. So that by trial and error the first peak value of Z-score was obtained at 1000m threshold distance. The figure 4-13 and its legend shows that the result of Incremental Spatial Autocorrelation of a fatal traffic crash in Addis Ababa city in 2007 (the Z-score versus threshold distance), which is used for identification of appropriate threshold distance. According to this figure and its legend shows, the first peak Z-score of 2.28 occurs at 1000m threshold distance with a significance level of $P=0.025=2.5\%$ which means that there is

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

less than 5% likelihood of clustered pattern could be the result of random chance. In other words with a 95% confidence interval, the fatal traffic crash in 2007 E.C occurred in the city were clustered under the threshold distance of 1000m.

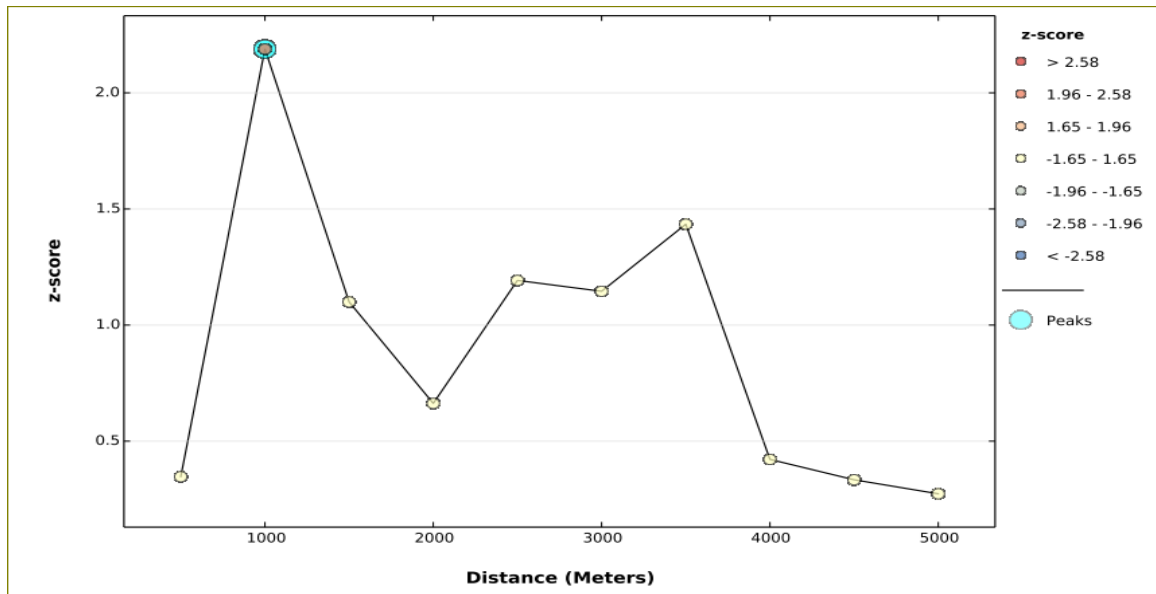


Figure 4-13 spatial autocorrelations by a function of distance for fatal traffic crash of 2007

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

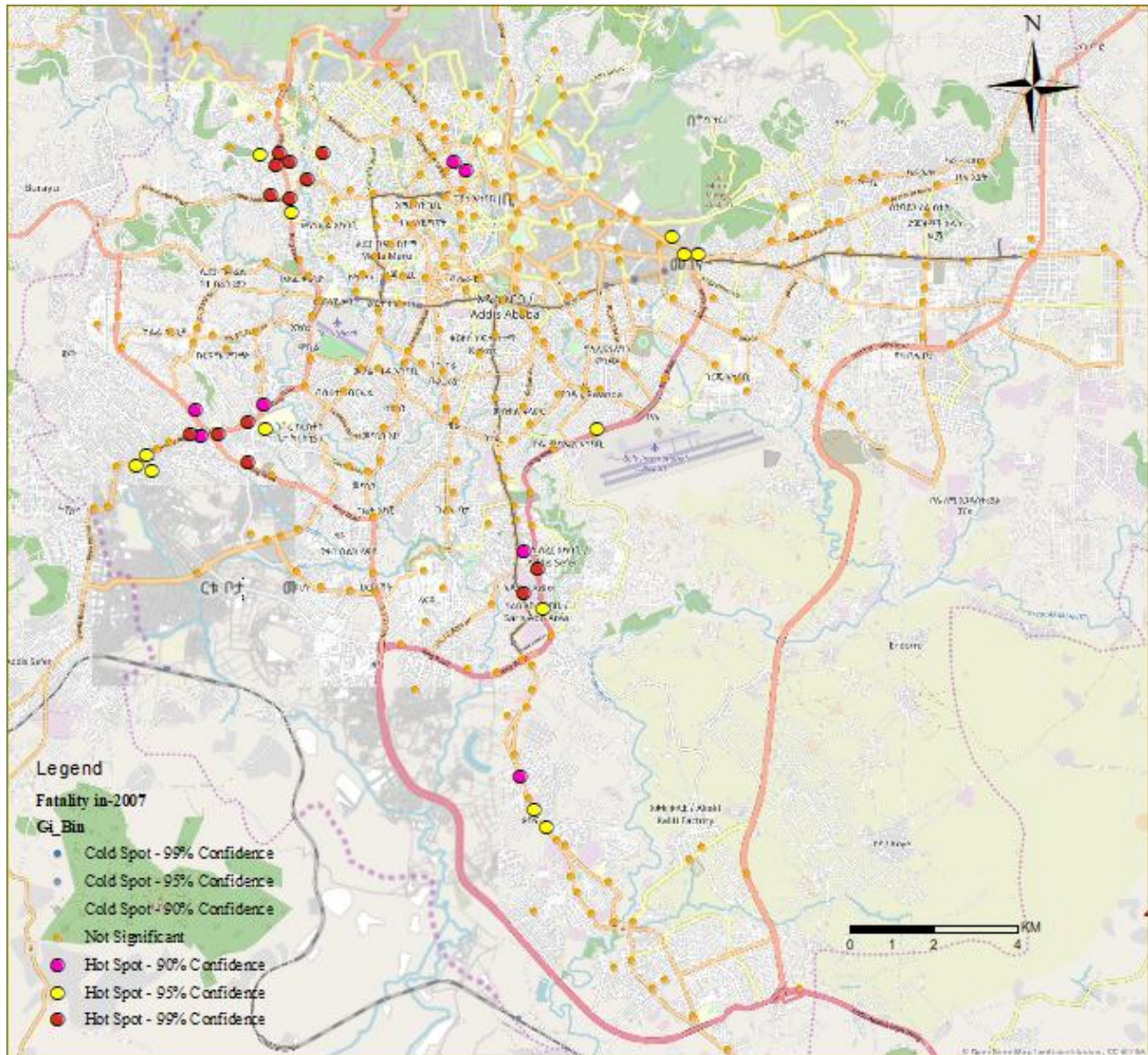


Figure 4-14 Getis-Ord G_i^* based hotspot analysis of fatal crash in 2007

Figure 4-14 above and its legend shows that hotspot locations for fatal traffic crash in Addis Ababa city in 2007 based on Getis-Ord G_i^* hotspot analysis. There are around six locations were identified as statistically significant hotspot fatal traffic crashes in the city with a 99% confidence interval. The areas in, which fatal traffic crash hotspots occurred in the city at 99% and 95% confidence interval are: along railway at Kality, on ring road at Saris Addisu Sefer, Atena Tera, at Ambo new road and ring road intersection (Asra Simint), around Zenebework Hospital on ring road and Megenagna intersection are some of the hotspot locations of fatal traffic crash in 2007 E.C.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

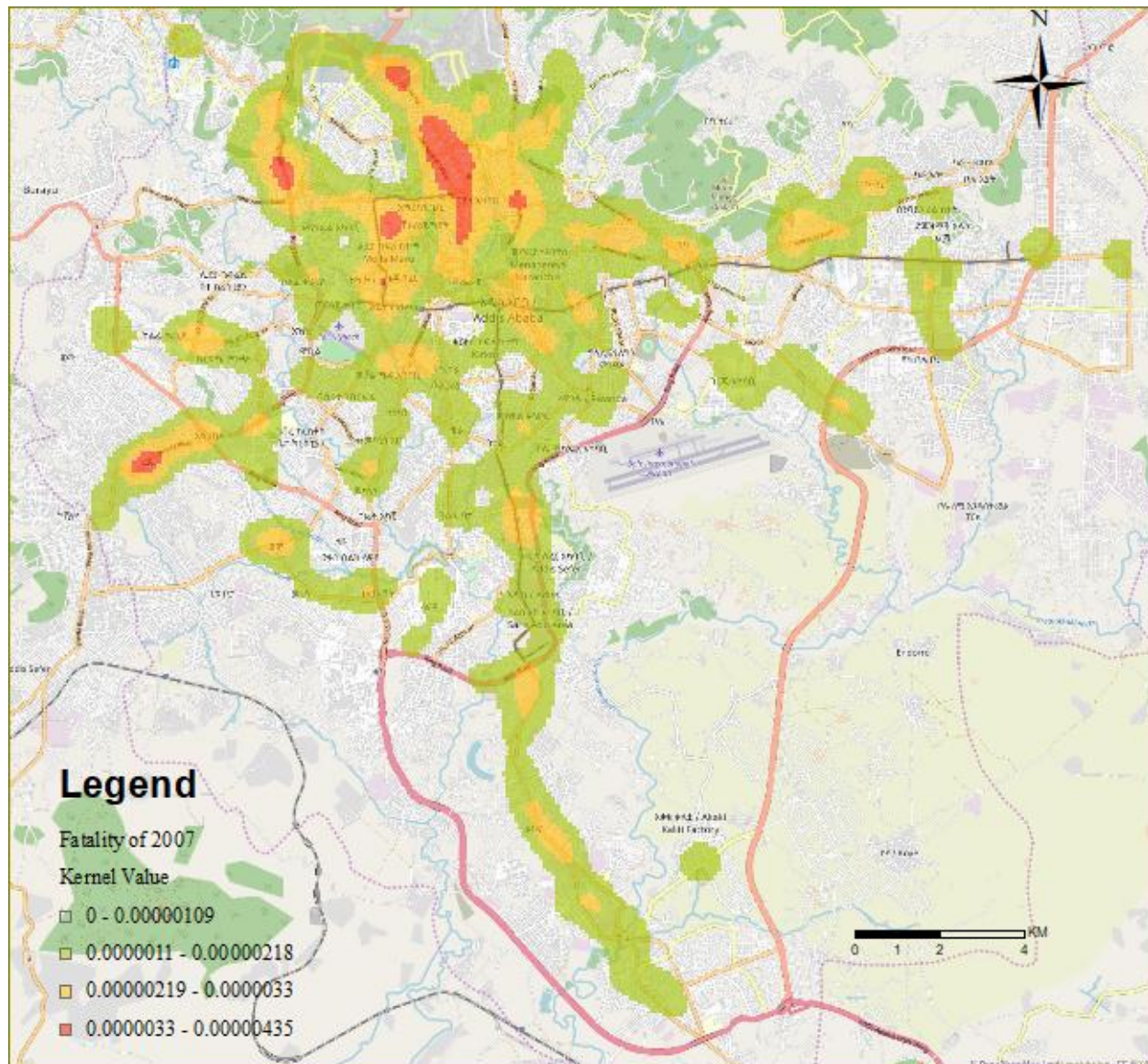


Figure 4-15 Kernel Density Estimation based hotspot analysis of fatal crash in 2007

Figure 4-15 above and its legend shows that the distribution of hotspot locations of a fatal traffic crash in 2007 in Addis Ababa city based on Kernel Density Estimation analysis. The searching radius of kernel density estimation determined using k^{th} (number of nearest traffic crashes) average nearest neighbor distance tool is 1000m at k-value of three fatal traffic crashes. After executing the KDE toolbox using a 1000m, searching radius kernel density value is generated. Based on this kernel density value of fatal traffic crash, the maps of the city on which fatal traffic crash displayed were categorized into four different levels of kernel density value in this study.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

The red color (0.000033-0.0000435 kernel density value) is selected as a high hotspot area. Accordingly, the following area was identified as the hotspot location with the help of online google map of the city and ArcGIS kernel density estimation approach:

- a. Along Jimma road around Repi Soap and Detergent Factory, around Darmar LRT station and Arat kilo intersection.
- b. Sebategna (Shema tera, Doro tera and Shera tera).
- c. Tewedros intersection to Minilik square to Semien hotel to Sheger Park to Addisu Gebeya noc.
- d. Asra Simint to Atena era along the ring road.

B. Distribution of road traffic injury crash hotspot in 2007

Road traffic injury crashes in this study include slight injury and serious injury occurred on the streets of Addis Ababa city. The maximum, the minimum and the average nearest neighbor distance after the aggregation of traffic injury traffic crashes within 100m XY tolerance distance using calculating distance band (nearest neighbor) toolbox obtained were 1600m, 285m and 500m respectively. The hotspot analysis of traffic injury crash based on the Kernel Density Estimation approach and Getis-Ord G_i^* hotspot analysis is detailed as follows. The maximum and the average distance were used in ISA to determine either the first peak or maximum peak Z-score at which the clustering occurs in the collected data so that the distance at the first peak z-score can be used for Getis-Ord G_i^* hotspot analysis. The distance occurs at the first peak z-score of 26 with the p-value of 0.000 is 4500m which is used as the appropriate threshold or searching radius of Getis- Ord G_i^* hotspot analysis.

Figure 4-16 bellow and its legend show that the distribution of injury traffic crashes hotspots area in 2007 on the street of Addis Ababa city based on Kernel Density Estimation. The searching radius of kernel density of injury traffic crash of 2007 determined by average ($k^{th}=10$) nearest neighbor distance event is 1400m. The following areas with the kernel density values of (0.000004 – 0.000005) or red color shaded area identified as the hotspot areas of injury traffic crashes in the city within the searching radius of 1400m:

1. Lancha, Meskel flower, Gotera, Wello sefer, Rwanda, African Avenue Bole road area.
2. Tegbared to Mexico to Leghar to Stadium to Urael to Hayahulet (parallel to the railway route) area.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

3. Geja sefer, Sudan street, Beherewi, Ambassador, Yohanes street, Kazanchis (Menilik II Avenue and Taitu Street) area.
4. Gojjam Berenda, Atikilt Tera, Giorgis, Menilik II square, Ras Mekonnen Dildiy, AAU social science faculty, Shiro Meda area.
5. Megenagna intersection area.

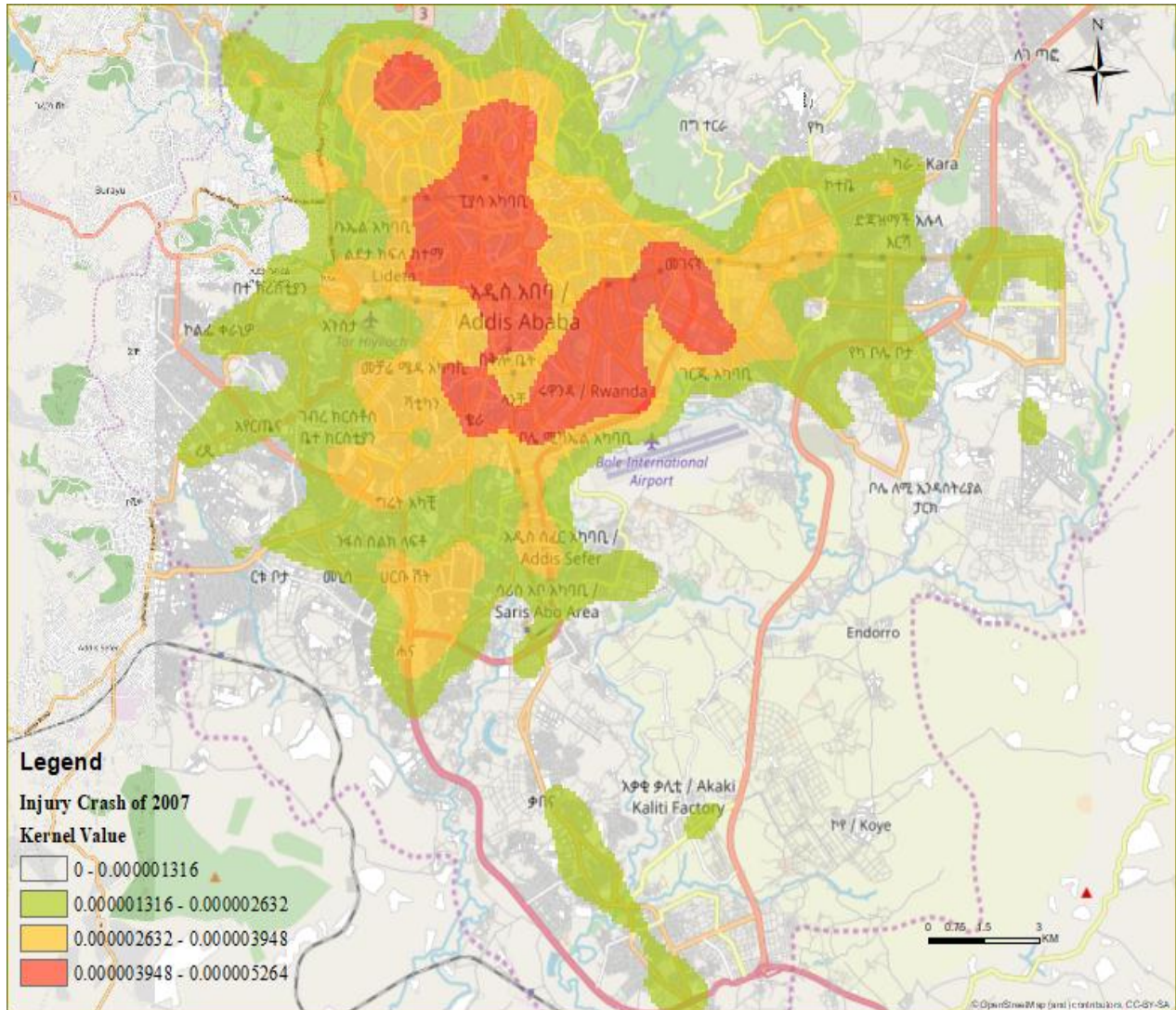


Figure 4-16 Kernel Density Estimation based hotspot analysis of injury crash in 2007

Figure 4-17 below and its legend illustrate that the distribution of road traffic injury crash hotspot locations in 2007 on the street of Addis Ababa city based on Getis- Ord Gi* hotspot analysis. The following locations were identified as the hotspot locations at 95% and 99% confidence interval or red and yellow color dot shown by the figure 4-17 below.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

1. Torhailoch to Mexico to Lagahar to Urael to Megenagna to Gurd Sholla along the LRT route.
2. Lideta to Abinet to Autobus Tera to Georgis along the LRT route.
3. Stadium to Lancha to Gotera to Nifas Silk-2 along the LRT route.
4. Bole Michael to Bole bridge to Megenagna along the ring road.
5. Estifanos to Shoa Dabo to Wollo sefer to Rwanda to Bole Bridge.

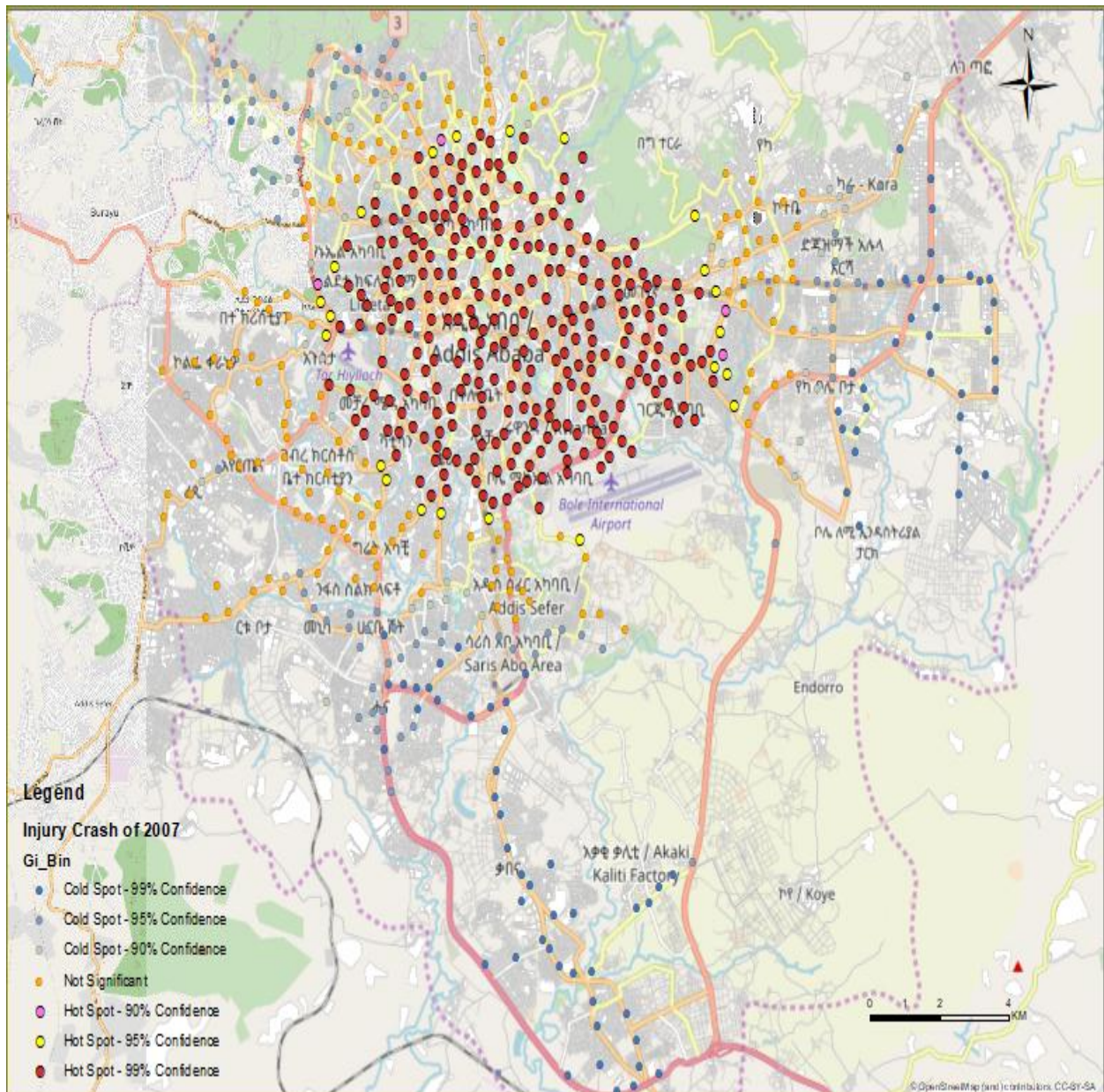


Figure 4-17 Getis-Ord G_i^* based hotspot analysis of injury traffic crash in 2007

C. Distribution of road traffic non-injury crash hotspot in 2007

Non-injury traffic crashes include property damage or physical object traffic crash only. The distribution of property damage traffic crashes location in the city on the map and its density or hotspots were plotted with the help of ArcGIS software, kernel density estimation and Getis-Ord G_i^* hotspot analysis. Integrate the data, collecting events and calculating the distance function (nearest neighbor distance) are used to find the maximum 1600m, the minimum 250m and the average nearest neighbor distance of 500m for further threshold distance determination for traffic non-injury hotspot crashes. The threshold distance is determined with the help of executing the ISA (incremental spatial autocorrelation) toolbox existing in the ArcGIS software using the average and maximum nearest neighbor distance determined through the calculating distance toolbox as an input as an incremental and beginning distance respectively for the determination of appropriate threshold distance. The threshold distance obtained for this analysis after the execution of the ISA toolbox at the first peak Z-score value of 13.81 and p-value of 0.000 is 6000m.

Figure 4-18 bellow and its legend show that the distribution of road traffic non-injury crashes hotspot location in Addis Ababa city based on Getis-Ord G_i^* hotspot analysis in 2007. The hotspot location of 2007 non-injury crash identified at 95% and 99% confidence interval were the following road alignment under 4500m threshold:

1. Kara kore to Ayer tena to Zenebework to Torhailoch to Amanuel hospital to Asrasimint to Atena tera along the ring road.
2. Ayer tena to Michael Adebabai to German Adebabi to Haile Garment intersection to Oromia Water Work construction at Kality to Bole Michael along the ring road.
3. Adey Abeba LRT station to Gotera to Lancha along the LRT route and Michew Square to Pushkin Square to Mekenissa Abo to German Adebabi the road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

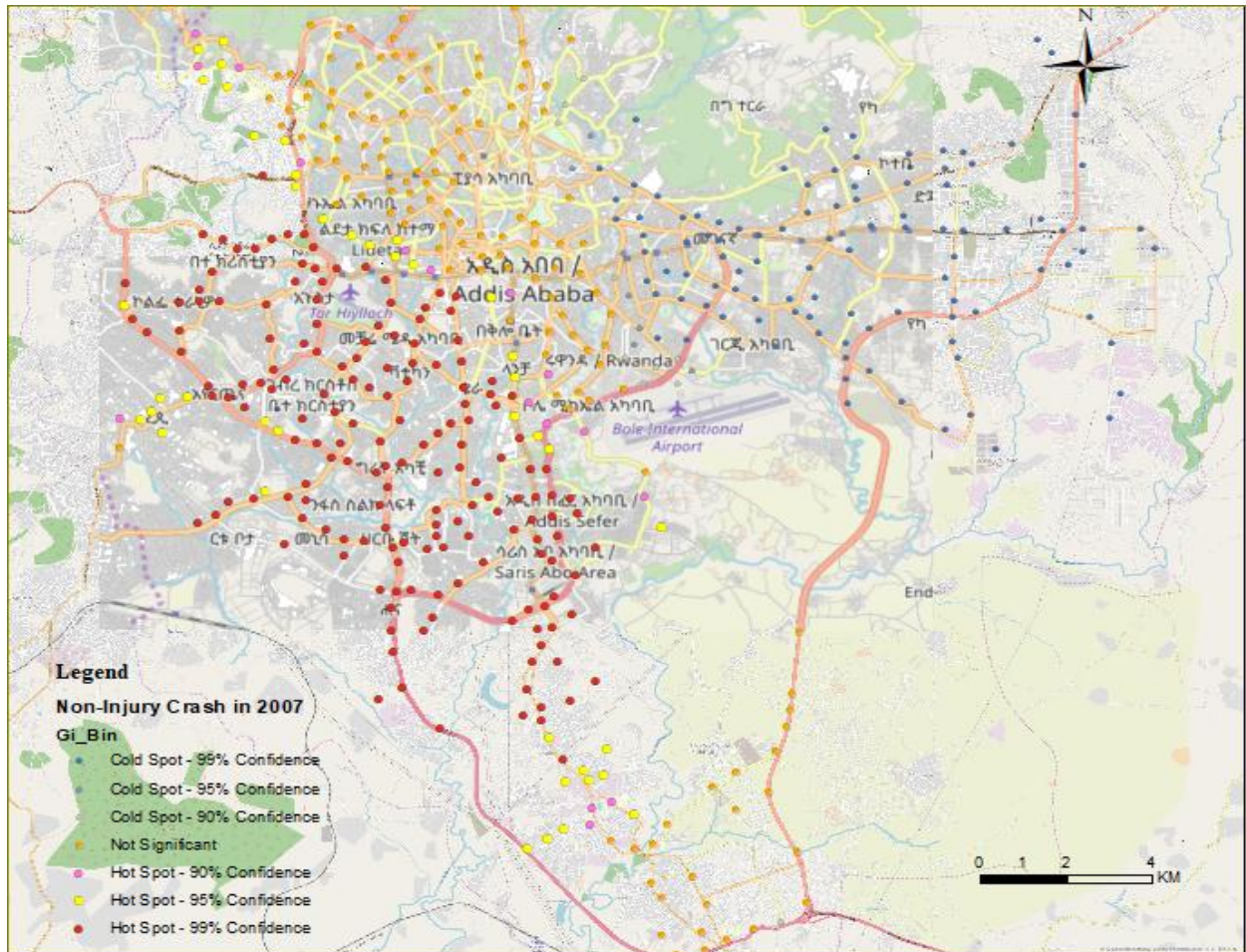


Figure 4-18 Getis-Ord G_i^* based hotspot analysis of non-injury traffic crash in 2007

Figure 4-19 below and its legend demonstrate that the distribution of road traffic non-injury crashes hotspot areas based on the Kernel Density Estimation approach in 2007. The searching radius of kernel density estimation of non-injury crash 1500m used in this analysis is determined based on average ($k^{th} = 10$) nearest neighbor distance of events. The using the searching radius obtained (1500m) the following location was identified as non-injury traffic crash hotspot in 2007 E.C in the city based on KDE approach:

1. Gotera Junction area in all directions and Saris to Adey Ababa to Nifas silk-1 along the LRT route.
2. The area enclosed in Laghar to Mexico to Lideta to Abinet to Sebategna to Autobus tera to Gojjam berenda to Anwar mosque to Teklehymanot (Arbagnoch square) to Ambassador to the stadium to Laghar road alignment was vulnerable to a non-injury traffic crash in 2007.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

3. Autobus tera to Mesalemia to Chid Tera to Abebe Bikila Stadium to Kolfie Keranio to Winget Technical College area.

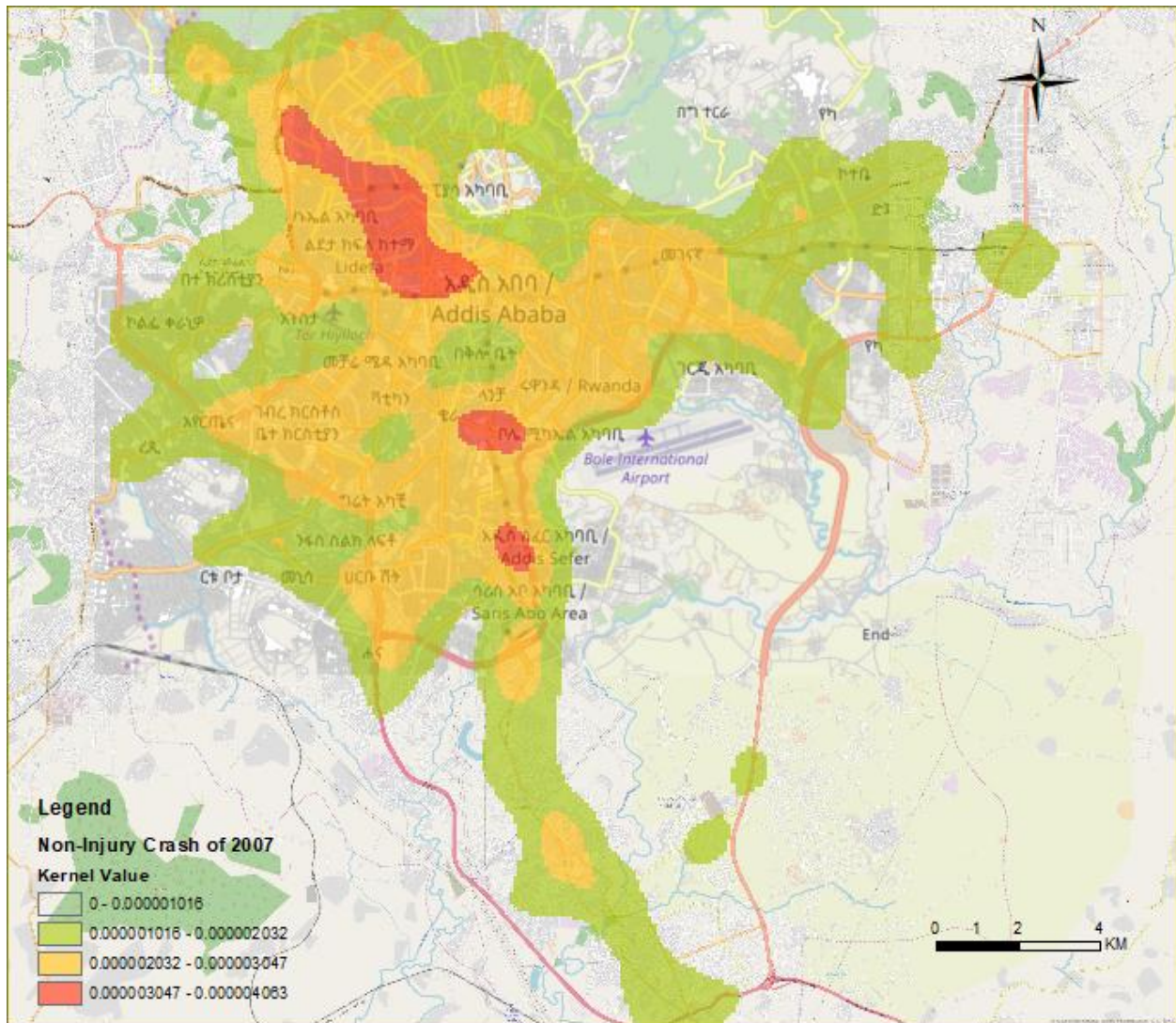


Figure 4-19 Kernel Density Estimation based hotspot analysis of non-injury crash in 2007

4.2.4.2. Distribution of road traffic crash hotspot in 2008

A. Distribution of road traffic fatal crash hotspot in 2008

This topic deal with only the distribution and identification of hotspot location of the road traffic fatal crashes on Addis Ababa city street in 2008 E.C with the help of ArcGIS software. The first step before identifying the hotspot location of traffic crashes using ArcGIS software is to integrate the traffic crashes locations within a 100m XY tolerance distance (Appendix-B). The second and third step is collecting events and calculating distance function (the minimum, the maximum and average distance between the locations of traffic crash at least between one neighbors' points). The result retained after the integration of fatal traffic crashes locations within 100m XY tolerance distance using collect event data (Appendix-B) as input in calculating distance toolbox, the maximum, minimum and average distance of 2300m, 220m and 500m respectively. The value of maximum distance and the average distance furtherly used in ISA (Incremental spatial autocorrelation) as an input of starting value of threshold distance and incremental distance value respectively to determine the appropriate threshold or searching radius for Getis- Ord G_i^* hotspot analysis. Since to determine the appropriate threshold distance by executing ISA tools couldn't possible to obtain the either the first or the maximum Z-score using the maximum and average nearest neighbor distance but, through trial and error 1000m was obtained at the maximum value of Z-score 2.58 and p-value of 0.01 which is less than 0.05. It indicates that the fatal traffic crash location in 2008 in the city are clustered under the radius of 1000m. Therefore the appropriate searching radius of hotspot analysis based on Getis- Ord G_i^* hotspot analysis is 1000m at the confidence interval of 95%. Figure 4-20 bellow and its legend show that the distribution of hotspot location of a fatal traffic crash in 2008 based on Getis-Ord G_i^* hotspot analysis under the analysis of 1000m threshold distance. According to this figure, the following areas identified as a hotspot location of a fatal traffic crash in the city in 2008 E.C at 95% and 99% confidence interval.

1. Twedros Square, Gojjam Berenda, Addis Ketama sub-city administration office, Addis Ketema secondary school, Mearab hotel, Sebetagna, St. Michael Church (Addisu) on Aoutobus tera to Pastor road, Pastor intersection, Addis Ababa Primary School on the pastor to Enqulal Fabrica intersection road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

2. Asra simint to Lukanda to Kolfe secondary school on Ambo new road and Atena Tera on the ring road.
3. Ayer Tena intersection and Ayer Tena intersection to Kara kore around Silte Sefer and Ayer Tena medium clinic.
4. Akaki Kality post office to Akaki Kality sub-city administration office to Tirans Ethiopia at the diversion of road and around Akaki Kality Noc gas station.

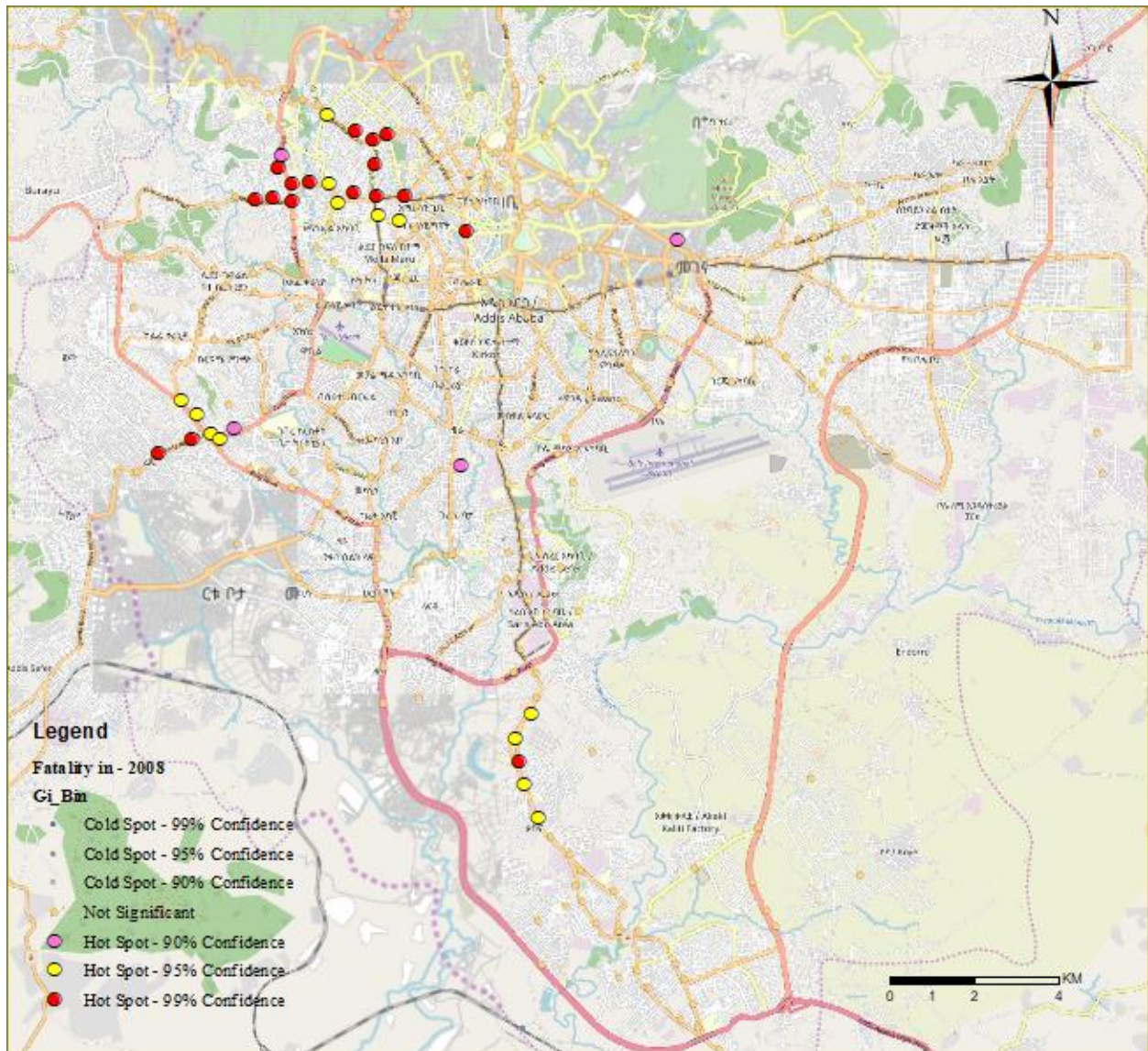


Figure 4-20 distribution of Getis-Ord G_i^* based fatal crash hotspot location analysis in 2008

Figure 4-21 bellow and its legend show that the location and distribution of hotspot of traffic fatal crashes in Addis Ababa city based on the Kernel Density Estimation Approach. Under the

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

consideration of at least three neighbor locations of a fatal traffic crash, the searching radius of Kernel Density Estimation obtained for fatal traffic crash of 2008 in the city with the help of calculating distance toolbox (Average $k^{\text{th}} = 3$ location of fatal crash location nearest neighbor distance) 1000m was obtained. The following sites were identified as hotspot area of fatal traffic crash under the searching radius of 1000m based on highest Kernel density value obtained (0.000004-0.000006) or red color shaded area of the figure 4-21 bellow in 2008 E.C fatal traffic crashes in the city:

1. Minilik Square to Afincho Ber to 6-Kilo roundabout to Menen.
2. Minilik square to Afincho Ber to St. Mary to 5- kilo to 6-kilo.
3. Adey Abeba to Nifas Silk-1 along the LRT area.
4. Sebategna to American Gibi around the Dubai Tera area.

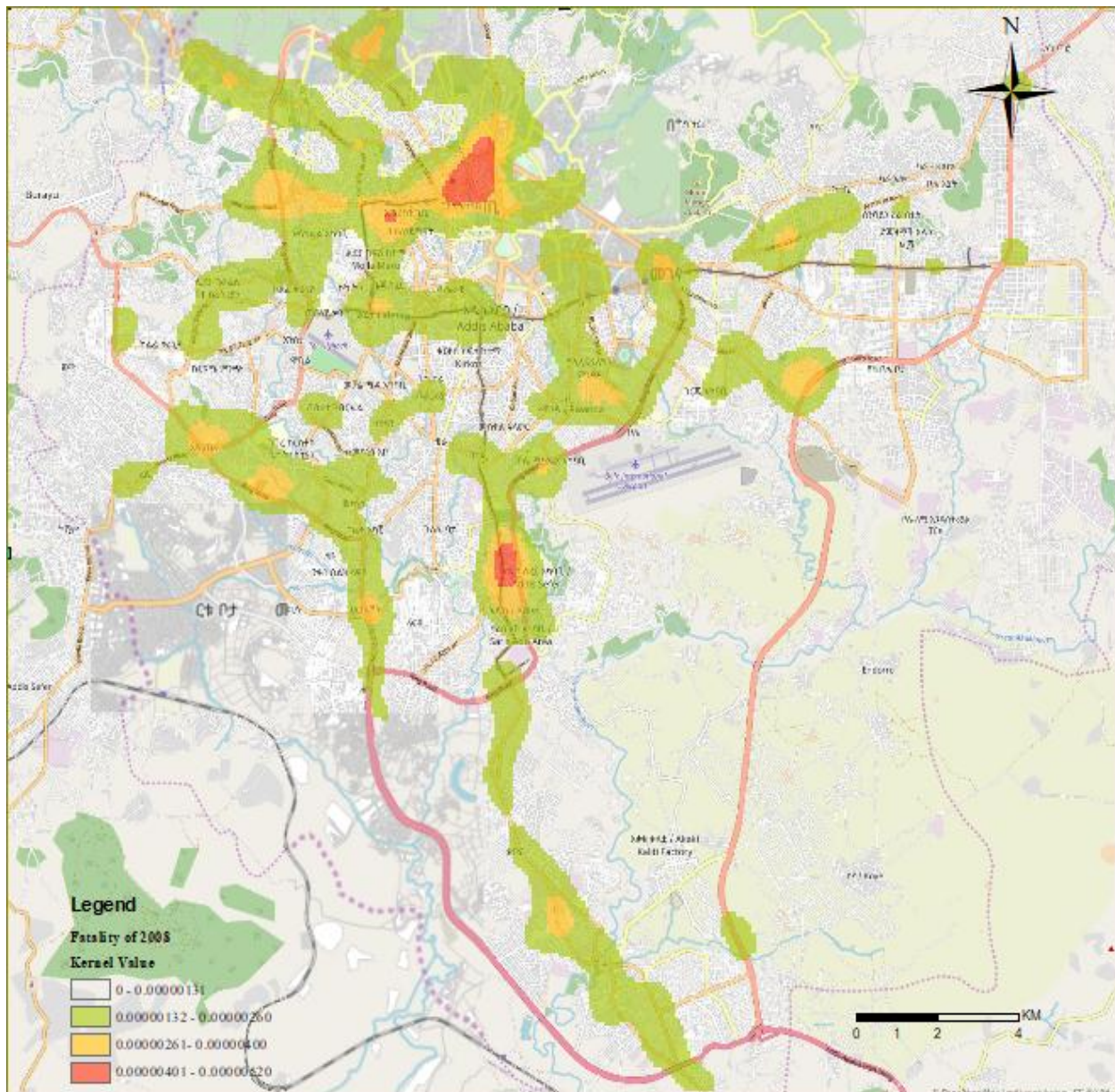


Figure 4-21 Kernel density Estimation based hotspot analysis of fatal crash in 2008

B. Distribution of road traffic injury crash hotspot location in 2008

The distribution of traffic injury crash hotspots is the combination of slight injury and serious injury. The minimum, average and maximum nearest neighbor distance of injury traffic crash location in the city after integrating traffic crash within the XY tolerance distance of 100m and collect events (Appendix-E) and executing calculate distance function toolbox of ArcGIS software 275m, 500m and 1600m are obtained. Using the average and maximum nearest

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

neighbor distance as incremental and beginning distance respectively for the searching of best threshold distance for the hotspot location identification in ISA toolbox resulting 4500m threshold distance at the first peak Z-score of 31.92 and p-value 0.00. Figure 4-22 below and its legend shows that the distribution of hotspot location of road traffic injury crashes in the Addis Ababa city based on Getis-Ord G_i^* hotspot analysis in 2008 under 4500m searching radius. The following locations were identified as hotspot location of injury crashes in 2008 E.C at 95% and 99% confidence interval based on Getis-Ord G_i^* hotspot analysis.

1. Megenagna to lamberat bus station to Finland Embassy road.
2. Torhailoch to Coca-cola to Lideta to Mexico to Stadium to Megenagna intersection along LRT route and within a radius of 100m.
3. Nifas silk-2, Gotera, Haleluya General Hospital, Lancha, Meshwalekya, Riche along LRT and on the road joining to the LRT side.
4. Bole Michael, Bole bridge to Megenagna intersection on the ring road and kazanchis, st.Urael to bole Medhanlalem.
5. Kera to Bulgaria to Mexico road and Sarbet Junction, Vatican Embassy to Mekanissa Abo junction.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

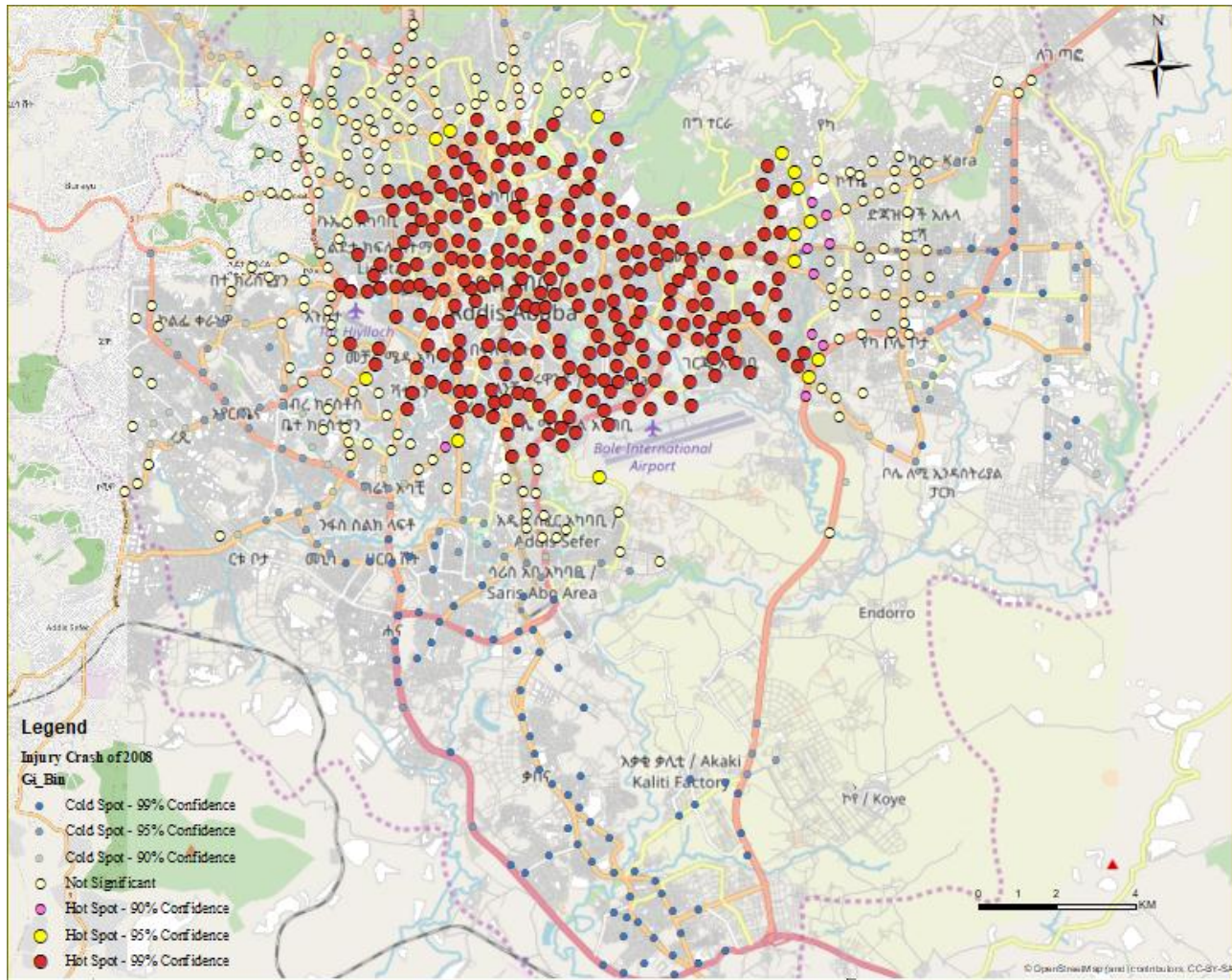


Figure 4-22 Getis-Ord G_i^* based hotspot analysis of injury traffic crash in 2008

The second method of hotspot location analysis of injury traffic crashes used in the city is KDE. An input parameter used to run KDE is the searching radius. The kernel density searching radius for injury crash of 2008 obtained using average ($K^{th} = 10$) nearest neighbor distance event is 1400m. Figure 4-23 and its legend demonstrates that the distribution of hotspot area of road traffic injury crashes in 2008 in Addis Ababa city based on Kernel Density Estimation approach. Based on the highest kernel density value (0.000004-0.000005 or red color) the following area and routes are selected as some of the hotspot locations of injury crashes in the city in 2008:

1. Gotera to Lancha to Temenga yaz along the LRT
2. Hayahulet to Megenagna intersection along LRT and Megenagna intersection to former bob Marley square intersection along the ring road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

3. Wollo sefer to Rwanda to Bole Bridge
4. Gulale medihanalem to Pastor Intersection and Gojjam berenda to Georgis to Sidst Kilo.
5. Abinet to Lideta to Mexico to Stadium to St. Urael.

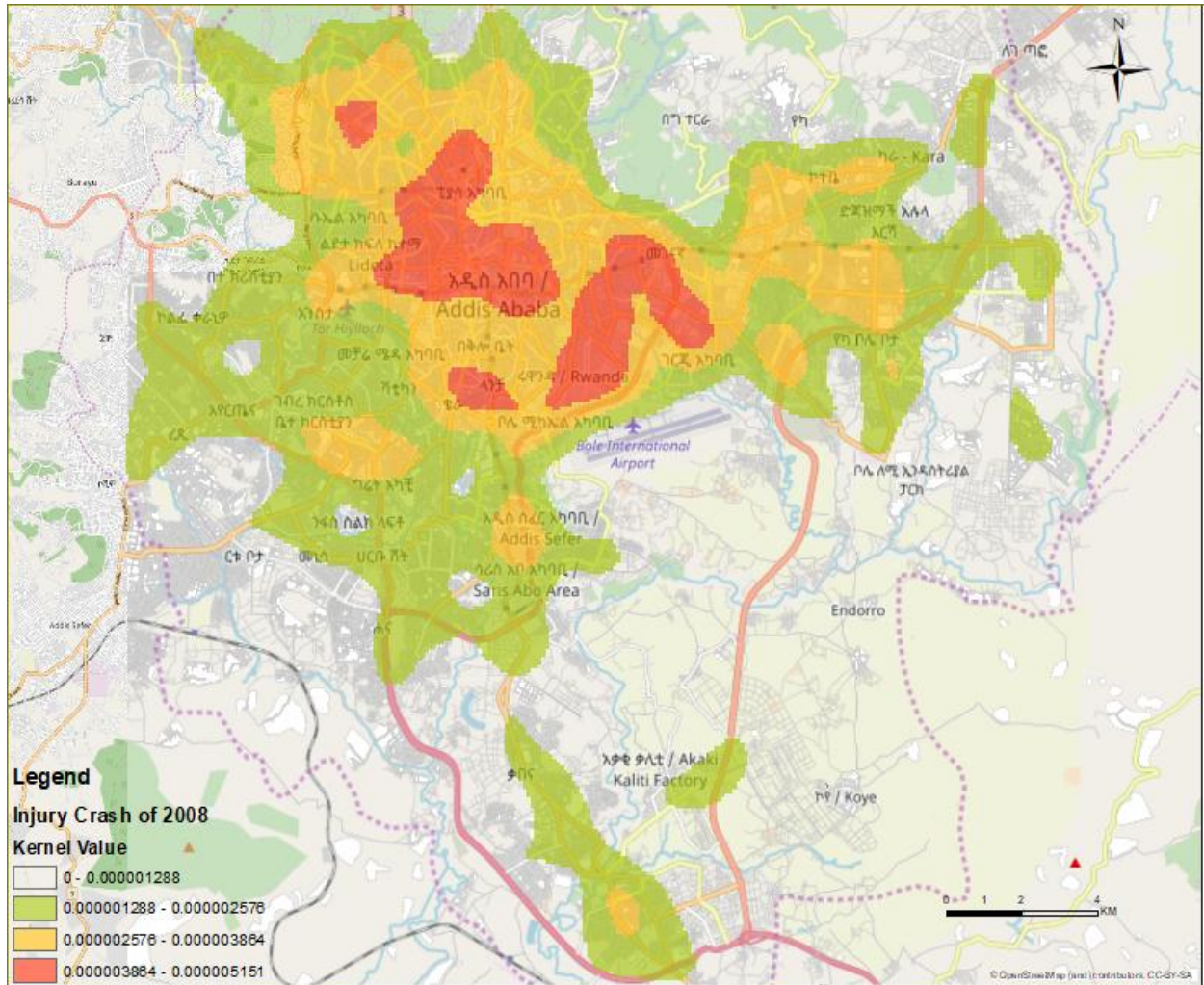


Figure 4-23 Kernel Density Estimation based hotspot analysis of injury traffic crash in 2008

C. Distribution of road traffic non- injury crash hotspot location in 2008.

The location of road traffic non-injury crashes hotspot in Addis Ababa city during 2008 E.C. is analyzed and identified based on Kernel Density Estimation and Getis-Gi* hotspot analysis approach as follows. After doing, integrating and collecting traffic crashes within the XY tolerance distance of 100m, a calculating distance function is proceeded (Appendix-H). Calculating distance toolbox is used to determine the minimum, average and maximum nearest neighbor distance of traffic crash location at least between two points of collected events. The

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

minimum, average and maximum nearest neighbor distance obtained for this analysis is 265m, 500m and 2500m respectively. The next step is to determine the appropriate threshold distance to analyze hotspot location of traffic non-injury crash in the city in 2008 using the value executed by calculating distance toolbox as input in the ISA toolbox. The ISA toolbox generates the Z-score versus threshold distance graph using average and maximum nearest neighbor distance as an input as incremental and beginning distance respectively. The appropriate threshold distance at which clustering of data occurs at the first peak or the maximum z-score value (Jayvant Choudhary 2016). For this analysis, the appropriate threshold of 6000m was obtained at the first peak z-score of 19.61 and with the p-value of 0.000. The figure 4-24 bellow and its legend show that the distribution of road traffic non-injury crash hotspot location in Addis Ababa city based on Getis-Ord G_i^* hotspot analysis in 2008.

1. Jemo-3 to jemo-1 to Lebu-mabrat hail intersection to Haile Garment.
2. Ayer tena to Michael Adebabai to German Adebabi to Haile Garment intersection to Oromia Water Work construction at Kality to Bole Michael along the ring road.
3. Akaki Kality sub-city Administration office to OWWCE to Kality LRT station to Saris to Gotera to Lancha along the LRT route.
4. Gotera to Kera to Pushkin intersection to Karl Square and German Adebabi to Nifas Silk sub-city administration office to Kera.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

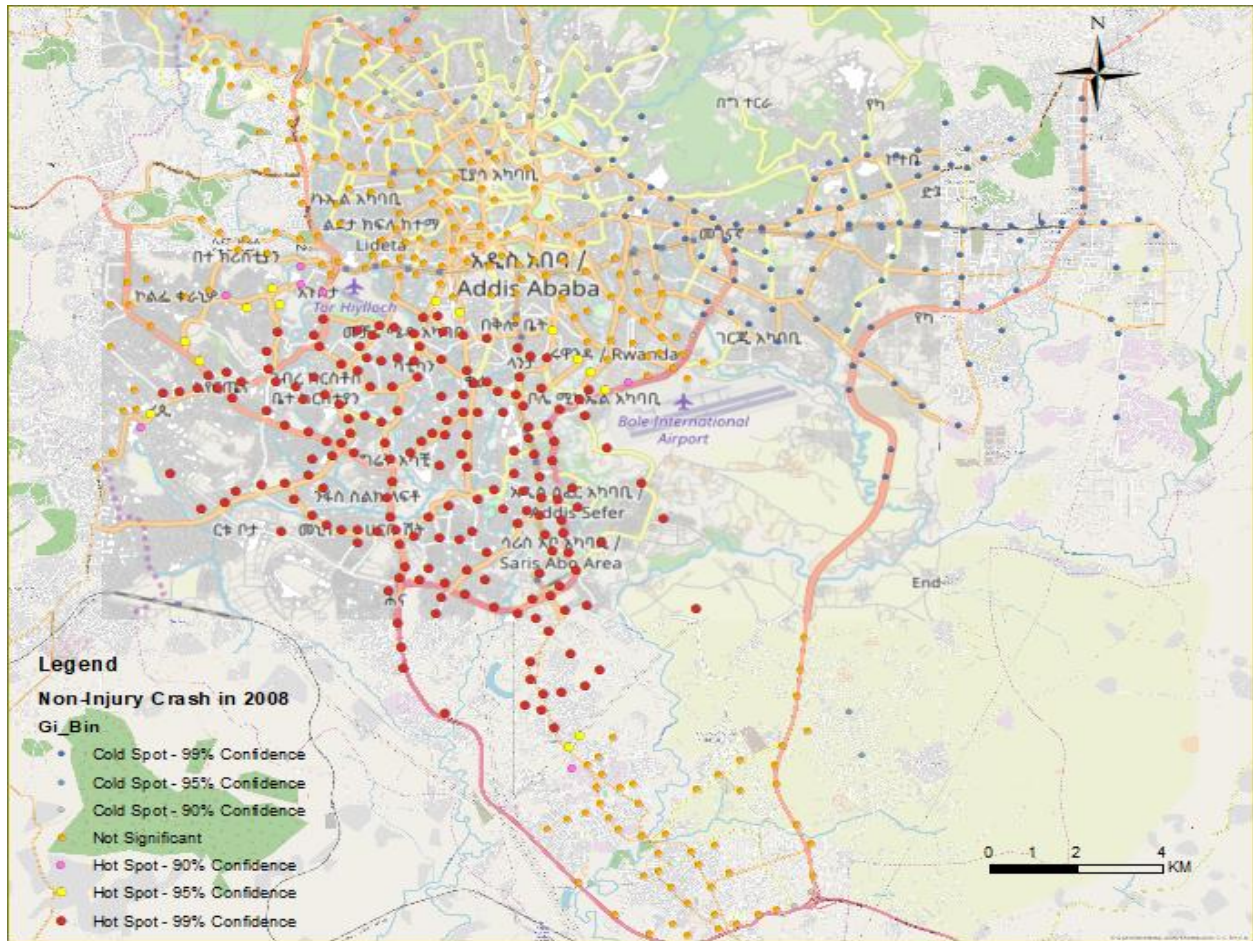


Figure 4-24 Getis-Ord G_i^* based hotspot analysis of non- injury crash in 2008

The second approach of hotspot analysis is KDE. The searching radius of the kernel density approach to identify the hotspot location for a non-injury crash in 2008 E.C determined using the average ($k^{\text{th}}=10$) nearest neighbor distance of events is 1400m. Figure 4-25 bellow and its legend show that the distribution of hotspot location of traffic non-injury crash in Addis Ababa city based on the Kernel Density Estimation approach in 2008 E.C.

1. Bisrat Gabriel and Alexander Pushkin Intersection area and Akaki Kaliti around Saris to Adey Abeba LRT route area.
2. The area enclosed within Stadium to Laghar to Mexico to Lideta to Darmar to Abinet to Sebategna to Autobus Tera to Gojjam Berenda to Anwar mosque to Teklehymanot to Ambassador returned Stadium road alignment were vulnerable to a non-injury crash in 2008.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

3. In front of Nifas Silk Sub-city Wereda 06 administration office area, Aphincho ber to Menen to Kechene and Pastor to Enkular factory to Addisu Gebeya to Rafael to Medhanalem to St. Paul hospital to pastor intersection area suffered by the non-injury traffic crash in 2008.

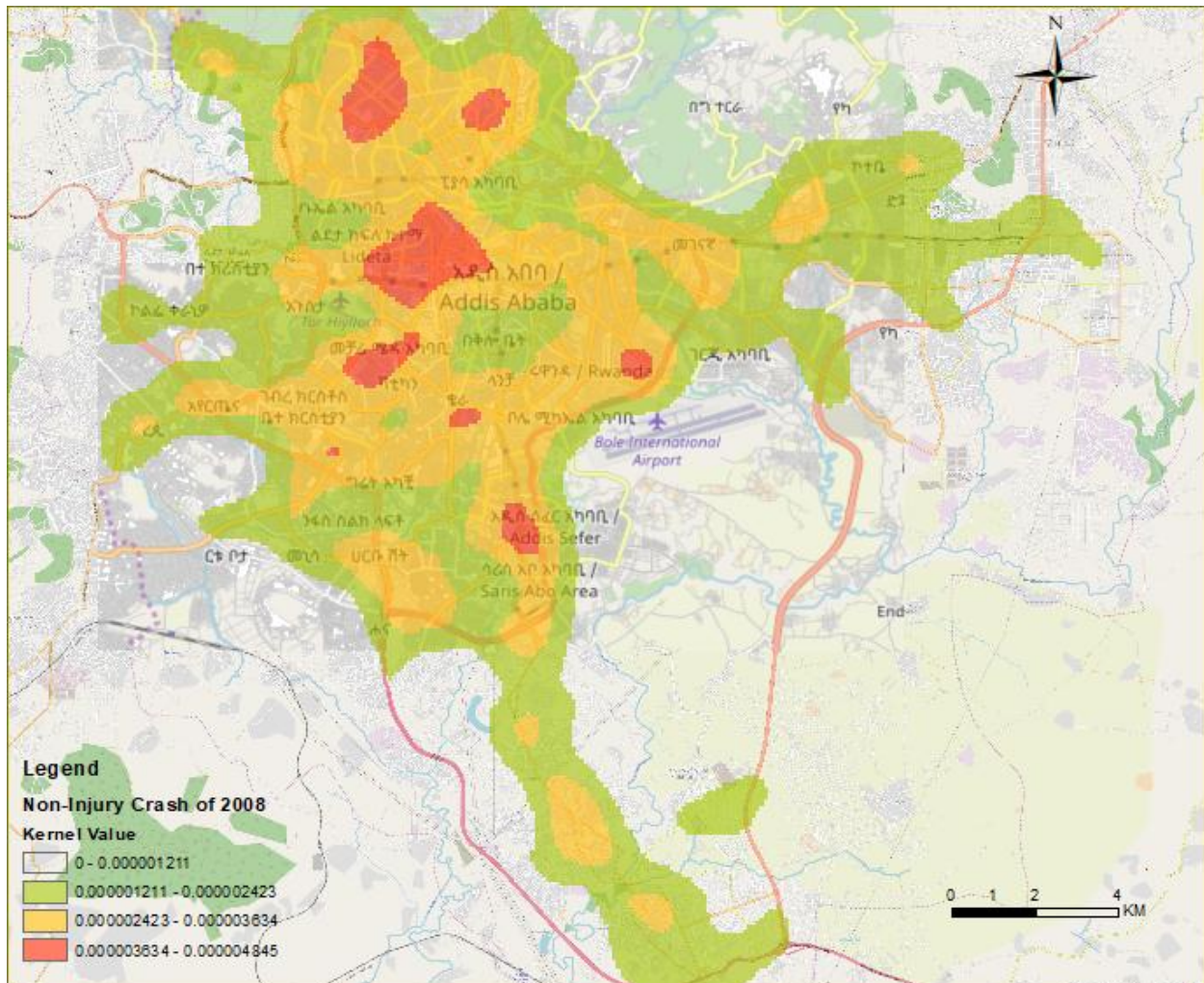


Figure 4-25 Kernel Density Estimation based hotspot analysis of non-injury crash in 2008.

4.2.4.3. Distribution of road traffic crashes hotspot in 2009

A. Distribution of road traffic fatal crashes hotspot location in 2009

The result of minimum, average and maximum nearest neighbor distance obtained after integrate, collect events (Appendix-C) and calculating distance were 260m, 500m and 2400m respectively in the analysis of fatal traffic crashes in 2009 in Addis Ababa city. The value of average and maximum distance obtained was further used in ISA tools as incremental and starting distance respectively to determine the appropriate threshold distance for Getis-Ord G_i^* hotspot analysis. To determine the appropriate threshold distance by executing ISA tools using average and maximum value as input it is difficult to obtain the either the first or the maximum Z-score under this using but, through trial and error 2200m was obtained at the maximum value of Z-score 2.26 and with the p-value of $0.024 < 0.05$ recommended significance level for transportation. It indicates that the fatal crash of 2009 is clustered at a threshold distance of 2200m at a 95% confidence interval.

The next step is the analysis of hotspot fatal crash data location using the kernel density estimation approach and Getis-Ord G_i^* hotspot analysis. Figure 4-26 bellow and its legend show that the distribution and hotspot of road traffic fatal crashes locations in Addis Ababa city in 2009 based on Getis-Ord G_i^* hotspot analysis. According to this figure, the hotspot locations of fatal crashes in 2009 occurred in the city were presented at two levels of confidence 95% and 99% (95% confidence interval is used mostly used). The area in the city statically significant hotspot location of road traffic fatal crash based on Getis- Ord G_i^* hotspot analysis with more than 90% confidence interval shown in a different color of dot point. The location identified as a hotspot of road traffic fatal crashes in the city with the 95% and 99% confidence interval are the following:

1. Megenagna intersection to Gurd Sholla LRT station.
2. In front of Akaki Kality sub-city woreda five and around the intersection between bole to Kality ring road and Kality to Abo road.
3. Sebetagna to Autobus Tera to Pastor Intersection.
4. Amunael to Asra Simint to Atena Tera along the ring road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

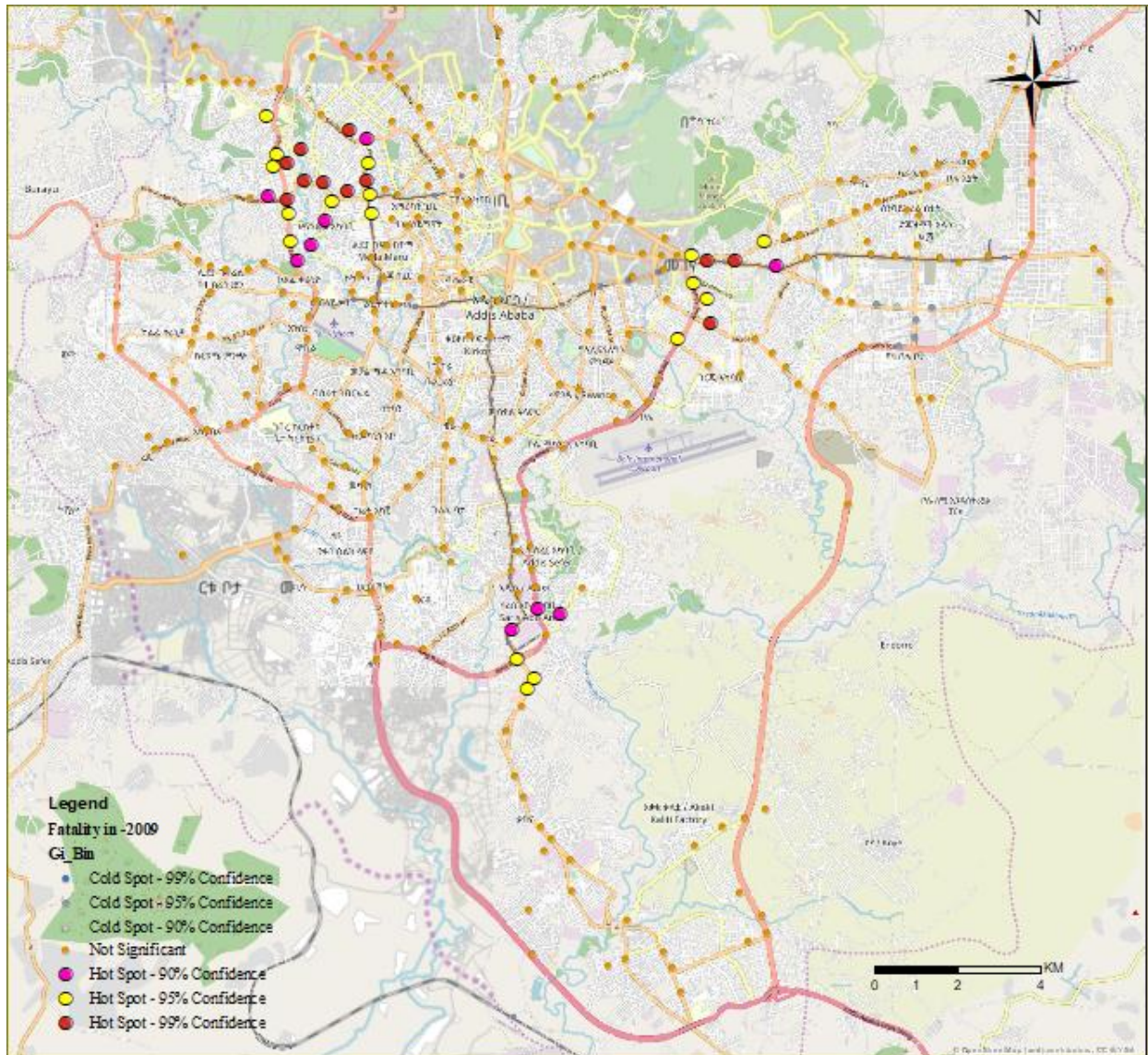


Figure 4-26 Getis-Ord G_i^* based hotspot analysis of fatal crash in 2009

The second approach used in this study to identify the hotspot location of road traffic fatal crashes is Kernel Density Estimation (KDE). Based on KDE the hotspot area of fatal crashes in 2009 in the city using the searching radius of 900m obtained with the help of k^{th} ($k=3$) average nearest neighbor distance were identified. Figure 4-27 bellow and its legend show that the distribution of hotspot fatal crash in 2009 in Addis Ababa city based on the Kernel Density Estimation approach. The hotspot area based on the highest kernel density value of (0.000004-0.000005) or red color shaded area are the following:

1. Megenagna intersection

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

2. Sebetegna to Autobus Tera to Pastor Intersection.
3. Around Addisu Gebeya Noc roundabout (Gullale intersection)
4. Lideta to Darmar road and Akaki kality around Adey Abeba area.

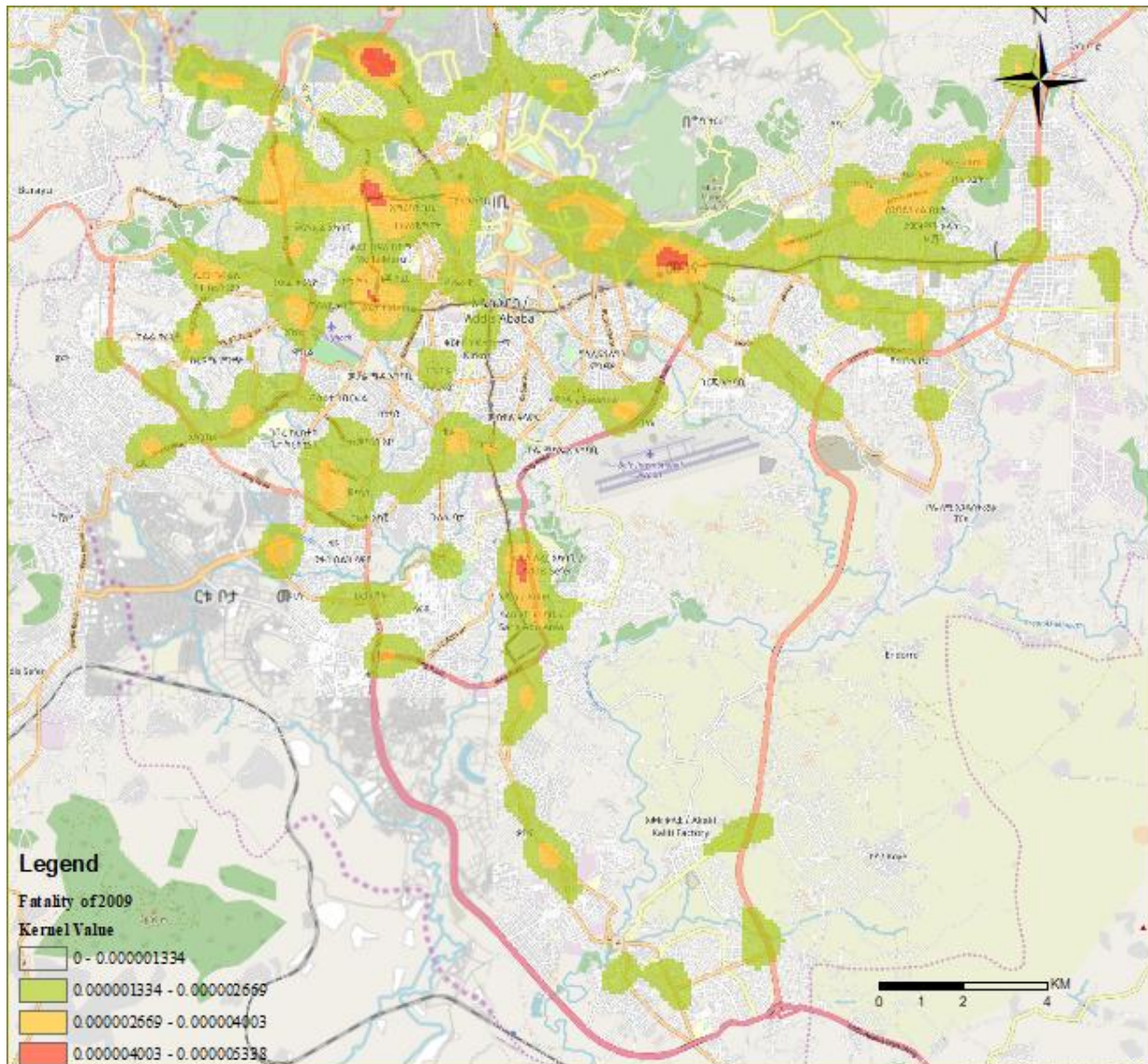


Figure 4-27 Kernel density estimation based hotspot analysis of fatal crash in 2009

B. Distribution of road traffic injury crashes hotspot location in 2009

Another category of a road traffic crash is injury crash, which includes both slight injury and serious injury. Prior to identifying the hotspot location, there are different steps to be followed. The first step is to integrate the point data and collecting events or locations of traffic crashes within XY tolerance distance of 100m (Appendix-F). The second step is to determine the

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

minimum, the average and the maximum nearest neighbor distance of traffic injury crash location using collect events as input in calculating distance toolbox and the value obtained after executing calculating distance toolbox is 300m, 500m and 3200m and those values are minimum, average and maximum nearest neighbor distance of traffic injury crash location. The third step is to determine the appropriate threshold distance for the analysis of hotspot location of road traffic injury crash in the city based on the Getis-Gi* hotspot analysis using the ISA toolbox in ArcGIS software. Using the average and maximum nearest neighbor distance as input in ISA as incremental and starting distance respectively the threshold distance result obtained after executing the ISA at the first peak Z-score ($Z=31.92$) and p-value of 0.000 is 4500m. This implies that the injury crashes clustered under the threshold of 4500m at the 95% confidence interval.

Figure 4-28 bellow and its legend show that the distribution of hotspot location of road injury traffic crashes in the Addis Ababa city based on Getis-Ord Gi* hotspot analysis. Based on the Getis-Ord Gi* hotspot analysis the following area was identified as hotspot location of 2009 E.C injury crash at 99% and 95% confidence interval (the red color dot) and at 95% (Yellow color dot).

1. Mexico to Stadium to Megenagna to Civil Service College to CMC.
2. Georgis to Arat kilo to British Embassy to Megenagna along the principal arterial road.
3. Gergis to Sidist kilo to Jal-meda on the principal arterial road.
4. Bole Michael to Megenagna intersection on the ring road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

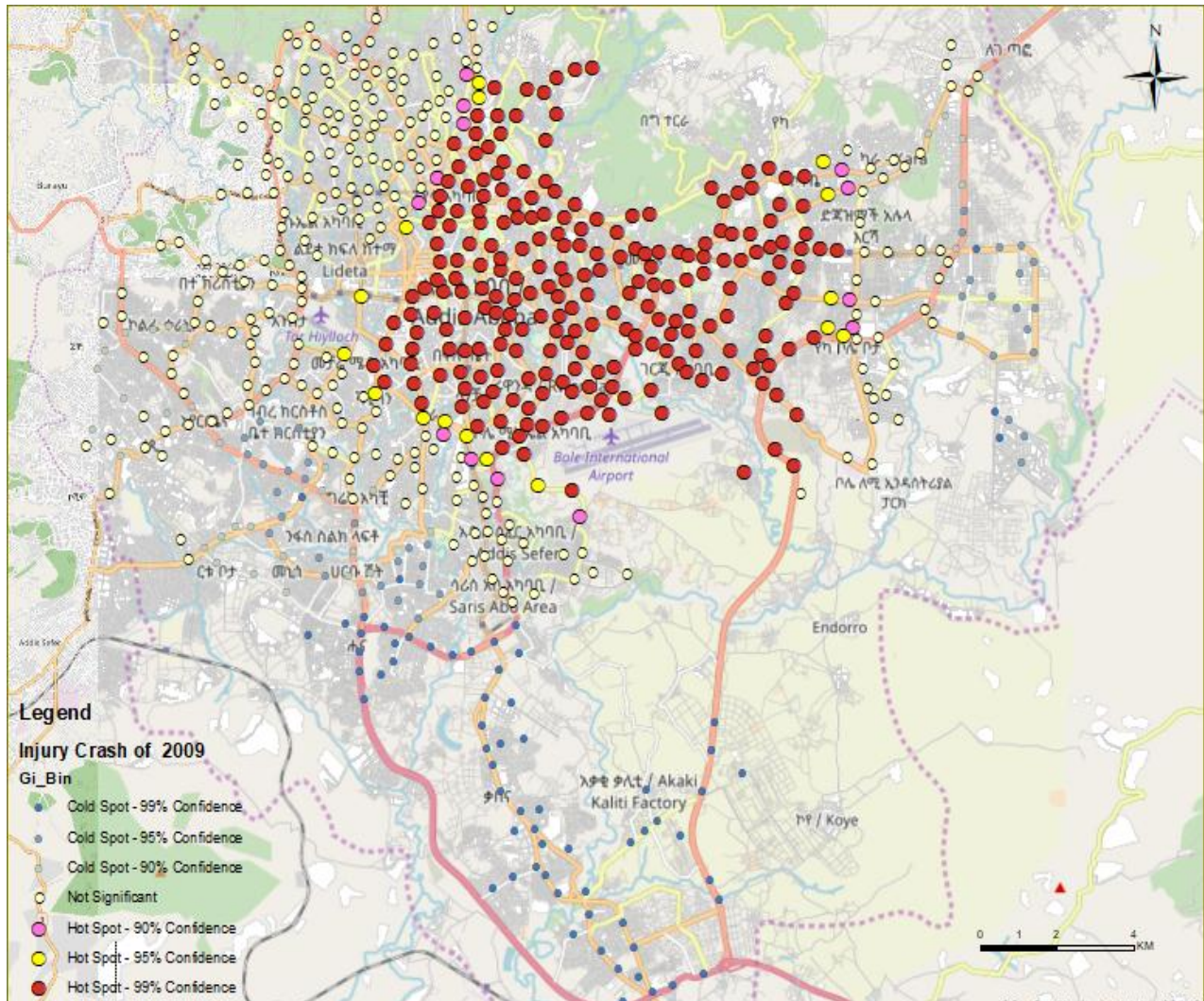


Figure 4-28 Getis-Ord G_i^* based hotspot analysis of injury crash in 2009

Figure 4-29 below and its legend show that the distribution of the hotspot area of road traffic injury crashes in 2009 in Addis Ababa city based on Kernel Density Estimation Approach. The threshold distance of injury crash of 2009 determined with the help of average ($k^{th}=10$) nearest neighbor distance tools is 1400m. The following area was selected as the hotspot area of an injury crash in 2009 E.C based on the highest kernel density value of 0.0000035-0.0000050 or red color as described in figure 4-29 below under the searching radius of 1400m:

1. Legahar to Hayahulet intersection along the Light Railway Transport (LRT).
2. Autobus Tera to Giorgis to Arat kilo intersection
3. Minilik square to Sidist Kilo intersection.

4. Megenagna intersection to Bole Bridge on the ring road.

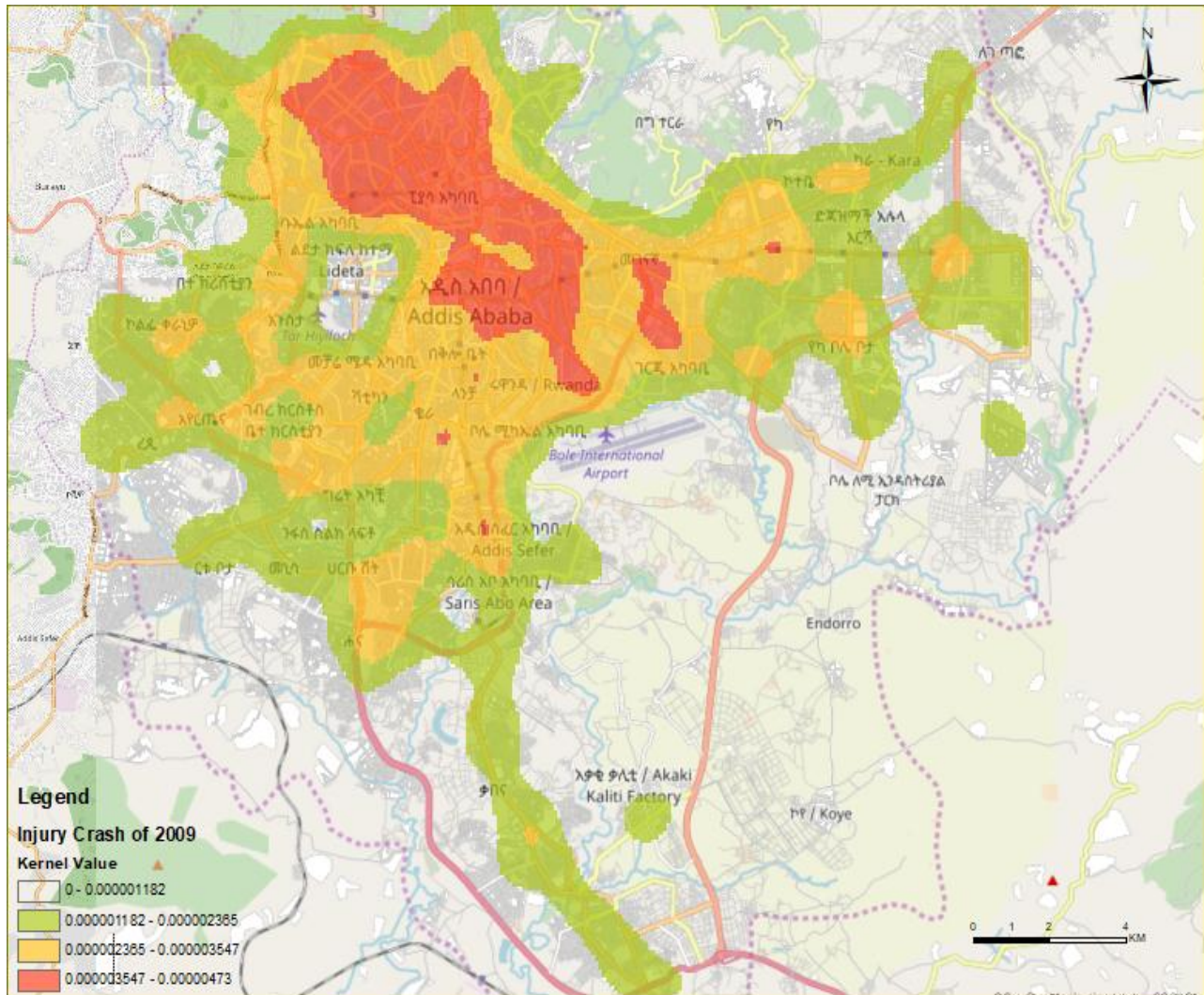


Figure 4-29 Kernel density estimation based hotspot analysis of injury crash in 2009

C. Distribution of road traffic non-injury crashes hotspot location in 2009

Under this topic, it is tried to discuss the hotspot location of non-injury crashes (property damage) in Addis Ababa city in 2009 E.C. The same procedure as in the above topic was followed to identify the hotspot location of road traffic non-injury crashes in the city. The key processes involved to identify the hotspot location are:

1. Integrating data within 100m XY tolerance distance and collecting events (Appendix-I).
2. Calculating the distance (minimum, average and maximum nearest neighbor distance of crash location). When executing calculating distance for non-injury crash the minimum,

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

average and maximum nearest neighbor distance obtained is 300m, 500m and 1250m respectively.

3. Determination of threshold distance or searching radius for the analysis of hotspot traffic non-injury crash based on Getis-Ord G_i^* hotspot analysis with the help of the ISA toolbox in ArcGIS software. ISA toolbox is used to determine the appropriate threshold distance at which clustering of data occurs using average and maximum nearest neighbor distance as an incremental and beginning value for searching of the appropriate radius for analysis of hotspot. After executing the ISA toolbox, the searching radius occurs at the first peak Z-score of 17.94 and p-value of 0.00. For this data analysis, the appropriate 5500m was obtained as a searching radius of Getis-Ord G_i^* hotspot analysis for a non-injury crash in the city during 2009 E.C.

The figure 4-30 bellow and its legend show that the distribution of hotspot location of road traffic non- injury crashes in Addis Ababa city in 2009 E.C based on Getis-Ord G_i^* hotspot analysis. The following location and route were selected as hotspot location at 95% and 99% confidence interval.

1. Haile Garment intersection to Oromia Water Work Construction Enterprise (OWWCE) at Akaki Kaliti to Bole Michael along the ring road.
2. Akaki Kaliti sub-city administration to Oromia water work to Saris to Adey Ababa to Gotera to Lancha along and around the ring road.
3. Sarbet to Kera to Gotera road and German Adebabayi to Mekinissa Abbo intersection to the Vatican to Sarbet.
4. Ayer Tena to Michael Adebabayi to German Adebabayi to Garment Adebabay to Hana Mariam along the ring road.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

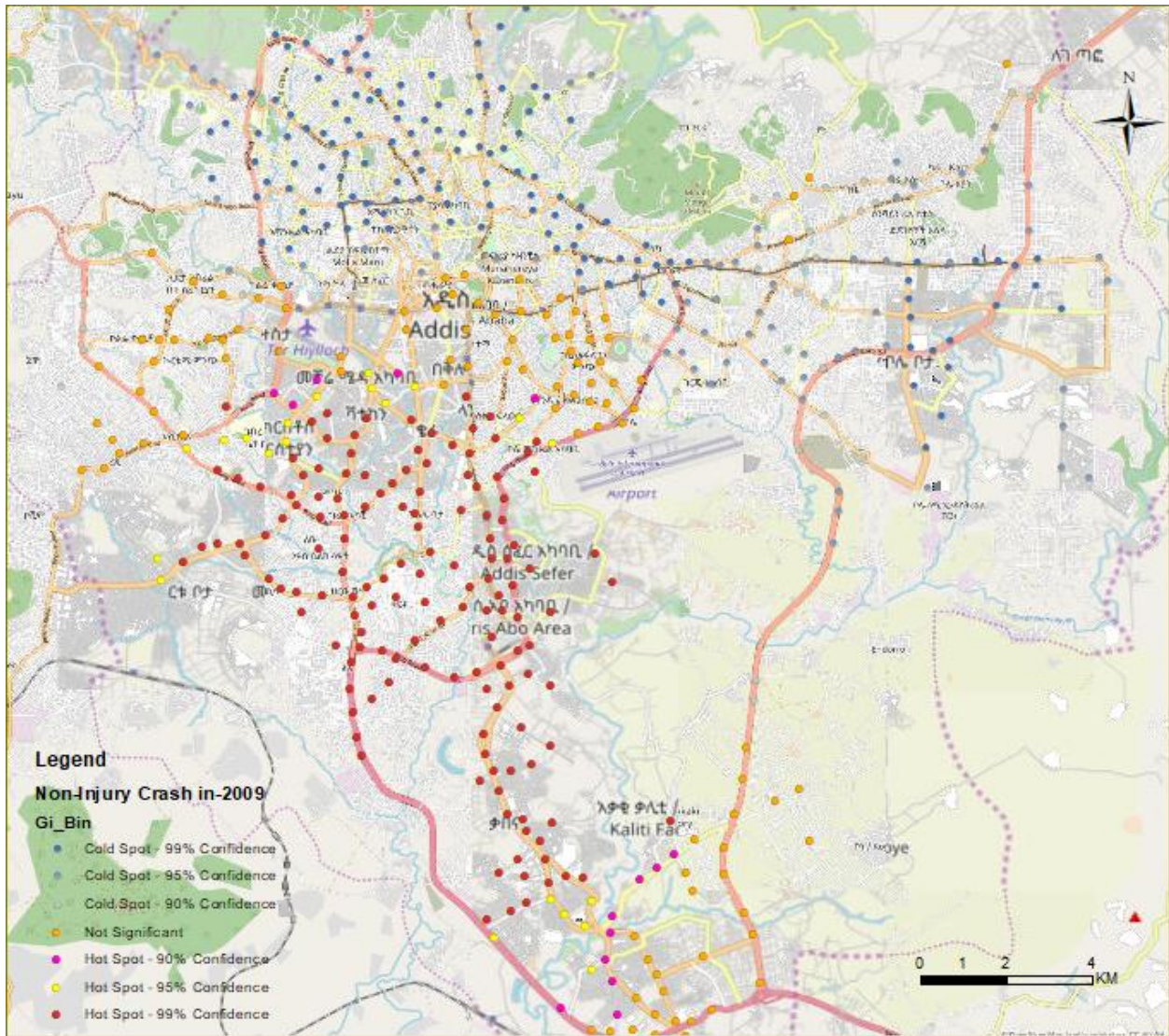


Figure 4-30 Getis-Ord Gi* based hotspot analysis of non-injury crash in 2009

The second approach used in this study to address the hotspot location of non-injury traffic crashes in the city is Kernel Density Estimation. The searching radius determined for this study using the average ($k^{\text{th}}=10$) nearest neighbor distance is 1500m. Figure 4-31 below and its legend show that the distribution of hotspot area of road traffic non-injury crashes in Addis Ababa city based on Kernel Density Estimation Approach. The following area is selected as the hotspot location of non-injury crashes in the city in 2009 E.C based on the highest kernel density of 0.000002636-0.000003515 or red color shaded area shown in the figure below:

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

1. Mesalamia to Autobus Tera to Gojjam Berenda to Atekilt tera and sebetegna to Mearab hotel to Anwar Mosque to Cinema Ras to Arbagnoch Square,
2. Pastor to Enkulal Factory to Yohanis to Georgis road and Sebetegna to Autobus Tera to Pastor Intersection to Medhanialem.
3. Addisu Gebeya from the end of the ring road to Sheger Park to Seimen hotel to Gulale sub-city public library road.
4. Haile Garment Square to Lebu Mibrat Hail Adebabayi road and German Adebabayi to mekanissa Abo intersection to Total Square.
5. Ethiopia hotel to National palace to Kazanchis and St. Urael to Megenagna along LRTroad.
6. Oromia water work construction at kality to Fana Real State along the ring road.
7. Akaki Kality LRT station to Abbo Junction to Saris to Adey Ababa to Hoover Real state.

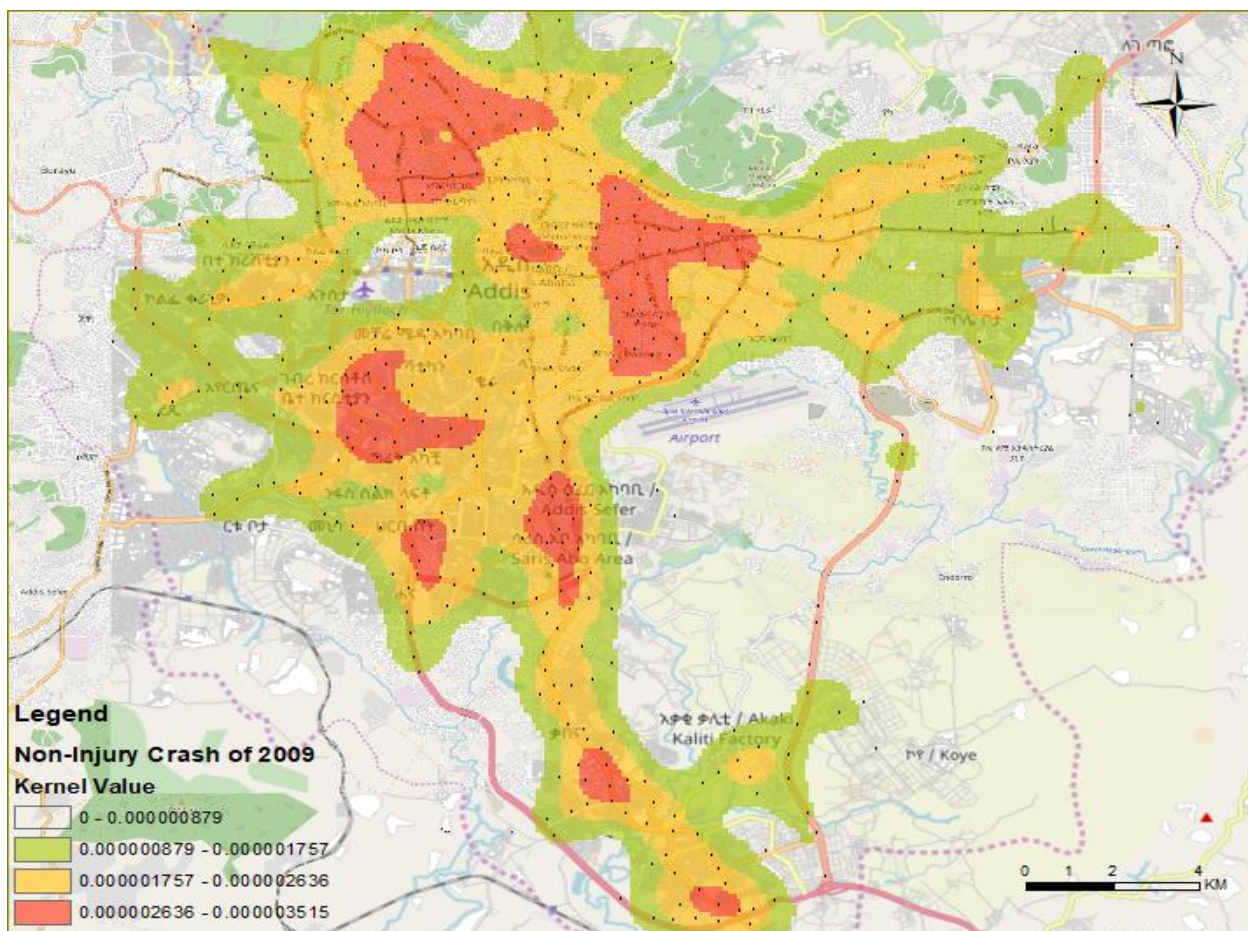


Figure 4-31 Kernel density estimation based hotspot analysis of non-injury crash in 2009

4.3. Speed violation analysis

The speed violation analysis in this study depends on the recorded data during the enforcement of speeding by the traffic police and traffic control at different road types and posted speed in the city for three months. The gathered data by those two concerned bodies is 26, 256-speed violation data. The analysis under this topic incorporates the driver information such as age, sex, and experience of driving, vehicle types, posted speed limit and extent of the speed of driver participated in the speed violation gathered during the enforcement by Addis Ababa sub-city police commission. The gathered data were analyzed in detail using Microsoft excel and its statically significance is checked with the help of the SPSS program.

4.3.1. Distribution of driver age involved in exceeding posted speed.

Most of the time, the major contributing factor of exceeding the speed limit is the behavior of the drivers such as age, sex, and experience of the driver. In the analysis of speed limit violation related to a driver age group at significance level of $\alpha=0.05$ with the degree of freedom 3 the chi-square value ($\chi^2_{critical}$) which is read from the chi-square distribution table is 7.81 and the calculated chi-square value (χ^2_{test}) is 45,181 with P-value of 0.00 using SPSS. Since the calculated value of χ^2_{test} is greater than the $\chi^2_{critical}$ at the significance level of $\alpha=0.05$, the null hypothesis there is no significant variation of speed limit violator driver by age group is rejected. It indicates that there is a significant relationship between driver age and number of a driver involved in speed violation. Among 26,256 speeders recorded during enforcement in Addis Ababa city within not more than three months using radar gun instrument, 866 drivers' have no recorded age and 75 drivers' age is less than 18 years which is not legally allowed to drive in Ethiopia. When the drivers involved in speeding compared by their age category, those drivers' with an age less than 25 years old are lesser participated age group since acquiring driving license considers at a minimum of 18 years old. According to this study, the highest percentage of speed violation were occurred by age group of drivers' less than 40, which has shared more than 60% of speeders recorded in the city. More than 57% is shared by drivers who have an age between 25 to 40 years from the total of recorded speed violator driver in the city, which is consistent with different studies in different countries like (Fildes 1991) and (Glendon 2007). The different reason raised in previous research for younger drivers more likely engagement in excessive speeding than others age group includes to underestimate the potential of risk,

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

overestimation of their own driving skills and peer influence (Møller and Haustein 2014) and social pressure (driving slowly and carefully while with parents, but riskier when with friends) (Forward 2008). In a similar study by (Judy J. Fleiter 2010) younger and male drivers were most frequently engaged in excessive speeding. Generally, the number of drivers participated in excessive speeding has decreased as the age of the driver becomes old as shown in figure 4-32.

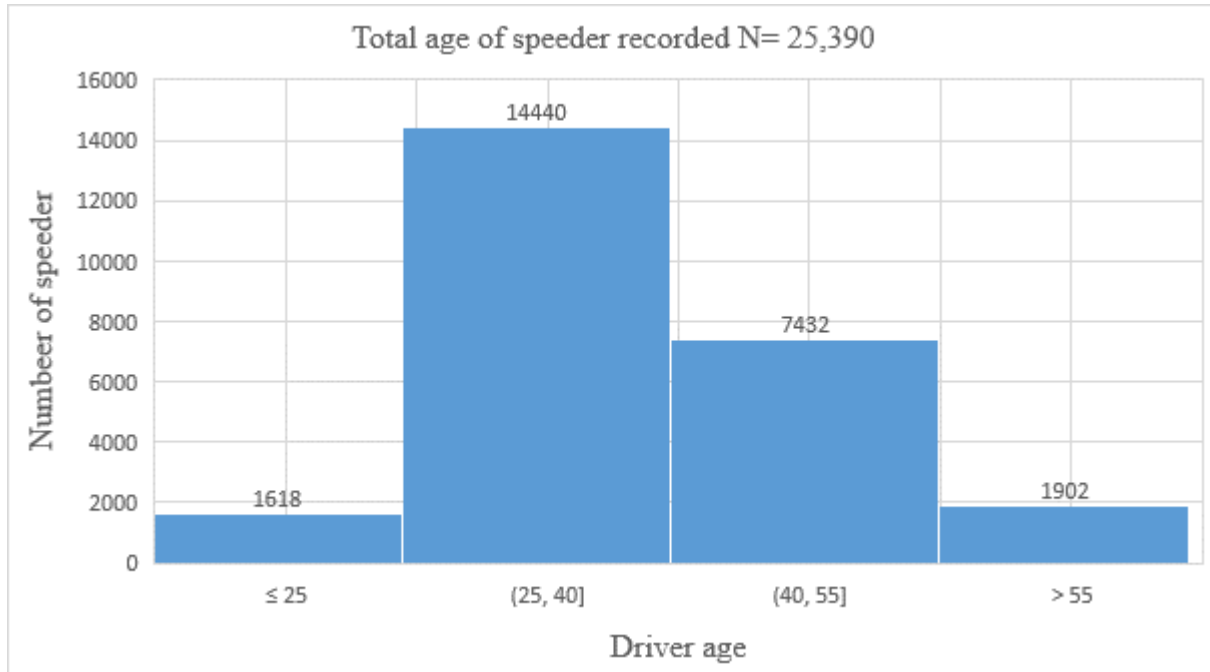


Figure 4-32 Distribution of driver age involved in posted speed limit violation

4.3.2. Distribution of driver involved in exceeding the speed limit by experience

The driving experience is another driver's behavior assessed in this study as a factor influencing the speeding. To check whether there is a significant difference among the driving experience or not on speeding, the Chi-square test was conducted to observe the significance of the driving experience of the driver participated in the speeding because each comparable data is categorical type. Before checking its significance through chi-square test using SPSS program, the collected data were categorized into five groups such as drivers under five years' experience, those drivers having between five and ten years driving experience, drivers those driving between fifty to twenty and those drivers driving the vehicle more than twenty years. Accordingly, the chi-square test was conducted using SPSS program at significance level of $\alpha=0.05$, with the degree of freedom four (4), the result of calculated Chi-square value ($\chi^2_{\text{test}}=3,768$) is obtained and the chi-

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

square value at the significance level of $\alpha=0.05$ with a degree of freedom four (4) which is read from the chi-square distribution table is 9.49. Since the value of calculated $\chi^2_{\text{test}}=3,768$ (p-value=0.00) is greater than the critical $\chi^2_{\text{critical}}=9.49$ (p-value=0.05) the null hypothesis there is no significant relationship between speeding and driving experience is rejected. It is evident that speeding is highly related to the driving experience of a driver. According to figure 4-33, those drivers having under five driving experience in the city were much more likely to participate in exceeding the posted speed limit than another drivers' category. In addition, the findings show that in both genders the number of drivers involved in speeding decreases as the driving experience of driver increases in both genders. In similar studies, on the difference of driving experience on traffic rule violations by (Yaoshan Xu 2014) revealed that novice drivers were highly engaged in traffic rule violations regardless of time pressure. Even though it needs further investigation in the city, the main reasons why the drivers to violate the posted speed limit are: hurry, lapse of concentration, because of the speed limits are too low and to pass or overtake a car according to the study by in the similar study by (Francisco .A 2013), and (Diamantopoulou K. 2003).

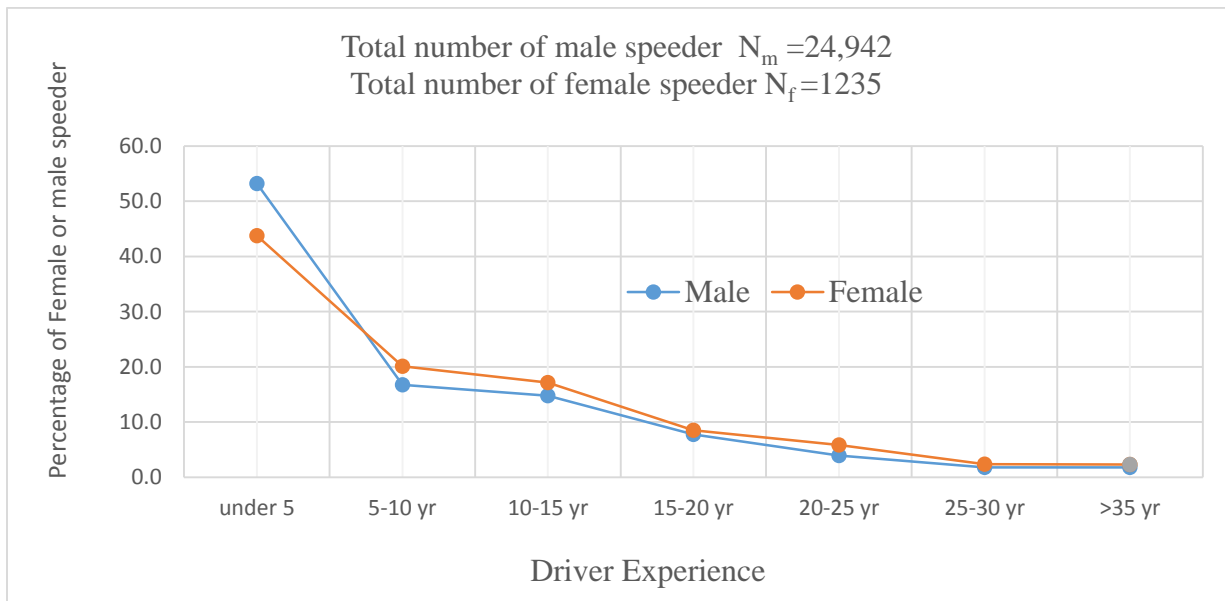


Figure 4-33 Distribution of female and male speeder by experience group

4.3.3. Distribution of driver involved in exceeding the speed limit by gender

Another factor that distinguishes speeders' is the gender of the driver. An analysis comparing gender at the significance level of $\alpha=0.05$ with the degree of freedom 1, the chi-square value $\chi^2_{critical}$ which is obtained from the chi-square distribution table is 3.84 and the calculated chi-square value (χ^2_{test}) which is obtained with the help of SPSS program is 21,470. Since the value of calculated chi-square ($\chi^2_{test}=21,470$) is greater than the chi-square at the significance level of $\alpha=0.05$ ($\chi^2_{critical}=3.84$) the null hypothesis, there is no significant relationship between driver gender and the number of driver engagement in speed violation is rejected. This means that there is a significant relationship between speeding and gender. In this study, among the posted speed limit exceeders, the number of a male was highly involved than female as described in figure 4-35. From 26,256 recorded speed limit violation, almost 95.3% ($n=24,942$) of violation was occurred by a male driver, while only 4.7% ($n=1235$) of speed violation was occurred by female and the rest were unrecorded gender of the driver (0.3%, $n=79$). This means that male drivers are highly associated with speeding than female drivers. In a similar study, by (Sharifah Liew 2017) male drivers have higher scores than female drivers in speeding, red-light running, not wearing seatbelt or helmet, overtaking at double solid line and other traffic rules violations. Further studies, regarding gender difference on the traffic rule violations by (Moller.M 2014) show that peer pressure contributes to increased speeding behavior among male drivers. According to figure 4-34, the age distribution of those drivers participated in excessive speeding by both genders has the same distribution pattern. The majority of speeders' in the city in both genders occurred by drivers between 30 to 40 age group which has shared 41.2% and 39% of females and males respectively. In general, comparing regarding gender and age, the male driver is most frequently involved in speeding with the ratio of 1(one) female to 20 male drivers and among the posted speed limit violator high proportion of speed violation was recorded by young drivers in both genders. This finding indicates that male driver is more experiencing speeding behavior as compared to the female drivers, which is in line with the finding by (Sharifah Liew 2017) and (Carol A. Holland 1996). Further studies regarding gender difference in speeding and other traffic offenses have shown that underestimation of potential of risk, overestimation of driving skill and overconfidence leads male drivers in speeding and other traffic offenses behavior than female drivers (Francisco .A 2013).

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

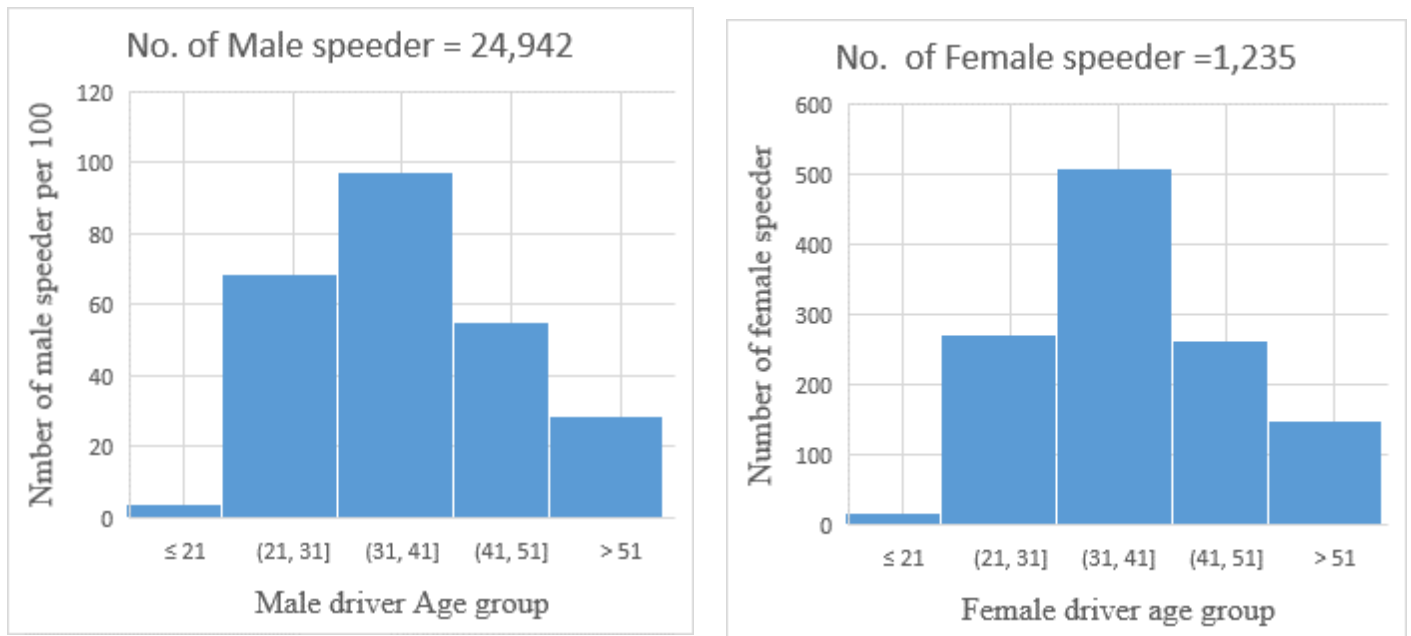


Figure 4-34 Male and Female speeder age distribution

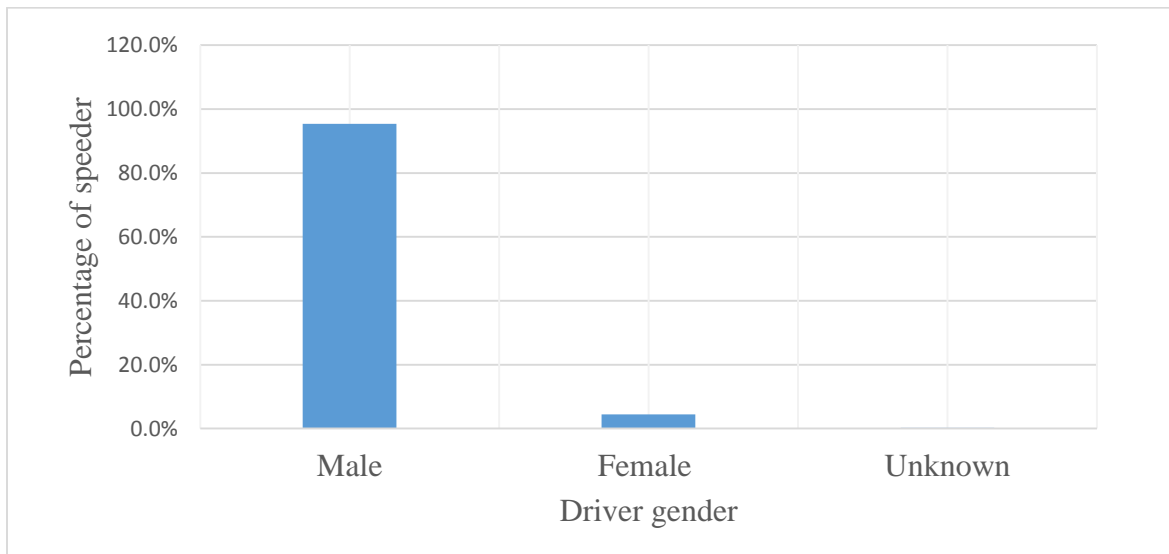


Figure 4-35 The excessive speeding engagement by gender of the driver

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

4.3.4. Distribution of vehicle types involved in speeding in Addis Ababa city

Figure 4-36 shows the distribution of vehicle types involved in the speeding. As an analysis, result confirms that speed violation is caused by Automobile, pickup, min-bus, truck, mid-bus, taxi, bus, 3WD and 2WD with a percentage of 53.23%, 16.29%, 10.43%, 8.20%, 4.26%, 3.21%, 2.16%, 2.01%, and 0.21% respectively. The first four vehicle types highly involved in excessive speeding are the automobile, pickup, mini-bus, and truck, which covers more than 75% of speed violations, occurred in the city. This finding has an agreement or consistent with the studies by (Adrian B. Ellison 2010) that has revealed Automobile (Car) as one of the most frequent vehicle categories in speeding.

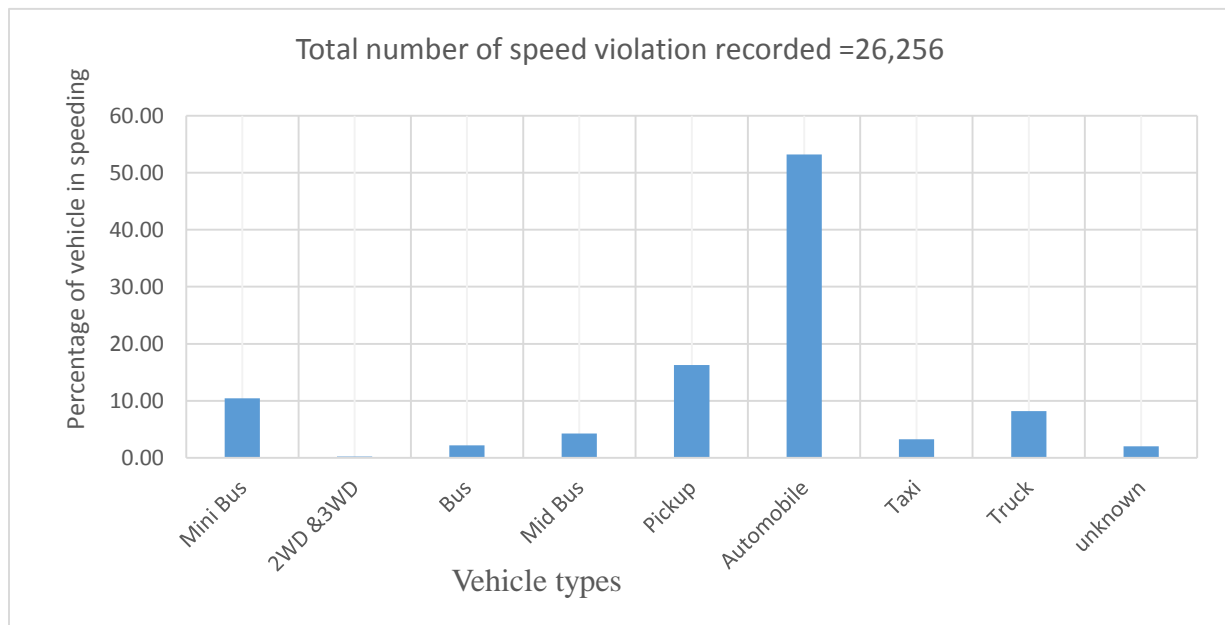


Figure 4-36 Distribution of vehicles types engaged in excessive speeding

Table 4-2 Summary of chi-square test value under excessive speeding.

Variable	Significance level	($\chi^2_{critical}$)	(χ^2_{test})	p-value	DF	Ho (reject or fail to reject)
Age of driver	0.05	18.31	15,492	0.00	3	Reject
Driver experience	0.05	9.49	3,768	0.00	4	Reject
Gender of driver	0.05	3.84	21,470	0.00	1	Reject
Vehicle type	0.05	14.07	4518	0.00	7	Reject

When the null hypothesis is rejected, the null hypothesis is rejected.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

s, (there is no statically significant variation between variable and frequency of speeding).

4.3.5. The extent of Speeding of drivers' relative to the posted speed limit

Speed is one of the major risk factors for road traffic crashes and resulting in fatality and injuries on the body of people and damage on the property. The study on the effect of speed has shown that a 1% change in vehicle speed approximately resulting a 2% change in injury crashes and a 4% change in fatal frequency (OECD 2018). This means that as the extent of speed above the posted speed limit increases a crash risk also increases. The extent of speeding means that the difference between the actual speed of operating vehicles and the posted speed limit. The positive deviation of vehicle speed from the posted speed limit represents the extent of a driver exceeding the speed limit while operating on the road network. The distribution of positive deviation of the speed of the vehicle from the posted speed limit on the Addis Ababa city road network is shown in figure 4-37, 4-38 and 4-39. Those figures illustrate the extent of the positive speed deviation of speeders' distribution above the posted speed limit in the city during an off-peak hour. Those speeders exceeding the posted speed limit on average by 16kmphr with the standard deviation of 9kmphr with outlier data (i.e. drivers driving within the interval of the posted speed limit + 16kmphr \pm 9kmphr) during an off-peak hour in the city. Among the speeders, 31% of them were exceeding the posted speed limit by less than 10kmphr and 69% of the drivers were exceeding the posted speed limit by more than 10kmphr.

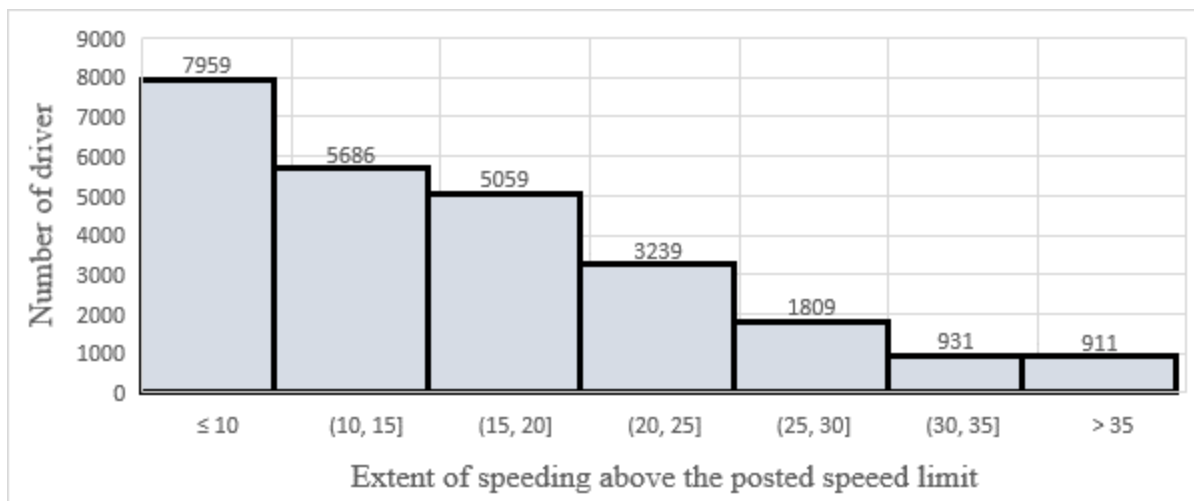


Figure 4-37 The extent of speeding distribution above the speed limit

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

4.3.6. The extent of Speeding of drivers per day of the week

Table 4.3 below demonstrates that the extent of the speed of driver exceeding a posted speed limit versus a day of the week and posted speed limit on the street of the city. According to this study, which was based on the speed violation recorded by police commission there is no significant extent of speeding of driver above the posted speed limit between weekend and weekday.

Table 4-3 Positive mean speed deviation analysis by day of the week

Posted speed limit of the city.	Mean of the extent of speeding above the posted speed limit (Kmph)	
	Weekday	Weekend
30kmphr.	22	20
40kmphr.	18	18
50kmphr.	15	17
80kmphr.	7	7

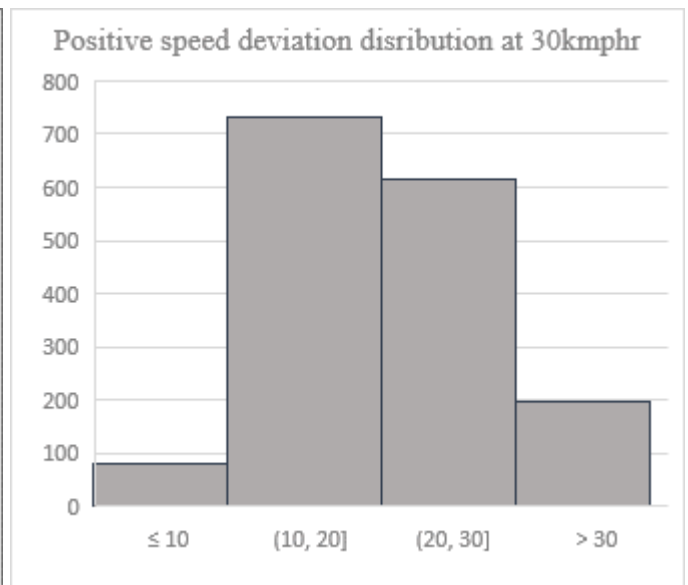
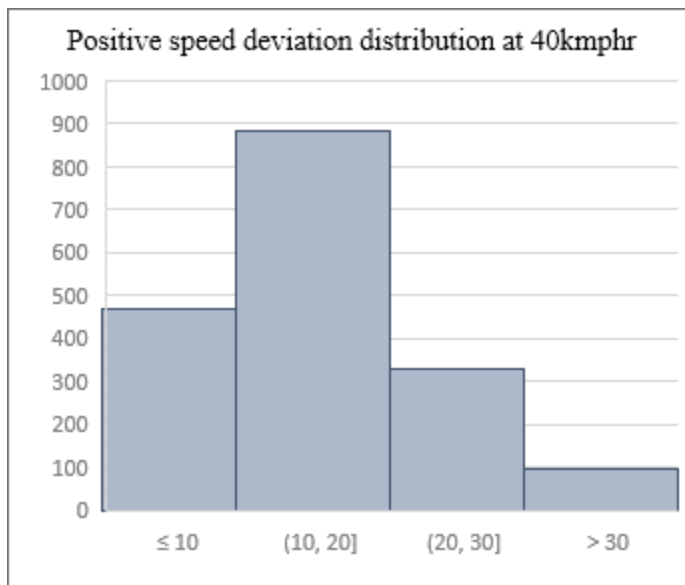


Figure 4-38 The extent of driver speed above 30kmphr and 40kmphr posted speed

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

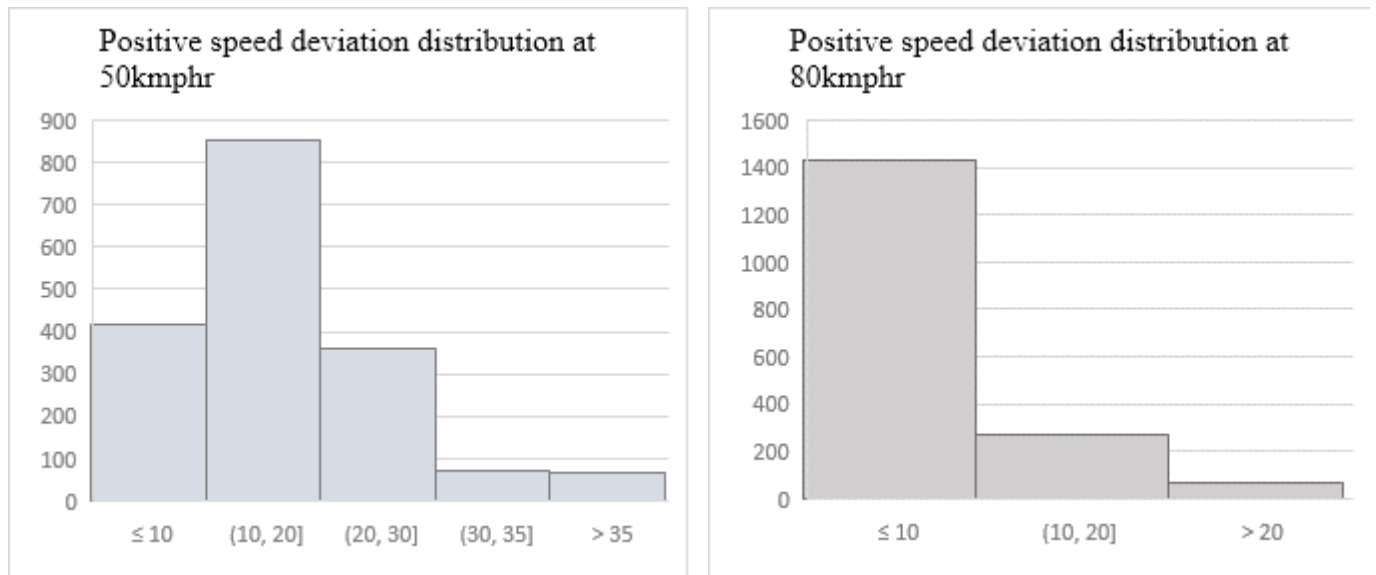


Figure 4-39 The extent of driver speed above 50kmphr and 80kmphr posted speed.

Figure 4-40 below shows that the mean positive deviation from the posted speed limit versus the age of the driver. The trend is almost similar there is no significant variation of positive mean speed deviation from the posted speed limit throughout the age group of the driver. All of the drivers' age groups categorized below engaged in speeding were driving with a positive mean speed deviation of 15kmphr and 16kmphr from the posted speed limit.

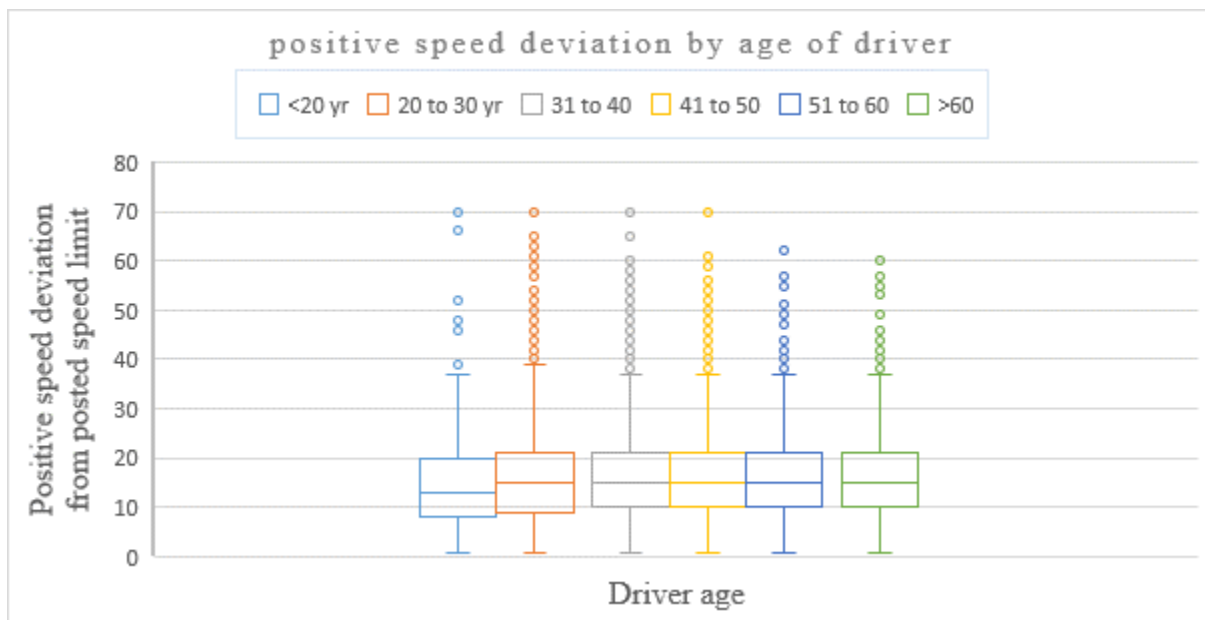


Figure 4-40 The extent of speeding by the age of the driver

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

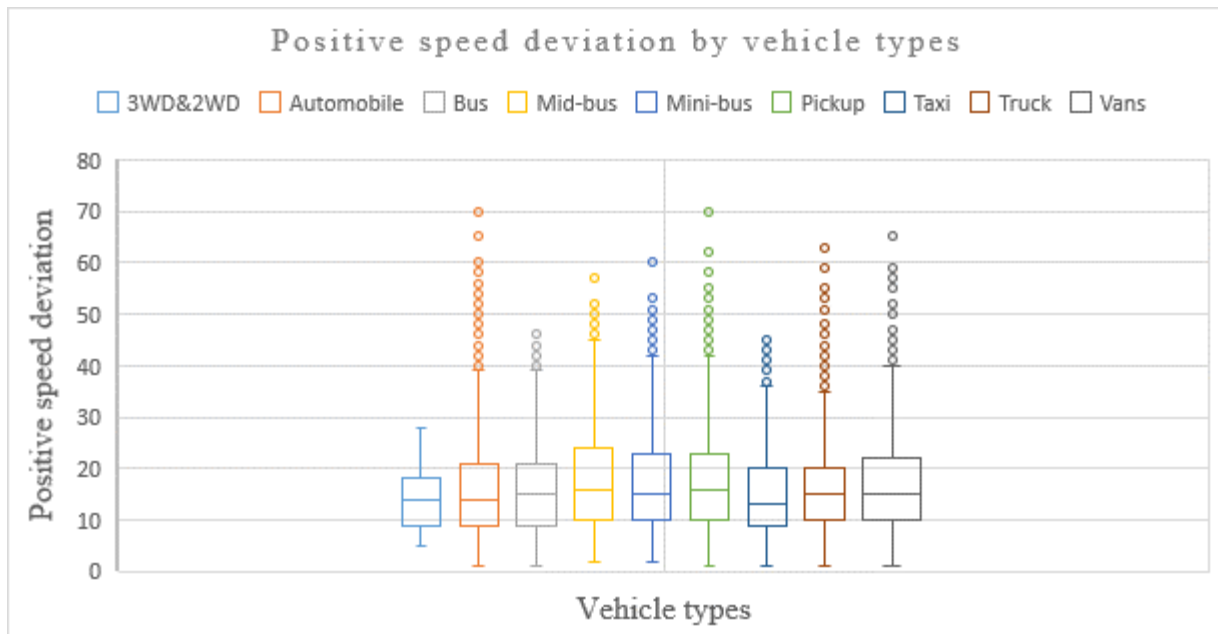


Figure 4-41 The extent of speeding by vehicle types

Figure 4-41 above shows that the extent of speeding above the posted speed limit in the Addis Ababa city versus vehicle types involved in speeding based on the data gathered by the traffic police commission of the city. According to this figure, there is no significant variation of positive mean speed deviation from the posted speed limit between vehicle types charged by traffic police because of speeding.

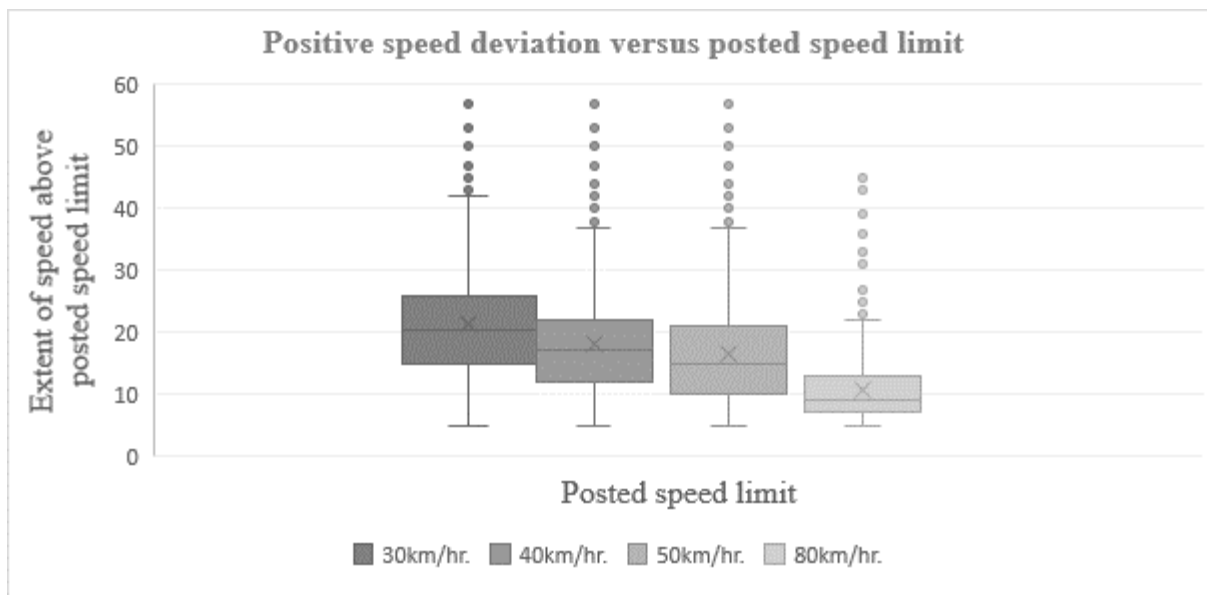


Figure 4-42 The extent of speeding by the posted speed limit of the city

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Figure 4-42 above shows that the extent of speeding versus posted speed limit. According to this analysis, the mean of positive speed deviation of a driver at 30kmphr, 40kmphr, 50kmphr, and 80kmphr posted speed limit in the city is 21kmphr, 17kmphr, 14kmphr and 10kmphr with the standard deviation of 8kmphr, 8kmphr, 8kmphr, and 6kmphr respectively. In addition, this analysis also proves that the extent of speeding of driver decreases as the posted speed limit increases in line with the study by (Judy J. Fleiter 2010). Even though, the reason why the extent of speeding above the posted speed limit increases as the posted speed limit decreases needs further investigation, it can be concluded, that the posted limit of 30kmph and 40kmph in the city is inappropriate speed and it should be revised based on the function of the road and traffic crash historical data.

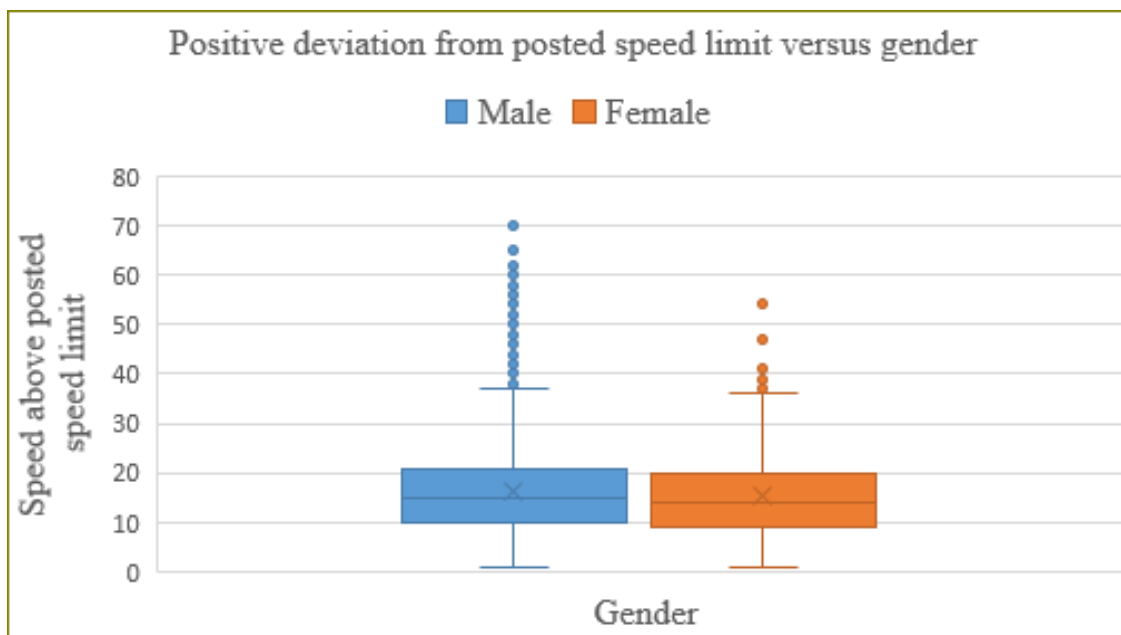


Figure 4-43 The extent of speeding by gender of the driver

Figure 4-43 above shows that the extent of speeding by the gender of the driver. Another relationship of speeding is that of driver gender (the extent of positive speed deviation from posted speed limit in terms of gender). The male driver is highly involved in speeding than females. However, based on the data gathered for this study, there is no significant difference in the extent of speeding above the posted speed limit by gender. Male drivers are driving on

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

average 16kmph above the posted speed limit and females are driving with an average speed of 15kmph above-posted limit.

4.4. Excessive speeding and hotspot locations in the city

Investigation of the hotspot location of road traffic crash has done based on the historically recorded data of traffic crash in the city using ArcGIS software. Speed enforcement by traffic police with the help of radar instruments ongoing in the city where high frequency of a road traffic crash has suspected. Some of hotspot location of traffic crash identified under this study and location of speed enforcement ongoing in the city by the traffic police to reduce the suspected speed-related traffic crashes detect the same location.

Among them:

- ❖ Bole Michael to Bole bridge, Torhailoch to Holland Embassy to Asrasimint and, Zenebework to Ayertena along the ring road is the place where hotspot location of fatal crash and injury crash identified and also the speed enforcement is on ongoing in the city by traffic police. At those locations, the posted speed limit of the road is 80kmph and the drivers also violating this posted speed by more than 10kmpr.
- ❖ Makanissa, Bisrat Gabriel to Abo Junction, Pastor Intersection to Enkual Fabrica, Sheger FM radio and Sheger Menefasha identified as a hotspot location of injury traffic crash in this study by ArcGIS software and those place where speed enforcement done by traffic police suspected as hotspot in the city at the posted speed limit of 30kmph and 40kmph. At those locations, the drivers were driving with the more than 20kmph above the posted speed.
- ❖ Haile garment to Gelan Condominium, Bole to Rwanda, Meskel Square to Shoa Dabo and Karl intersection to Lideta junction are some of the common locations of hotspot locations identified under this study and the locations where speed enforcement done by traffic police at the 50kmph posted speed limit. The drivers were violating the posted speed limit by more than 15kmph at those locations.

The result from this study shows that there is the link between the excessive speeding and traffic crashes in the city. According to the result of this study drivers has violating the posted speed limit with more than 10kmph at the hotspot locations identified in the city and the drivers violate the posted speed limit with the high extent at the lowest posted limit in the city. In general, the

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

posted speed limit in the city is inappropriate and it should have to be re-evaluated in order to create the safe road based on the operating speed of the vehicle, geometric design of the road and history of traffic crashes.

Chapter-Five

5. Conclusion and Recommendation

5.1. Conclusion

The conclusions of results under this study suggest the following;

1. The study shows that there is a significant variation between female and male driver, among the age group and driving experience of driver and vehicle types involved in the traffic speed violation in the city. Comparing gender, the male driver is more frequently involved in excessive speeding than females.
2. The finding from this study also revealed that youth drivers (drivers under 40 years old) are highly engaged in excessive speeding than older drivers in the city. Novice drivers (less than 5years driving experience) most likely participated in the violation of posted speed limits in the city and as the driving experience increases the engagement of drivers in the excessive speeding decreases.
3. In another finding under this study, the first four vehicle categories more likely engaged in excessive speeding are an automobile, pickup, mini-bus, and truck.
4. Further finding in this study on speeding in the city, also revealed that among the speeders, 69% of them were driving more than 10kmph above the posted speed limit and on average the drivers violating the posted speed limit by 16kmph. The extent of speeding above the posted speed limit decreases as the posted speed limit increases.
5. The most risk factors of a traffic crash in Addis Ababa city were driving following too closely, failure to give-way for another vehicle, improper overtaking, and failure to give way for pedestrians and over speeding. Most of the fatal traffic crashes in the city about 62% of them occurred due to failure to give way for pedestrians, driving following too closely (8%) and over speeding (5%). This study also revealed that those vehicles types like an automobile, pickup, and minibus highly engaged in traffic crashes also highly engaged in posted speed limit violations in the city.
6. The highest percentage of fatal crashes (34%) was occurred during the night time block (18:00-24:00) and particularly based the single hour contribution (19:00-20:00) time has shared 10% of fatal crashes in the city.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

The second objective of this study is the investigation of the hotspot location of traffic crashes using ArcGIS software on the map of Addis Ababa city.

- ✚ The hotspot locations of fatal crash spotted by both kernel density estimation and Getis-Ord G_i^* methods are; Megenagna intersection, Sebategna, Asira Simint to Atena Tera along the ring road, Adey Ababa, Autobus station to Pastor intersection to Medihanialem church and Repi soap and detergent factory along Jimma road in the city. The hotspot locations of traffic fatal crashes somehow vary for each year during 2007-2009 E.C. Majority of fatal crashes in the city occurred around the intersection, on the principal arterial and the ring road of the city.
- ✚ The hot spot location of injury traffic crashes in the city by both Kernel Density Estimation (KDE) and Getis-Ord G_i^* methods are the following: Tegbared to Mexico to Legahar to Stadium to Hayahulet to Meganegna intersection along the LRT route, Bus Station to Gojjam Berenda to Atekilt Tera to Giorgis to Minilik square, Wollo Sefer to Rwanda to Bole bridge and Bole bridge to Megenegna Intersection along ring road.
- ✚ Another finding in this study is an assessment of the hotspot location of non-injury traffic crashes in Addis Ababa city. The finding obtained with the help of ArcGIS software through Kernel Density Estimation shows that Mesalemia to Bus station to Gojjam Berenda to Anwar Mosque to Teklehaymanot and pastor intersection to Enkulal Factory to Giorgis, Ayertena intersection to Michael Adebabai to German Adebabai to Haile Garment to OWWC at Kality along ring road, Adey Abeba to Gotera to Lancha along LRT route and Mekenissa Abo junction to German Adebabai to Sarbet as critical route on which the non-injury traffic crashes occurs in the city.

In general, to some extent there is a variation of traffic crash location in city from year to year may be due to the road safety measurement.

5.2. Recommendation

Based on the funding of the study and conclusion, the following recommendation was listed for the concerned body.

- As the study findings confirm, most of the fatal traffic crashes in the city occurred on the major road and ring road of the city that may be due to speeding. Thus, road safety education, campaign, and training should be provided in the schools, through SMS (short message service) and even using Mass media in the city for the society as a short-term solution.
- The study also revealed that most of the fatal crashes happened in the city during the nighttime block (6:00 pm to 8:00 pm). Therefore properly providing light pole, speed breaker and road marking and sign at the hotspot location may reduce fatality.
- For the identified hotspot (black spot) locations of road traffic crashes in the city, further investigation should be done to identify major risk factors for the most frequent occurrence of road traffic crashes in order to set remedial solutions for long-term solutions.
- In the case of identifications of the cause of road traffic crashes in Addis Ababa city, investigated by police commission is after a traffic crash occurred which could not give a real cause of road traffic crashes. Therefore, to reduce this problem installation of the camera at least for the identified blackspot or hotspot locations may really address the causes of traffic crashes for remedial solutions.
- Young and less experienced drivers occurred most frequently engaged in excessive speeding in the city. Among the speeders (N=25,594), 69% were driving with more than 10kmphr above the posted speed limit on the road. Therefore, the consequence of excessive speeding should be included in the curricula of school for drivers and giving training on the excessive speeding and campaigning through FM radio, TV and sending a message on the mobile of drivers frequently is recommended to create awareness about the speed in the driver. Another way of a remedial solution on speeding is speed enforcement through traffic police and hidden camera by charging drivers. The third approach of speed management is engineering measurement. To summarize, the following measurement was recommended as an engineering measurement to minimize speeding-related road traffic crashes:

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- ✚ At specific locations especially at the intersection, pedestrian crossing, near schools, and residential areas low speed are crucial. At these locations, providing physical speed-reducing measures like a speed bump, road narrowing, rumble strips and roundabouts can assist to ensure safe speed.
 - ✚ Since the posted speed in the city is not safe to speed. Setting appropriate speed limits by considering its influence on road traffic safety, mobility, and environment and then giving informing for a driver about the speed limit through consistent road marking and roadside signing is another measurement.
 - ✚ A consequence of speeding campaigns through FM radio, TV and social media including private media to create awareness in the society especially in drivers.
- According to this study, there is no tolerance speed and rank of charging of driver based on the extent of the speed of driver above the speed limit in the city, which means that those drivers violate the posted speed limit by 1kmphr and above 10kmphr charged by traffic police of the city equally. Thus, the concerned body should have to put the tolerance speed of driving above posted speed limit not to be charged and rank of the penalty based on the extent of speeding above the posted speed limit to reduce congestion at the office and to save time spent by a driver to pay penalty cost.
 - The speed violation gathered by traffic police commission of the city includes only driver behavior (age, sex, and driving experience), location of speed enforcement, posted speed limit and vehicle type's information. That gathered information is not enough for speeding analysis. The concerned body should have to include the following information, while speed enforcement:
 - I. Driver characteristics (education level, marital status, ownership of vehicle experience of a traffic crash, trip purpose and income of driver).
 - II. Road information (types of road, number of the lane, lane width, median type and availability and number of access on the road).
 - III. Vehicle information (age of vehicle and traveling kilometer per day or year).

Recommendation regarding the software under the investigation of hotspot location investigation.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

The hotspot location investigation of traffic crashes in Addis Ababa city under this study has done based on two approaches (Kernel Density Estimation and Getis-Ord G_i^*) in the ArcGIS software. The main advantage of Kernel Density Estimation (KDE) method lies in determining the spread of risk of a traffic crash and shows the probability of the buffer around it, which will ultimately possess a degree of risk of traffic crashes for the people who enter it.

Kernel Density Estimation (KDE) approach has some of drawbacks to determine the hotspot locations.

1. There is no clear and fast methods to determine the searching radius for hotspot investigation.
2. It lacks an investigation of the statistical significance of the high-density (hotspot) and low-density (cold spot) locations and the hotspot location covers the whole surface of the studied area (not concentrated on the road alignment).

Getis-Ord G_i^* hotspot analysis has the following advantage:

1. It gives the statistical significance of the high-density and low-density of traffic crashes and concentrates on the road alignment, which means that it does not covers the whole surface of the study.

Finally the researcher recommends the Getis-Ord G_i^* approach for the hotspot location investigation of traffic crash.

5.3. Limitations of this study.

There are some limitations to this study. Firstly, the excessive speeding data used for this study is typically for administrative purposes rather than for research purposes. Therefore, the only available excessive speeding data for three months used. This means that there is no recorded speed of the whole vehicle crossing while investigation. In addition, the needed variables like drivers' education level, employment status, age of the vehicle, road type, experience of a driver with traffic crash, the income of driver etc. were not available. In case of investigation of hotspot location, the latest two years data is not available only three years of traffic crash data from 2007-2009 E.C was used. The following are the limitation of the study under hotspot location investigation in the city.

- a. Investigation of the hotspot location of a road traffic crash in the city was done per severity of traffic crash types due to the unavailability of the severity index of a traffic crash in Ethiopia. Due to the unavailability of the severity index value of traffic crashes in the city, the hotspot location of the whole traffic crashes regardless of its severity was not studied under this study to prioritize the most urgent location.
- b. Lack of consideration of traffic and pedestrian volume due the difficulty of traffic and pedestrian volume count.
- c. Due to the lack of recorded data of on the road and intersection types' while they have collected the easting and northing of traffic crash location it was not studied the hotspot location per intersection and road type.

5.4. Proposed future work.

This section provides a set of recommendations on the possible extensions of this research as follows:

- Due to road traffic crash, our country has revealed for costs in terms of death, injuries and property damage. I recommend detail research on the investigation of road traffic crashes cost and severity index of traffic crashes in the city.
- Traffic crashes in the city vary by time of the day and day of the week. I recommend the investigation of hotspot location of traffic crashes in the city using ArcGIS software by considering the influencing factors like time of the day, day of the week, traffic volume posted speed limit, etc.
- Speed is one of the crucial parameters determines the road geometry and road safety problems. I recommend further research on the investigation of operating speed in the city to put speed limit and speed zoning in the city at the different posted speed limits, median types, road types, number of lane and number of the access point on that road segment.

References

- AASHTO. 2004. A Policy on Geometric Design of Highways and Streets. fifth. Washington, D.C: American Association of State Highway and Transportation Officials.
- AASHTO. 2001. A Policy on Geometric Design of Highways and Streets 4th Edition. Washington D.C, USA: American Association of State Highway and Transportation Officials.
- Abegaz T, Gebremedhin S. 2019. "Magnitude of road traffic accident related injuries and fatalities in Ethiopia." PLoS One 14(1). Accessed July 15, 2019. <http://repository.uneca.org/bitstream/handle/10855/5250/bib.%205641>.
- Adonteng, Williams Ackaah & David O. 2011. "Analysis of fatal road traffic crashes in Ghana." International Journal of Injury Control and Safety Promotion Vol. 18, No. 1,: 21-27.
- Adrian B. Ellison, and Stephen Greaves. 2010. "Driver Characteristics and Speeding Behaviour." Institute of Transport & Logistics Studies, University of Sydney.
- Afukaar, James Damsere Derry and Francis K. 2007. "Study of Vehicle Speeds on a Major Highway in Ghana: Implication for monitoring and control." Traffic Injury Prevention 8: 142-146.
- Anderson, Tessa K. 2009. "Kernel density estimation and K-means clustering to profile road accident hotspots." Accident Analysis and Prevention 41: 359-364.
- Ashish Dhamaniya, Satish Chandra. 2013. "Speed Characteristics of Mixed Traffic Flow on Urban Arterials." World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering Vol:7, No:11: 883-888.
- Bailey, T.C., Gatrell, A.C. 1995. "Interactive Spatial Data Analysis." Longman Scientific 313.
- Bekibele, C.O., Fawole, O.I., Bangboye, A.E., Adekunle, L.V., Ajav, R and Baiyeroju, A.M. 2007. "Risk Factors for Road Traffic Accidents among Drivers of Public Institutions in Ibadan, Nigeria." African Journal of Health Sciences 14(3-4): 137-142.
- Bham, Ghulam H. 2011. "Evaluation of Hotspots Identification Using Kernel Density Estimation (K) and Getis-Ord (Gi*) on I-630." Indianapolis, USA: International Conference on Road Safety and Simulation.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- BIGRS. 2017. Annual Road safety Report of Addis Ababa city . Addis Ababa: Bloomberg Philanthropies Initiative fo Global Road Safety .
- Carol A. Holland, and Mark.T Conner. 1996. "Exceeding the speed limit: an evaluation of the effectiveness of a police intervention." *Acciedent analysis andd prevention* 26: 587-597.
- CHAINEDY, Spencer. 2013. "Examining the Influence of Cell Size and Bandwidth Size on Kernel Density Estimation Crime Hotspot Maps for Predicting Spatial Patterns of Crime." *BSGLg*, 60: 7-19.
- Charles Zegeer, Dan Nabors, Dan Gelinne, Nancy Lefler, and Max Bushell. 2010. Pedestrian Safety Strategic Plan: Recommendations for Research and Product Development. Report No.FHWA- 10-035, Washington, DC20590- 9898: Highway Safety Research Center.
- Chien-Yuan Chen, and Qi-Hua Yang. 2018. "Hotspot Analysis of the Spatial and Temporal Distribution of Fires." Taiwan, China: Geographical Information Systems Theory, Applications and Management. 15-21.
- Deller. 2013. "The influence of road design speed, posted speed limits and lane widths on speed selection." Brisbane,Australia: Australasian Transport Research.
- Deogratias, Heng Wei & Eustace. 2010. "The Role of Driver Age and Gender in Motor Vehicle Fatal Crashes." *Journal of Transportation Safety & Security* 2: 28-44.
- Diamantopoulou K., Hoareau, E., Oxley, P. and Cameron, M. 2003. The feasibility of identifying speeding related crashes in police reported mass crass data. Monash University Accident.
- Elizabeth. 2012. Speed Limits a review of evidence. London: The Royal Automobile Club Foundation.
- Elvik, Rune , Peter Christensen, and Astrid Amundsen. 2004. Speed and road accidents: An evaluation of the Power Model. Oslo: The Institute of Transport Economics ,TOI.
- ERA. 2013. Ethiopian Road Aauthority Geometric design Manual. Addis Ababa: Ethiopian Road Aauthority.
- Feng Guo, Sheila G Klauer,Youjia Fang,Jonathan M Hankey, Jonathan F Antin,Miguel A Perez,Suzanne E Lee and Thomas A Dingus. 2017. "The effects of age on crash risk associated with driver distraction." *International Journal of Epidemiology* 46, No.1: 258-265.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- Fildes, B. N., G. Rumbold, and A. Leening. 1991. Speed Behavior and Drivers' Attitude to Speeding. victoria,Australia: Monash University Accident Research Center.
- Fitzpatrick .K, Lily Elefteriadou, Douglas W. Harwood, Jon M. Collins, John McFadden, Ingrid B. Anderson, Raymond A. Krammes, Nelson Irizarry, Kelly D. Parma, Karin M. Bauer, and Karl Passetti. 2000. Speed prediction for two-lane rural highways. Georgetown, USA.: U.S Departement of Transportation , Federal Highway Administration and Research, Development, and Technology.
- Fitzpatrick K, Paul Carlson , Marcus A. Brewer, and Mark D. Woolridge. 2003. Design Speed, Operating Speed and Posted Speed Limit Practice. Wshington, D.C, USA.: Transportation Research Board, 18-25.
- Fitzpatrick. K, Joseph D. Blaschke, C. Brian Shamburger, Raymond A. Krammes, and Daniel B. Fambro. 1995. Compatibility of Design Speed, Operating Speed, and Posted Speed. Austin, Texas.: Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
- Forward, Sonja. 2008. Driving violations. Investigating forms of irrational rationality. Uppsala , Sweden: Digital Comprehensive Summaries of Uppsala Dissertations for the degree of Doctor of philosophy.
- Francisco .A, Cristina .E and Constanza .C. 2013. "Speed and Road Accidents: Behaviors, Motives, and Assessment of the Effectiveness of Penalties for Speeding." American Journal of Applied Psychology 1: 58-64.
- Garber, Nicholas J. 2009. raffic and Highway Engineering, on traffic engineering studies. Fourth Edition. verginia: University of Verginia.
- Gaurav, Varsha .V. 2016. "Determination of Sample Size for Speed Measurement on Urban Arterials." Transportation Research Procedia 384-390.
- Getu.T, Simon Washington, Md. Mazharul Haque & Mark J. King. 2017. "Injury severity of pedestrians involved in road traffic crashes in Addis Ababa, Ethiopia." Journal of Transportation Safety & Security 9: 46-66.
- Glendon, A. Ian. 2007. "Driving violations observed: An Australian study." Ergonomics 50, No.8: 1159-1182.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- Greg, Chen. 2010. "Road traffic safety in African countries – status, trend, contributing factors, countermeasures and challenges." *International Journal of Injury Control and Safety Promotion* 247-255.
- Hany M. Hassan, Mohamed Shawky, Mohammad Kishta, and Atef M. Garib. 2016. "Investigation of drivers' behavior towards speeds using crash data and self-reported questionnaire." *ELSEVIER I*: 348–358.
- Harirforoush, Homayoun. 2017. *An Integrated GIS-Based and Spatiotemporal Analysis of Traffic Accidents: A Case Study in Sherbrooke*. Sherbrooke: Université de Sherbrooke.
- Harrington, D.M., and McBride, R.S. 1970. "Traffic violations by type, age, sex and marital status." California, USA: *Accident Analysis & Prevention*.
- Hui Zhao, Zhiyong Yin, Rong Chen. 2010. "Investigation of 184 passenger car–pedestrian accidents." *International Journal of Crashworthiness* Vol. 15, No. 3 : 313–320.
- Isha . A, Akshay Kumar. 2017. "Time Series Analysis of Accidents in Chandigarh City." *Journal of Environmental Nano Technology* 6: 1-6.
- Jayvant Choudhary, Anurag Ohri, Brind Kumar. 2016. "Spatial and statistical analysis of road accidents hot spots using GIS." India: *Transportation Research Group of India*.
- Jiregna, Hirpa. 2016. "Fatal Injury Crash Data Analysis and Directions to Reverse the Growing Rate of Road Traffic Related Fatality in Addis Ababa." Addis Ababa.
- Judy J. Fleiter. 2010. *Examining psychosocial influences on speeding in Australian and Chinese contexts: A social learning approach*. Queensland University of Technology: A thesis submitted for the degree of doctor of philosophy for Centre for Accident research and road safety Queensland school of psychology and counselling.
- Jun Wang. 2006. *Operating Speed Models for Low Speed Urban Environments Based On In-Vehicle GPS Data*. Georgia: Georgia Institute of Technology.
- Kang, K. 1998. "Ordered Probit Model of the Speed Selection Behavior: Results Based on a Korean Micro Data." *Transportation, Traffic Safety and Health – Human Behavior*. Tokyo, Japan.
- Letty. A, Ingrid van Schagen,. 2005. "Driving speed and the risk of road crashes: A Review." *Accident Analysis and prevention Elsevier Ltd*. 217-224.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- Mansour H. Hosseinlou, Salman Aghidi Kheyraadi, and Abbas Zolfaghari. 2015. "Determining optimal speed limits in traffic networks." *international Association of traffic and safety science* 36: 36-41.
- Mariangela .Z, and Francesco.p,. 2018. "Prediction Models for Space Mean Speed on Urban Roads." *Proceedings of International Conference on Computational Intelligence and Data Engineering*. Italy: Unversity of Cagliari. 12.
- Mavis Agyakwah. 2018. Spatio-temporal patterns of vehicular accidents in Accra (Ghana). A Master dissertation submitted to faculty of Geo-Information Science and Earth Observation of the University of Twente, Enschede, The Netherlands.
- McShane, W. R., E. S. Prassas and R. P. Roess. 1998. *Traffic Engineering (2nd Edition)*. New Jersey: Prentice-Hall, Inc.
- Ministry of Tansport. 2014. "New Zealand,Speed report 2014.(Available in www.transport.govt.nz."
- Mohammed Fayaz, Mrudula S and Sarah Jaison George. 2018. "Black spot identification using accident severity index method." *INTERNATIONAL JOURNAL OF CURRENT ENGINEERING AND SCIENTIFIC RESEARCH (IJCESR) VOLUME-5, (ISSUE-3): 2394-0697*,.
- Møller, Mette, and Sonja Haustein. 2014. "Peer influence on speeding behaviour among male drivers aged 18 and 28." *Accident Analysis & Prevention* 64: 92-99.
- Moller.M, Sonja Haustein. 2014. "Peer influence on speeding behaviour among male drivers." *Accident Analysis and Prevention* 64: 92-99.
- Mountain, Hirst and Maher. 2005. "Are speed enforcement cameras more effective than other speed management measures? The impact of speed management schemes on 30 mph roads." *Accident Analysis and Prevention* 37: 742–754.
- Murat Karacasu, Arzu Er, Safak Bilgiç, Hasan B.Barut. 2011. "Variations in Traffic Accidents on Seasonal, Monthly, Daily and Hourly Basis: Eskisehir Case." *Procedia Social and Behavioral Sciences* 20: 767–775.
- Nilsson, G. 2004. "Traffic safety dimensions and the power model to describe the effect of speed on safety." *Lund Institute of Technology* 221.
- OECD. 2018. *Speed and Crash Risk*. Paris: International Transport Forum.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- OECD. 2006. "Speed Management risk." Brussels, Belgium: European conference of ministers of transport.
- Petridou E., M. Moustaki. 2000. "Human factors in the causation of road traffic crashes." *European Journal of Epidemiology* 16(9), 819–26.
- Polus, A., Livneh, M., and Craus, J. 1984. Effect of Traffic and Geometric Measures on Highway. In *Transportation Research Record No 960*.
- Robert Kahn, P.E. and Allison Kahn Goedecke, MBA. 2011. "Roadway Striping as a Traffic Calming option." *ITE II*: 30-37.
- Rudolphine Nyoni. 2018. A GIS Based Approach to Identify Road Traffic Fatal Accident Hotspots in the Greater Durban City from 2011 - 2015. A Master dissertation submitted to the School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Westville campus.
- Saeed, FH Nofal and AAW. 1997. "Seasonal variation and weather effects on road traffic accidents in Riyadh city." *Department of Community Health Sciences, College of Applied Medical Sciences, King Saud University, Riyadh Saudi Arabia* 111: 51-55.
- Sharifah Liew, RizatiHamidun,Nor FadilahMohd Soid. 2017. "Differences of Driving Experience and Gender on Traffic Offences Among Malaysian Motorists." *MATEC Web of Conferences matecconf/201* . Kajang, Malaysia : MATEC Web of Conferences matecconf/201 .
- Silverman, B. W. 1986. *Density estimation for statistics and data analysis*. 1st. Edited by 1st. New York, USA: Chapman & Hall.
- Simon P. Washington, Matthew G. Karlaftis, and Fred L. Mannering. 2003. *Statistical and econometric methods for transportation data analysis*. first. Washington, D.C. USA: Chapman & hall/CRC Press Company.
- Solomon, D. 1964. "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle." Washington, D. C: Federal Highway Administration.
- Soriguera, J. M. Torné& D. Rosas. 2013. "Assessment of Dynamic Speed Limit Management on Metropolitan Freeways." *Journal of Intelligent Transportation Systems* 17: 78-90.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

- Svenson, O., Eriksson, G., Slovic, P., Mertz, C.K., and Fuglestad, T. 2012. "Effects of main actor, outcome and affect on biased braking speed judgments." *Judgment and Decision Making* 7, 235-243.
- Tariku Hailu, Belay Hagos. 2017. "Road Crashes in Addis Ababa, Ethiopia: Empirical Findings between the Years 2010 and 2014." *An International Multi-Disciplinary Journal, Ethiopia* VOL. 11 (2), S/NO 46: 9-10.
- Tefft, Brian C. 2013. "Impact speed and a pedestrian's risk of severe injury or death." *Accident Analysis and Prevention* 50: 871-878.
- Tessa K. Anderson. 2006. "Comparison of spatial methods for measuring road accident 'hotspots': A case study of London." *Journal of Maps* 55-63.
- Truong, L.T and Somenahalli, S.V.C. 2011. "Using GIS to Identify Pedestrian-Vehicle Crash ." *Journal of Public Transport* 14(1): PP 99-114.
- UNECA, United Nations Economic Commission for Africa. 2009. Case Study : Road safety in Ethiopia. Addis Ababa: United Nations Economic Commission for Africa. Accessed July 15, 2019. <http://repository.uneca.org/bitstream/handle/10855/5250/bib.%205641>.
- Vaa.T, and Phillips.R. 2009. Campaigns and Awareness Raising Strategies in Traffic Safety (CAST). Deliverable 1.3: Results of meta-analysis: effects of road safety campaigns. Brussels.: European Commission, Directorate-General for Transport and Energy.
- Wang, Jun. 2006. "Operating-speed model for low-speed urban tangent streets based on in-vehicle global positioning system data." *Journal of Transportation Research Board*, No 1961 24-35.
- WHO. 2015. Global status report on road safety report in 2015. Geneva: World health organization.
- WHO. 2018. Global status report on road safety report in 2018. Geneva: World health organization.
- WHO. 2013. Global Status Report on Road Safety Reprt in 2013. Geneva: World Health Organization.
- WHO. 2017. World Report on Road Traffic Injury Prevention: Speed Management. Geneva: World Health organization.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

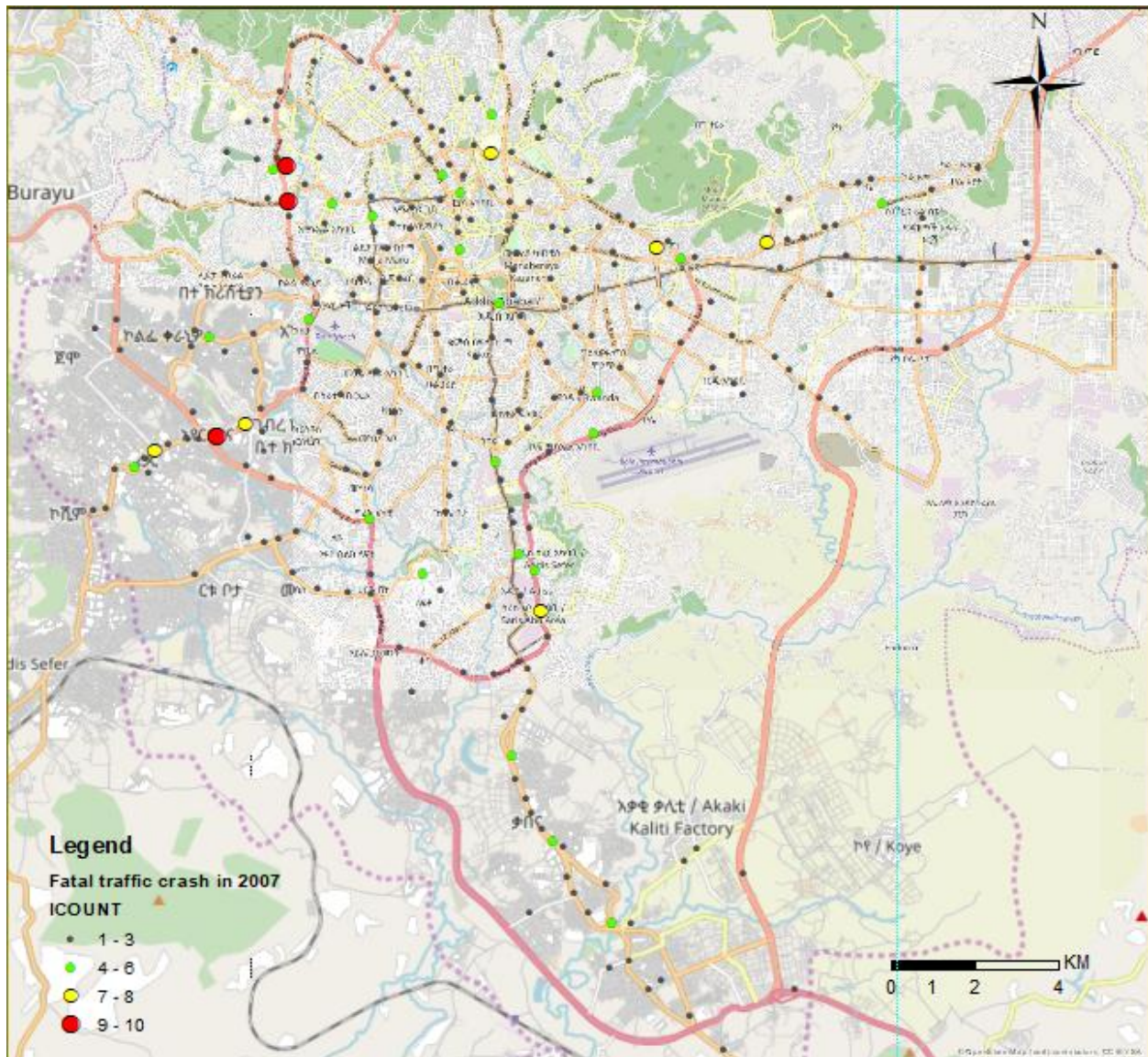
- Williamson D., Sara McLafferty., Phil McGuire, John Mollenkopf, & Victor Goldsmith, V. 1999. "A better method to smooth crime incident data." ESRI ArcUser Magazine January–March. Available online at: <http://www.esri.com/news/arcuser/0199/crimedata.html>.
- Yaoshan Xu, Yongjuan Li, and Li Jiang. 2014. "The effects of situational factors and impulsiveness on drivers' intentions to violate traffic rules: Difference of driving experience." *Accident Analysis and Prevention* 62: 54-62.
- Yazan, Issa. 2016. "Effect of driver's personal characteristics on traffic accidents in Tabuk city in Saudi Arabia." *Journal of Transport Literature* 3: 25-29.
- Zamanov, M. S. 2012. Development of a prediction model for speed limit violations on tangent road sections. Gelderland, Netherlands: Faculty of Civil Engineering & Geosciences, Delft University of Technology.
- Zeyang Cheng, Zhenshan Zu and Jian Lu. 2018. "Traffic Crash Evolution Characteristic Analysis an Spatiotemporal Hotspot Identification of Urban Road Intersections." *Sustainability* (DOI 10.1007/s12517-013-0974-6) 1: 1-17.

Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Appendices

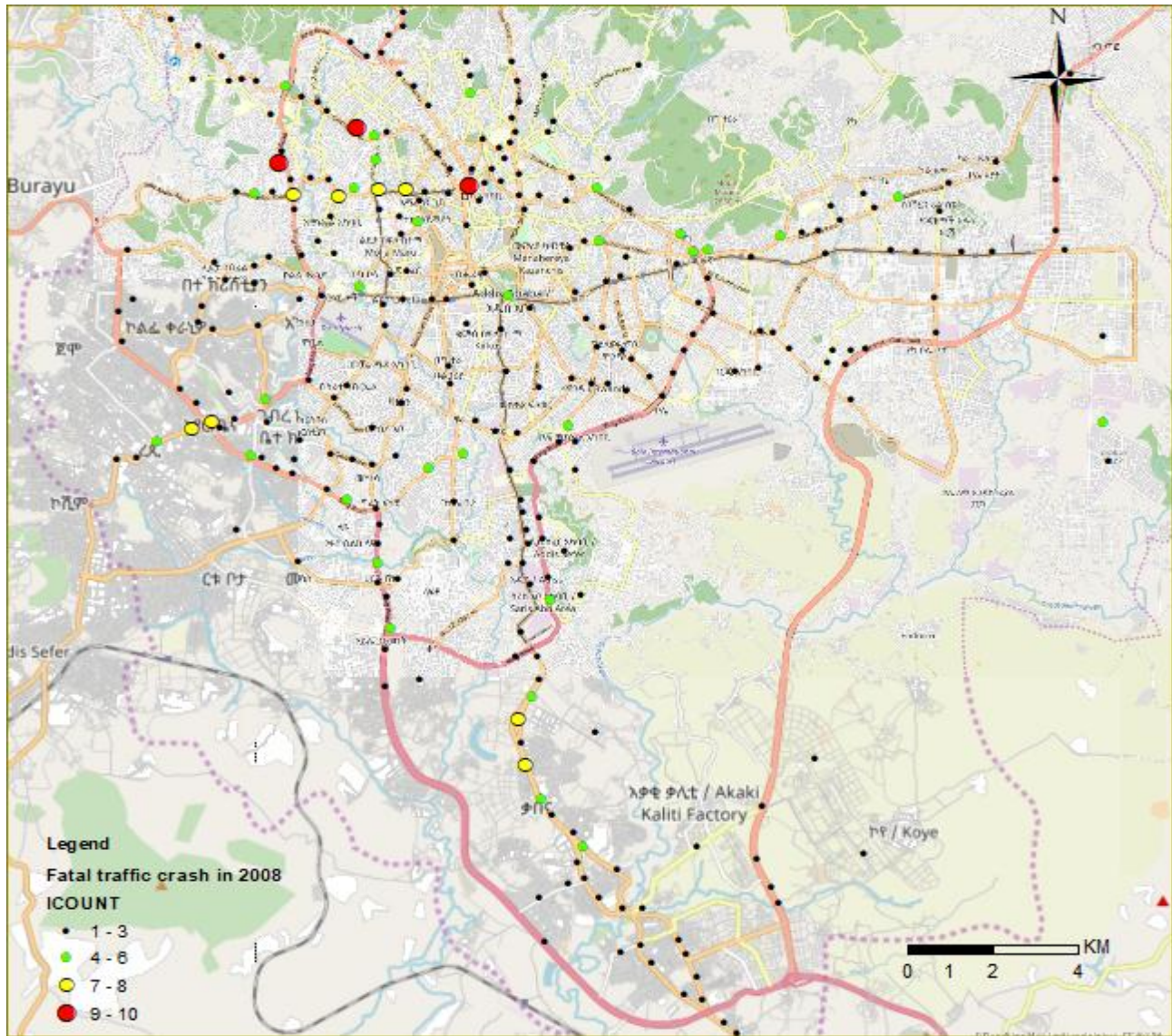
Appendix-A

I count (number) of traffic crash per types of traffic crashes per year within the 100m XY tolerance distance



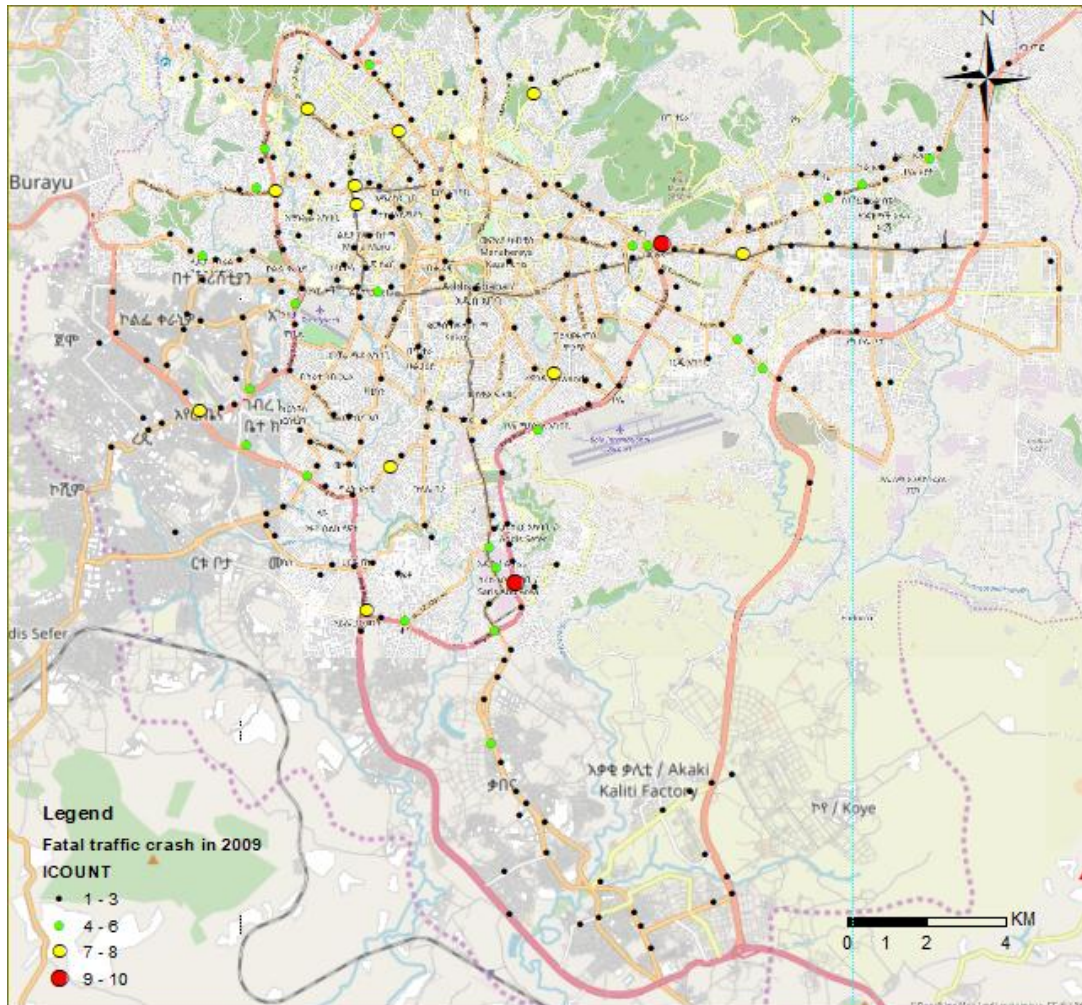
Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Appendix-B



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

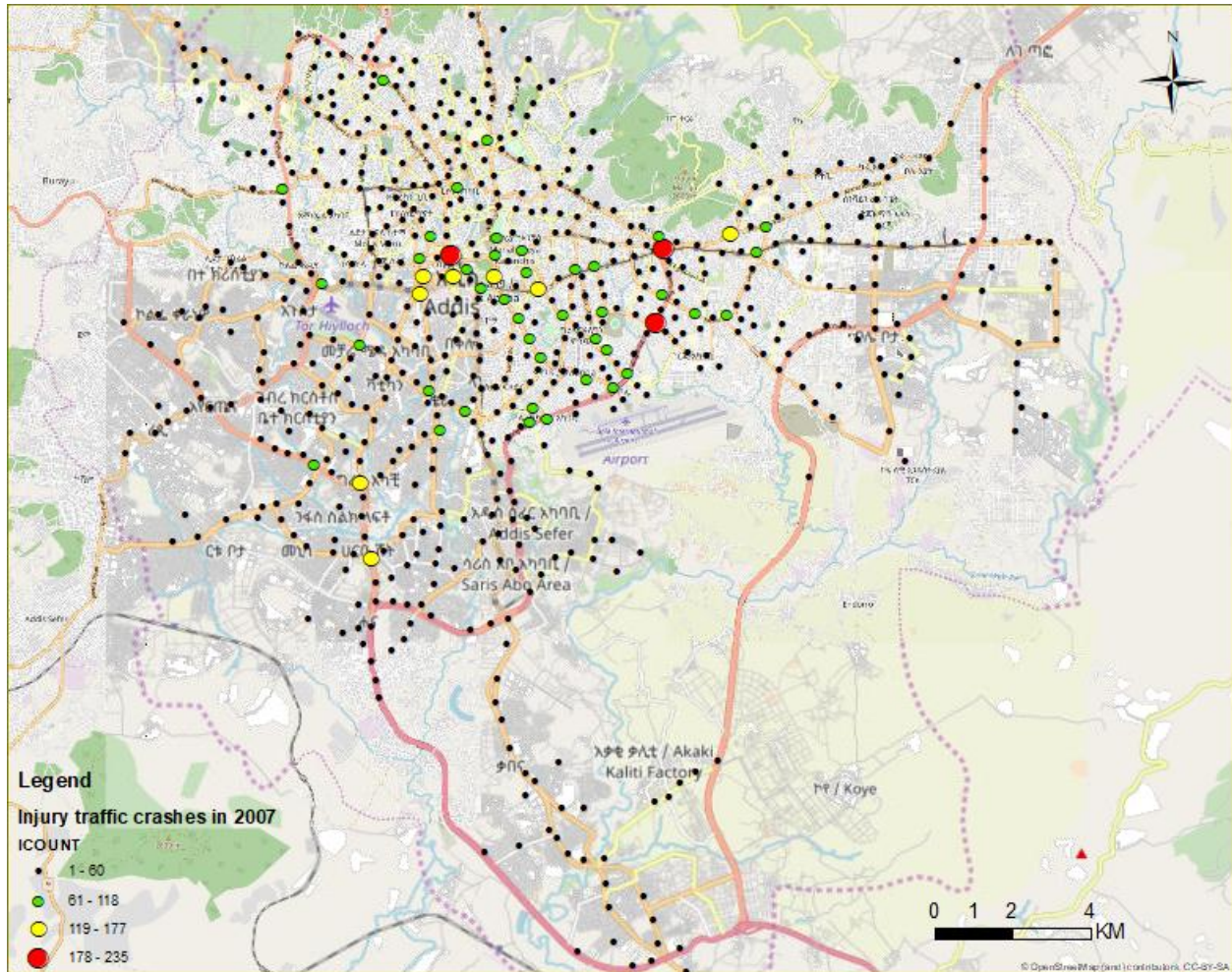
Appendix-C



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

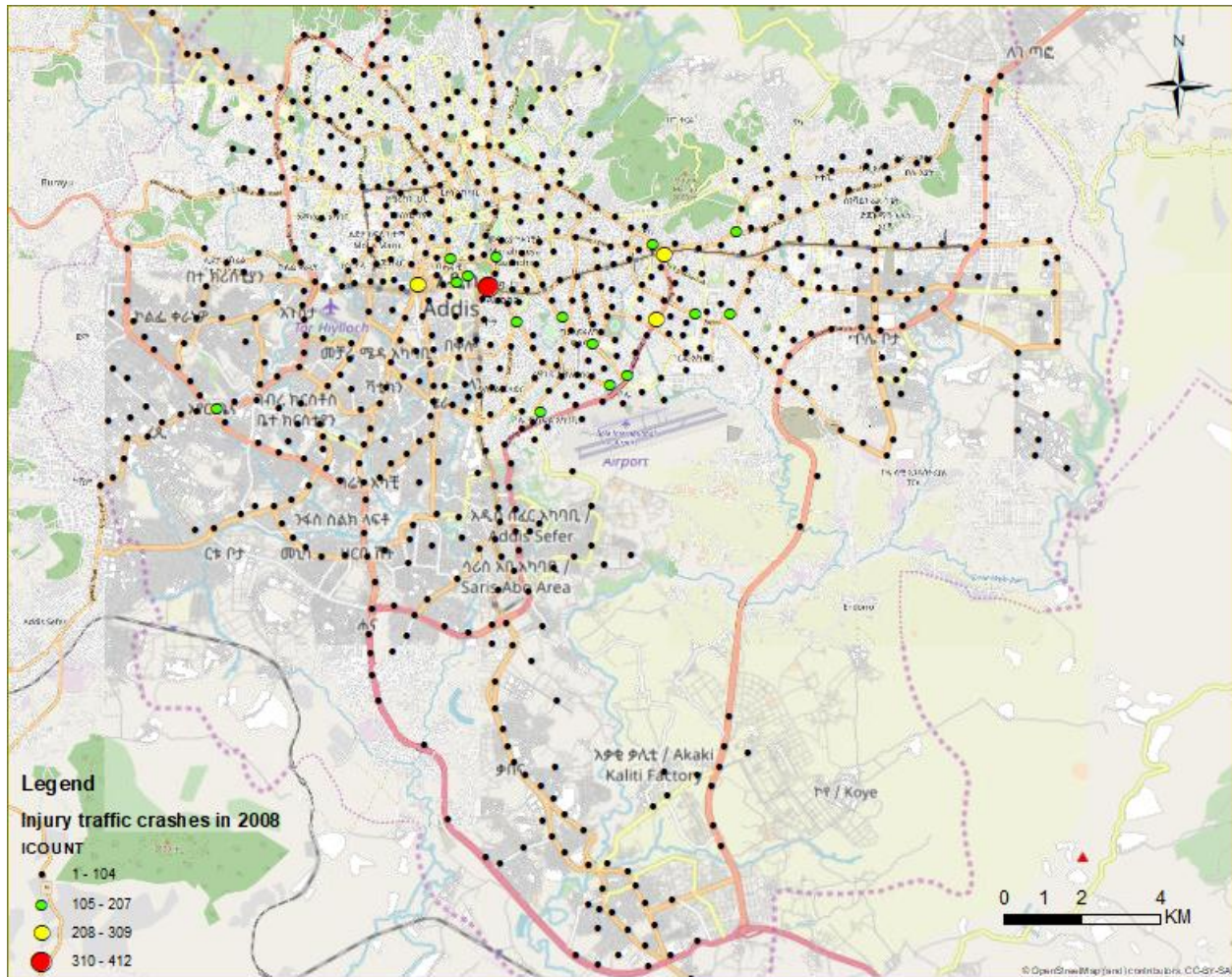
Injury crashes

Appendix-D



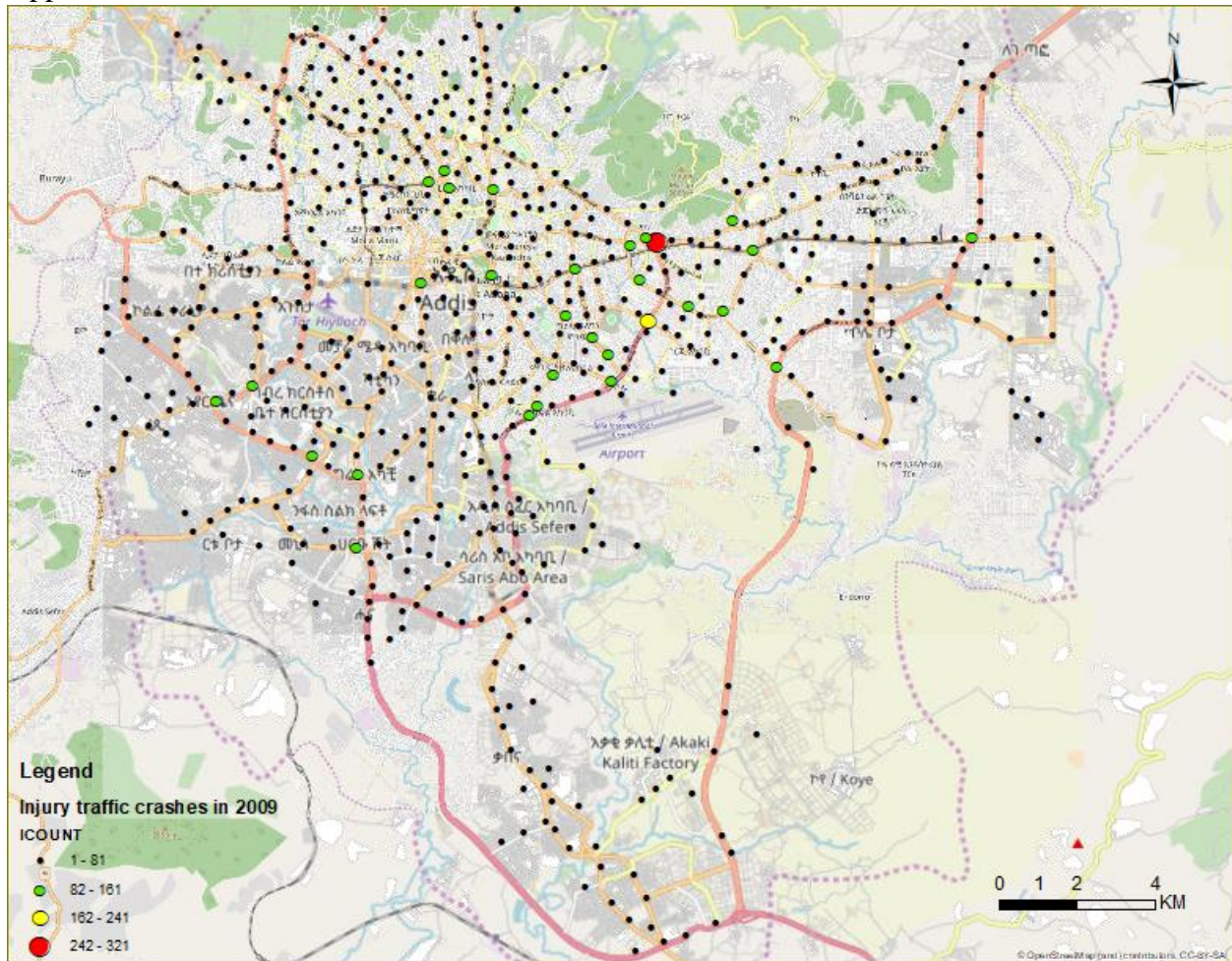
Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Appendix-E



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

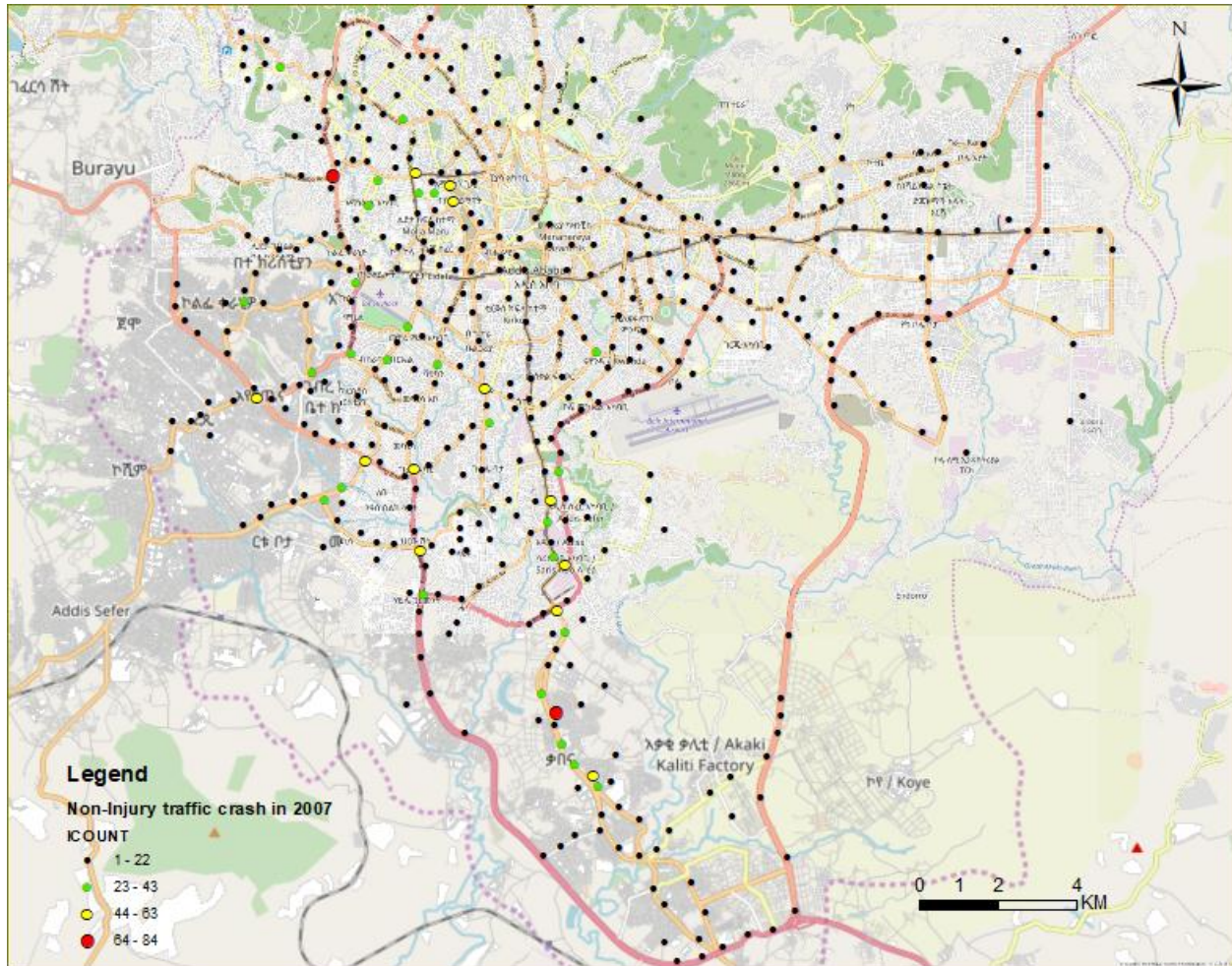
Appendix-F



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

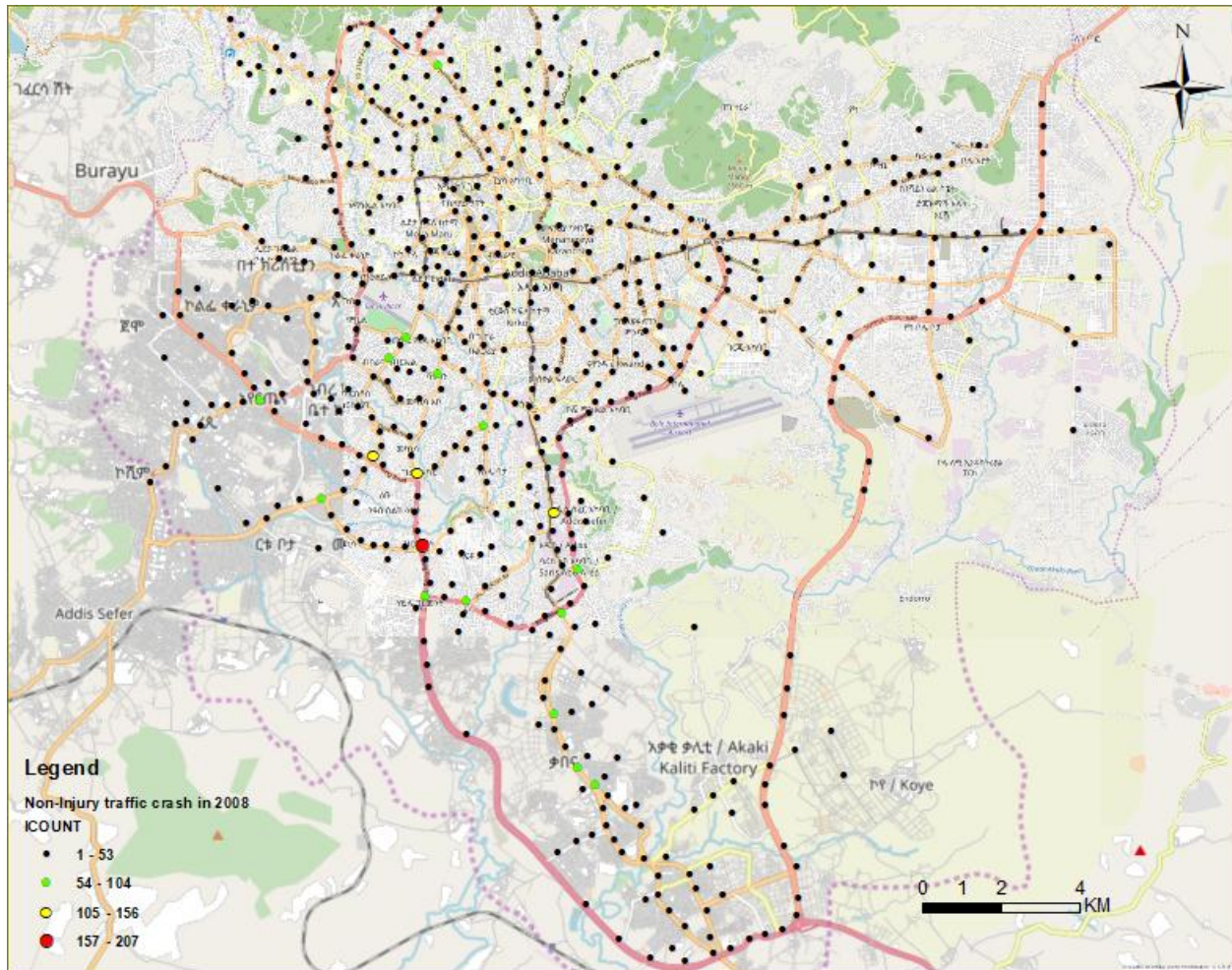
Non-injury traffic crashes

Appendix-G



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Appendix-H



Investigation of Hot Spot Location and Excessive Speeding In Addis Ababa, Ethiopia

Appendix-I

