GIS Based Approach to Identify Road Traffic Accident Hotspots: A case of Debre Markos Town

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A Thesis submitted to the department of Geomatics Engineering

(MSc in Geoinformatics Engineering)

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ADVISOR'S APPROVAL SHEET

To: Geomatics Engineering Department

Subject: thesis submission

This is to certify that the thesis entitled: GIS Based Approach to Identify Road Traffic Accident Hotspots: A case of Debre Markos Town submitted for partial fulfillment of the requirements for the degree of masters in Geoinformatics. The graduate program of the Department of Geometics Engineering and has been carried out by Abebaw Mengist Adane ID NO. PGR/18084/11 under my advising. Therefore, we recommended that the student has fulfilled the requirements and hence hereby she can submit the thesis to the department.

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CANDIDATE’S DECLARATION

I, Abebaw Mengist hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university and all sources of material used for this thesis have been properly acknowledged.

Candidate Name: Abebaw Mengist Adane

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This MSc Thesis has been submitted for examination with our approval as thesis advisor/co-advisor.

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We, the undersigned, members of the Board of Examiners of the final open defense Abebaw Mengist Adane have read and evaluated her thesis entitled: GIS Based Approach to Identify Road Traffic Accident Hotspots: A case of Debre Markos Town and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master of Science in Geoinformatics.

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ABSTRACT

Road safety is a serious problem across the globe and its severity is more prominent in developing countries, especially in Africa. Ethiopia is no exception and road safety is one of the major challenges in the Debre Markos Town in the East Gojjam Zone will have to overcome in order to achieve its vision of being Ethiopia's most livable city by 2025. The prime goal of road safety is to reduce the number and severity of traffic accidents by identifying, implementing and evaluating measures to improve road safety. Road safety improvements are supposed to be applied to accident hotspots where they have the most significant impact, thus, identification of hotspots is an essential step in safety management. This study employed GIS spatial statistics tools to examine and map the trends and spatiotemporal distribution of road traffic accident hotspots in the Debre Markos Town from 2008 E.C.-2012 E.C.. A total of 180 road traffic accidents occurred. It was observed that the highest number of road traffic accidents occurred in 2018/2019 (2011 E.C). The majority (52.4%) of road traffic accidents occurred on weekends. Furthermore, the time period between 18:00-23:59 recorded the highest number of road traffic accidents (33%). Ninety-two and a half percent (92.5%) of road traffic accidents resulted from human error, 67.9% of these resulted from a vehicle-pedestrian collision due to pedestrians entering the roadway when unsafe to do so. Dual carriageways accounted for 30.4% of the total road traffic accidents, followed by freeways (26.7%) and single carriageways (25.8%). Spatial clustering of accidents and spatial densities of road traffic accident hotspots were evaluated using Global Moran's I spatial autocorrelation, Kernel Density Estimation (KDE) and Getis-Ord Gi* statistics respectively. Moran's I show that the occurrence of road traffic accidents was random. Ranking of hotspots using KDE was done with the help of pixel values of the observed locations while ranking of hotspots using Getis-Ord Gi* was done with the help of z-scores associated with statistical significance. Results of hotspot analysis delineated 10 hotspot locations at 90% - 99% confidence levels. Based on the Getis-Ord Gi* hotspot results, the Addis Ababa-Bahir Dar way is of critical concern as it appears consistently throughout the five-year period under study and accounting for 80% (8) of the total recorded road traffic accidents. The results can be effectively utilized by various agencies for adopting better planning and management strategies to reduce and prevent road traffic road traffic accidents in the Debre Markos town.

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LIST OF ACRONYMS

DSPRP	Debre Markos Structural Plan Revision Project
E.C.	Ethiopian Calendar
FRSC	Federal Road Safety Commission
FEMA	Federal Road Maintenance Agency
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
KDE	Kernel Density Estimation
RTA	Road Traffic Accident
STAC	Spatial and Temporal Analysis of Crime
WHO	World Health Organization
VIO	Vehicle Inspection Office

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

In recent years, there is a growing concern in road traffic accidents. These accidents often result in road trafficities, injuries or damages to people. Thus, road traffic accidents are one of the leading causes of human death worldwide (Christian *et al*., 2018). According to World Health Organization (WHO), over 1.2 million people die each year on the world's roads, and between 20 and 50 million people suffer non-road traffic injuries (WHO, 2009). The report also assessed 178 countries and presented that low-income and middle-income countries have higher road traffic road trafficity rates than more developed countries. Over 90% of the world's road trafficities on the roads occur in low-income and middle-income countries, which have only 48% of the world's registered vehicles (WHO, 2009). Urgent action is needed to achieve the ambitious target for road safety reflected in the newly adopted 2030 Agenda for Sustainable Development of reducing by half the global number of deaths and injuries from road traffic crashes by 2020 (Lagarde, 2007).

In Ethiopia, the number of death due to traffic accident is reported to be amongst the highest in the world, and 25.3 people dies per 100,000 populations in Ethiopia (WHO, 2015). It is observed that Debre Markos Town is one of the cities in which most road accident is recorded. An accident hotspot is an engineering term to denote the section of a road network where traffic accidents frequently occur (Gundogdu, 2010).

Hence, there is a need to identify the hot spot areas along the road with high accidents so as to minimize the risks. The identification of safety deficient areas on the highway network is aimed at a comprehensive safety program by traffic officials. One of the most important problems that traffic officials face is where and how to implement precautionary measures and provisions so that they can have the most significant impact for traffic safety (Khan *et al*., 2006). GIS is a very important and comprehensive management tool for traffic safety. Since 1990's, GIS technologies have been used more frequently for such studies due to the availability of low cost GIS with user-friendly interfaces (Khan *et al*., 2006). GIS has the ability to hold a vast amount of data that can be easily stored, shared and managed. It provides a platform for data analysis and visualization to explore relationships between data and it can easily provide graphical or nongraphical outputs. Meanwhile with the rapid development and adoption of GIS technology as a tool to manage, explore, analyze and visualize spatial data, spatial data analysis methods that are included in GIS software's modules, received increasing attention (Booth, 2004). Identification of safety deficient locations with GIS aided spatial analysis will certainly help to decrease the traffic accidents. The GIS technology can change the whole scope of the conventional techniques by visual dimensions to statistical analysis; GIS can be used for further analysis such as density and trend analysis of crashes. Such analysis can directly help planners understand the nature of the problems, facilitate better design and engineering solutions, and GIS can assist in the development of countermeasures in a short time. GIS allows Hotspot map to be electronically generated from a well-designed accident database and can also produce rankings of high accident locations based on either total accident occurring or accident rates. In addition to promoting linkage between various types of data and maps, GIS is able to visually display the results of analyses thus enabling sophisticated analysis and quick decision making. Hence, the main objective of this study is to identify traffic accidents hotspots location in Debre Markos Town based on five years (2014 – 2018) accident data recorded. Such analysis can directly help planners to understand the nature of the problems, facilitate better design and engineering solutions. GIS also allows highway departments to accurately capture and analyze traffic accident information as well as identify dangerous highway segment locations with high accident rates.

1.2. Statement of the Problem

Road Traffic Accidents are having a worsening effect on our society and economy. Among all accidents, road traffic accidents claim the largest toll of human life and tend to be the most serious problem worldwide. Worldwide, the number of people killed in Road Traffic Accidents (RTAs) each year is estimated at almost 1.5 million while the number of people injured could be as high as 50 million. In Ethiopia, the number of death due to traffic accident is reported to be amongst the highest in the word. According to WHO, 25.3 people die per 100,000 population in Ethiopia (WHO, 2015). According to the latest WHO data published in 2017, Road Traffic Accident Deaths in Ethiopia reached 27.140 or 4.27 % of total deaths. The age adjusted death rate is 36.67 per 100,000 of population ranks Ethiopia 22nd in the world. And, according to world Life Expectancy; Road Traffic Accident ranks 6$_{th}$ in leading causes of death in Ethiopia

(World Life Expectancy, 2018). It is observed that, Debre Markos Town is among the town in which high Road Traffic Accident is recorded.

Therefore, there is a need for optimizing RTA resources by identifying areas of priority in Debre Markos town, since the beginning of the decade of action for road safety. This is aimed at providing a better understanding of the patterns and trends of road traffic accidents in the study area. It is also important to determine the magnitude of the hotspots to the basis for improving road safety by allocating resources in high priority areas. In Ethiopia, RTA data is collected through the accident report forms, which are completed by the Traffic Police.

1.3. Objectives

The general objective of the study is to identify the road traffic accident hotspots locations in Debre Markos Town using GIS. The specific objectives are:

- To map the spatial and temporal distribution of road traffic accident
- To develop database using ArcGIS for future analysis.
- To develop map showing the magnitude of accident Hotspots.

1.4. Research Questions

- Where is the location of hotspot in Debre Markos Town?
- How to organize spatial and non-spatial data in GIS database for future analysis?
- What is the magnitude of the hotspots?

1.5. Significance of the Study

Accident information is useful to different stakeholders. The results of this study provide the Debre Markos Municipality Transport Authority, Debre Markos Town Municipality Engineers, Town Planners, Traffic Police, and drivers, with the spatial distribution of risky road segments and in particular, the location of road traffic road traffic accidents hotspots with their magnitudes in Debre Markos Town. This information can be used as the basis for improving road safety by allocating resources in high priority areas. Thus, it will provide the fundamental scientific approach in identifying, managing and preventing RTAs hotspots. The scientific approach is more likely to improve road safety and associated benefits, a commitment which over 100 countries have embarked on to set and implement ambitious national road safety plans in the battle to lessen the road carnage during the Decade of Action for Road. A safer road network is a sustainable one as transport is the heartbeat of Ethiopia's economic growth and social development. Moreover, it will add on to the literature on the application of GIS in identifying RTA hotspots.

1.6. Delimitation/Scope

The study focused on the identification of road traffic accident hotspots in Debre Markos Town using accident data of five years (i.e. from 2008 to 2012 E.C.). Debre Markos town is chosen for this study because of the current traffic accident happening in Ethiopia shows this town is among the town in which high accident is recorded. The study has a wide width starting from collecting primary and secondary data's to identifying the location of road traffic accident hotspots locations and mapping them with their magnitudes.

The study involves the necessity of identifying the location of road traffic accidents hotspots in order to improve and update the previous road traffic safety that causes many problems in the town as mentioned in above session and to provide good information for the stake holders to improve the traffic safety in the town.

The delimitation of the study is to generate the map showing the location of road traffic accident hotspots with their magnitudes that is causing loose of lives, injuries and property damage using GIS to minimize Road traffic accident for prosperous Debre Markos town.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

A literature review was performed on application of GIS in Road Traffic Accident analysis to identify hotspots location. This chapter contains two main parts; theoretical framework and conceptual framework. Theoretical framework explains about the relevant literature reviewed focusing on the application of GIS to identify road traffic accident hotspot locations. The choice of these frameworks is based on the notion that theories are fundamental tools in research problems, which facilitate the choice of methodological approaches to be used in studies as well as interpreting the findings (Elvik, 2002). The second part is conceptual framework developed to answer the aim, objectives and statement of the problems of the study. (Holló *et al.* 2010) Define a conceptual framework or model as an abstraction of reality, which helps to better understand the real world systems, facilitate communication and integrate knowledge across disciplines.

2.2. Theoretical Framework

2.2.1 Road Traffic Accident

Road Traffic Accident is an unfortunate incident that happens unexpectedly and unintentionally (Oxford university press, 2001); between two or more vehicles, a vehicle and a train, a vehicle and a cyclist, a vehicle and a pedestrian, a vehicle and an animal, a vehicle and a fixed object such as a bridge, building, tree, post or a single vehicle that overturned on or near a public road (Nyoni, 2017). According to (WHO, 2015), Worldwide, the number of people killed in Road Traffic Accidents (RTAs) each year is estimated at almost 1.5 million while the number of people injured could be as high as 50 million. In Ethiopia, the number of death due to traffic accident is reported to be amongst the highest in the world, and 25.3 people dies per 100,000 populations in Ethiopia (WHO, 2015). The total number of Road traffic accidents in Debre Markos Town from 2006/07 to 2012/13 on human and material is 180, and the average number of road traffic accidents in Debre Markos town from 2015/16 to 2019/20 was 13.6 percent for death, 14.5 percent for serious injury, 18.4 percent for slight injury and 53.5 percent property damage (Berhane, 2015).

Accident analysis studies aim at the identification of high rate accident locations and safety deficient areas (Deepthi and Ganesh, 2010). Traffic safety engineers around the world face one of the most imperative questions including where to implement safety precautionary measures so that they can have the most momentous impact for traffic safety (Choudhary *et al*. 2015). An accident hotspot is an engineering term to denote the section of a road network where traffic accidents frequently occur (Gundogdu, 2010). Identifying road accident hotspots plays a key role in determining effective strategies for the reduction of high-density accident areas (Anderson, 2009). When hotspots locations are known, it will assist the agencies responsible for road safety which include Federal Road Safety Commission (FRSC), Police; Vehicle inspection office (VIO), Federal Road Maintenance Agency (FEMA) and the road users to know the areas that need urgent attention when making safety decisions (Jobin, 2015).

2.2.2 Role of GIS in Road Traffic Accident Analysis

GIS is a computer-based system for storing, querying, analyzing and displaying geographic data (Nyoni, 2017). GIS is a very important and comprehensive management tool for traffic safety. Since 1990's, GIS technologies have been used more frequently for such studies due to the availability of low-cost GIS with user-friendly interfaces (Khan *et al*., 2006). GIS has the ability to hold a vast amount of data that can be easily stored, shared and managed. It provides a platform for data analysis and visualization to explore relationships between data and it can easily provide graphical or non-graphical outputs. Meanwhile with the rapid development and adoption of GIS technology as a tool to manage, explore, analyze and visualize spatial data, spatial data analysis methods that are included in GIS software's modules, received increasing attention (Booth, 2004). The importance of spatial analysis is the measurement of attributes and their relationships, taking into account the spatial location of the phenomenon under study (Camara *et al*., 2001). Spatial data and its analysis is one of the most important information for traffic accident analysis. GIS aided spatial data and spatial analysis provides a lot of information to analysts about hazardous locations, hot spots, warm spots etc. Using GIS, the analyst can merge accident and highway data, geocode the accident data and locations, calculate frequency and rate of accidents, select a variable for stratification to calculate mean and standard deviation of accident rates (Liang *et al.*, 2005).

A GIS could be utilized in safety studies because it has the capabilities of performing spatial analysis and mapping analysis, follow-up and updating tasks, and identifying and querying for any contributing factors to reduce accidents and use data from many diverse sources such as satellite imagery, aerial photos, maps, ground surveys, and global positioning systems (GPS) (ESRI, 2016). Many highway agencies have been using Geographic Information System (GIS) for analyzing accident data (Lim and Law, 2005). GIS aided spatial data and spatial analysis provides a lot of information to analysts about hazardous locations, hot spots, warm spots etc. The capability of GIS technology to process spatial and non - spatial data offers the opportunity for location analysis (Ferreira and Ferreira, 2011). Identification of safety deficient locations with GIS aided spatial analysis will certainly help to decrease the traffic accidents (Erdogan *et al*. 2008). Precise location of data could help guide programs including maintenance, vehicle inspection, emergency medical services and engineering to improve streets and highways. GIS-based accident information systems can identify relationships between spatial phenomena that are almost impossible to determine with a non-spatial database. Since 1990, there have been many studies about GIS technologies and its applications on traffic safety and accident analysis as a spatial pattern. Many agencies and researchers have reported the use of GIS analysis of accidents. The types of analyses, applicable for accident analysis, include intersection analysis, segment analysis, cluster analysis, density analysis, pattern analysis, proximity analysis, spatial query analysis and spatial accident analysis modeling techniques (Erdogan *et al*. 2008). (Erdogan *et al*. 2008) have used GIS for reducing number of the accidents by determining hot spots. He evaluates accidents distribution in a highway, located in the entrance of Afyonkarashiasar City. This research used two different methods of kernel density analysis for identification of hotspots. (Nyoni, 2017) performed a research in fulfillment of the academic requirements for the degree of Master of Science in the School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal Westville campus on GIS based approach to identify road traffic road traffic accident hotspots in the Greater Durban Town from 2011 – 2015. He identified the road traffic road trafficities hotspots within the greater Durban Town based on the location and attributes where the road accident occurred with the aid of Kernel Density Estimation (KDE) analysis and Getis-Ord Gi* hotspot analysis. (Affum and Taylor, 1997) described the development of a Safety Evaluation Method for Local Area Traffic Management (SELATM), which is a GIS-based program for analyzing accident patterns over time and for the evaluation of the safety benefits of Land Area Traffic Management schemes. (Hirasawa and Asana, 2003) at Civil Engineering Research Institute developed a traffic accident analysis system for Hokkaido, Japan. This system manages accident data, road structure and road accessory facilities using GIS technology. It allows for the analysis of accident frequencies, accident rates and seasonal effects on accidents. (Liang *et al*. 2005) developed a traffic accident analysis system using GIS at the University of Putra in Malaysia. Using this system, the user can identify high accident locations, obtain the accident location's ranking, visualize the road accident and location information, input and retrieve the accident database, perform statistical analysis on the selected accident location and so on within a short period of time. (Amare and Assegidew, 2015) carried out a research to analyze the road traffic accidents by applying GIS to identify hot spot sites of road traffic accidents along Bahir Dar to Gondar road. And, twenty-five accident hot spot sites were identified in traffic accident analysis using Kernel Density estimation method. To determine the dangerous road site, priority value from kernel density is used and hotspots are ranked by dividing the priority value by the hotspot section length. (Christian *et al*. 2018) have used GIS for identification of road traffic accident hotspots in the Cape Coast Metropolis, Southern Ghana. Traffic safety studies explore the effect of various factors on safety performance, either qualitatively or quantitatively, such as the influence of various geometric features of road design, weather conditions, lighting factors or geographical conditions on accident occurrences (Shankar *et al*. 1995). Several studies have been conducted to establish spatial patterns in vehicle or pedestrian accidents for the identification of critical locations. (Jones *et al*. 1996; Thomas, 1996) carried out a study for hot zones using spatial autocorrelation and kernel methods on road segments. (Kim *et al*. 2004; Levine *et al*. 1995) analyzed spatial patterns of pedestrian crashes in Honolulu, Hawaii using K-means clustering techniques. These spatial patterns show areas of high pedestrian crashes which have been explained in light of various demographic characteristics. (Bello, 2005) explored a stratified accident analysis in the town of Richardson. This research focuses on identifying the spatial patterns of traffic accidents to school age kids compared to other traffic accidents in the town, using kernel densities. (Sabel *et al.* 2005), developed a method using kernel estimation cluster analysis techniques to automatically identify road traffic accident hot spots in Christ church in New Zealand. KDE is a non-parametric method that involves introducing a symmetrical surface over each point feature, assessing the distance from the point to a reference location based on a mathematical function, and subsequently, adding the value of all the surfaces for that reference location (Levine, 2004). Kernel density hotspots with the populated field as GiZScore were performed with the Kernel density calculator function available within the ArcMap software spatial analyst tool at a search radius determined by ISA for each year under review. It calculates the magnitude per unit area from each hotspot features using the populated GiZScore field (Deepthi and Ganesh, 2010). A number of different kernel functions are available, such as Gaussian, Quartic, Conic, negative exponential and Epanichnekov (Gibin *et al*. 2007). Hotspots can be categorized into six classification schemes: equal interval, defined interval, quartile, natural breaks, geometric interval and standard deviation. In the natural breaks scheme, the classes are based on natural categories inherent in the data and based on Jenks algorithm (Deepthi and Ganesh, 2010). This algorithm is a common method of classifying data in a choropleth map, a type of thematic map that uses shading to represent classes of a feature associated with specific areas. This algorithm generates a series of values that best represent the actual breaks observed in the data, as opposed to some arbitrary classification scheme; thus, it preserves true clustering of data values. Further, the algorithm creates *k* classes so that the variance within categories is minimized (Manepalli and Bham, 2011). The break points are identified by the class breaks that best group similar values and maximize the differences between the classes. The features are divided into classes and create boundaries that correspond to relatively big jumps in the data values (Manepalli and Bham, 2011). This classification scheme is best suited in which the output of the Kernel density function is a raster file displaying the areas of low, low-medium, medium, medium-high and high densities of accident occurrence. Lighter shades represent locations with a lower traffic accident density, while darker shades represent locations characterized by the highest traffic accident density (Nyoni, 2017).

2.3. Conceptual Framework

The theoretical framework presented the review of literature on different theories related to the role of identifying hotspots in traffic safety and the role of GIS in Road Traffic Accident analysis. Also, different methods of identifying hotspots and determining the magnitude of the hotspots is presented. Depending on the reviewed theories, to answer the questions, objectives and statement of the problem of this study the conceptual framework is developed. The rationale for incorporating GIS for traffic accident hotspot identification in this study is that GIS offers a more effective and efficient platform to perform various analysis such as density and pattern analysis, spatial query analysis and spatial statistics techniques which aid the identification of hotspots. Since accident is spatially distributed in nature, use of Geographic Information System (GIS) will provide the capability to store, update, retrieve, compare and spatially display data. GIS allows Hotspot map to be electronically generated from a well-designed accident database and can also produce rankings of high-accident locations based on either total accident occurring or accident rates. Identifying road traffic accident locations within the Debre Markos Town using GIS-aided technique can highlight contributory factors that can assist the government and its agencies to implement corrective measures to make driving safe at such spots and improve these roads. Though several studies exist on traffic accident hotspot detection and analysis, (Xie and Yan, 2013) point out that, the kernel density estimation (KDE) approach is the most widely adopted method. This study uses the default Kernel function, Epanechnikov kernel. This kernel function is the most efficient in minimizing the mean integrated squared error. And, the magnitude of the hotspots can be determined using Jenks algorithm classification. This classification scheme was best suited to this study in which the output of the Kernel density function is a raster file displaying the areas of low, low-medium, medium, medium-high and high densities of accident occurrence. Generally, to determine the location of hotspots and their magnitude, spatial and non-spatial Road traffic accident needs to be collected. The spatial-data i.e. location of traffic accident is collected on the field using GPS and non-spatial data i.e. road traffic data will be collected from Police station. Road network is extracted from topographic map and satellite data. The spatial and non-spatial data is integrated to determine the hotspots using KDE tool in ArcGIS software environment, and finally a map showing hotspots with their location and magnitude is developed. Based on the reviewed theoretical concept, the developed conceptual framework methodology is shown below.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

Different activities that are carried out in this study can be classified in to three main faces: pre-field work, field work and post-field work. The main activities in pre-field work are; literature review and reconnaissance survey. During the field work stage, collection of primary data and secondary data were made and during post-field work; creating of geo database and overlay of spatial and non-spatial data will be made. The activity of data collection and data processing is summarized as follows by the below flow chart.

3.2 Description of the Study Area

Debre Markos is found 299 kms North-West of the capital Addis Ababa and 265 kms South-East of the Amhara National Regional state city Bahir Dar. The geographical coordinates of the town are 10°21" Latitude North and 37°43" Longitude East. Its total municipal area is approximately 60kms sq. The town is situated at 2420 meters above sea level (Figure 3.1). The weather condition of the town is woinadaga (temperate climate) which makes it suitable to live in. The mean anual rain fall is 1308mm and mean annual temperature of 16°c, while the maximum and minimum recorded temperature are 24°c and 4°c respectively (EGFED,2012). A slope ranging 2-10% is considered to be suitable for urban development activities. As shown in table 3.1, the majority (66%) of land in Debre Markos is in this range (2-10% and thus suitable topography for urban development. The slope below 2% covers 9% and above 15% covers 8.3% of the total area of Debre Markos town which are considered to be difficult for urban development.

Table 3. 1: Slope Classification

No	Gradient (%)	Area Coverage in sq.km	Area in %
I	0-2	8	8.9
2	2-5	20	22.3
3	5- 10	39	43.7
4	10-15	15	16.8
5	Above 15	7.5	8.3
	Total	89.5	100

Source: Debre Markos! Own municipality, 2009

The population of the town is 62,469. Disaggregated by sex, 29,901 were males and 32,568 females with the sex ratio in percentage of 52.2% (CSA, 2007). Up to 2014, it is estimated to be 107,684 of which 57,791 are females and 49,893 are Males (EGFEDD, 2012).

Debre Markos is a town in central Ethiopia and the previous capital of the Oromia Region. Debre Markos forms a Special Zone of Oromia and is surrounded by East Shewa Zone. It is located at 8.54°N 39.27°E and at an elevation of 1712 meters, 99 km southeast of Addis Ababa. The town sits between the base of an escarpment to the west, and the Great Rift Valley to the east. Based on the 2007 census conducted by the Central Statistical Agency of Ethiopia (CSA), Debre Mar-kos town has a total population of 220,212, an increase of 72.25 % over the population recorded in the 1994 census of which 108,872 are Men and 111,340 Women. With an area of 29.86 km2, Debre Markos has a population density of 7374.82; all are urban inhabitants. A total 60,174 Households were counted in this town, which results in an average of 3.66% to a house hold and 59,431 housing units. Climate condition of Debre Markos is classified as tropical Wet & Dry (WD).

According to DSPRP Spatial Study Report of 2018; Road Network, Transportation & Utilities accounts about 12.16% of the general existing land use of the town in which the road network is the dominant over the other details by accommodating 96 % of this particular land use. Debre Markos is a busy transportation center. The town is situated along the road that connects Addis Ababa with Bahir Dar. According to Debre Markos Transport Agency, the total number of vehi-cles in the town in 2020 is over 4000.

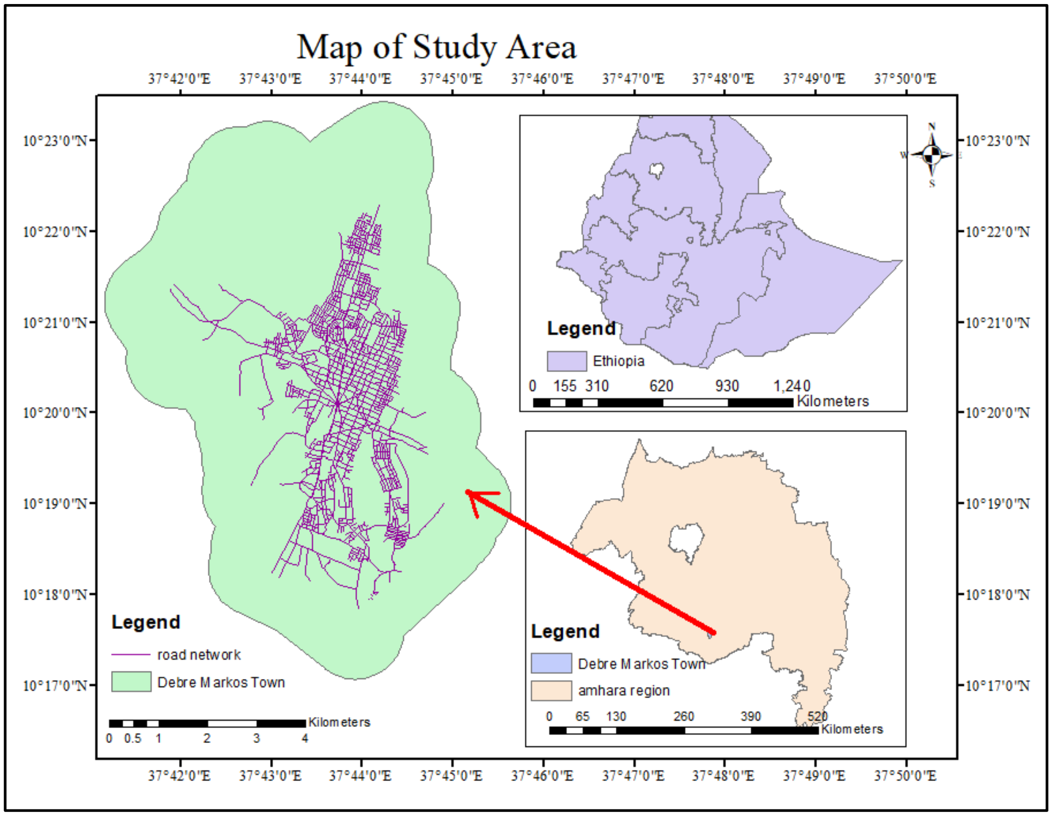

Figure 3. 1 Map of the Study Area

3.3 Data Source

The data used involves two sources i.e. primary and secondary data sources. The primary data source involves direct collection of information on the field using GPS (Global Positioning System) and observations. The data collected from primary sources is therefore, the geographic coordinates of the accident location. The secondary data source involves sourcing information from existing records i.e., from Debre Markos Town Police station, from Google earth, topographic map. The lists of materials used for the accomplishment of the study are tabulated as follows in table 3.2. shown below.

Table 3. 2: List of Materials used for the Study

A. Data to be used		Purpose	Source
1	Topographic Map of Debre Markos Town	For Extraction of Digital Road Network	Ethiopian Geo-spatial Institute
2	Rectified Google Earth Image	To update road networks which may not exist on Topographic Map	Google Earth Explorer
3	Geographic Coordinates of Accident Locations	Hotspot Location Identification	Accident location on the road
4	2015 to 2020 RTA data	Used as non-spatial data for identification of hotspots location and to determine magnitude of hotspots.	Debre Markos Town Traffic Police Station
B. Software's to be used			
	Name	Version	Purpose
1	ArcGIS Desktop	10.4	• Database creation Extraction of Road network • Overlay Spatial and non-spatial data hotspot analysis • To display map showing hotspot locations and magnitude
2	Microsoft Office • Word • Excel	2016	• Writing the research • Collecting road traffic accident data
3	GPS Spectrum Survey	3.2	• adjustment of coordinates
C. Equipment to be used			
	Hand Held GPS with High accuracy (ASUS 5.1 Mobile Phone)	AndoiTS GPS.apk	Collection of geographic coordinates of accident location

3.4 Data collection

The data to be collected for the study is categorized in to two. These are primary and secondary data collections:

3.3.1 Primary data collection

The primary data involves location of road traffic accident which will be collected on the field using GPS at the place where traffic accident occurs through field surveying and observation.

3.3.2 Secondary data collection

The secondary data used for the study includes;

- Topographic map of Debre Markos Town – collected from Ethiopian Geo-spatial Institute
  through administration procedures.
- Road Traffic Accident data - collected from Debre Markos Town Police station through administration procedures.

3.5 Data Analysis techniques

3.5.1 Integrate – Collect Events

Neighbourhood distance is the spatial extent of the analysis. This value regulates which accidents are analysed together in order to assess local space time clustering, hence, it is necessary to find an appropriate neighbourhood distance where spatial autocorrelation is maximised (ESRI, 2016). ArcGIS's Incremental Spatial Autocorrelation (ISA) tool was used to find the neighbourhood distance for each year. Prior to conducting ISA, the following tasks were conducted. Integrate with the Collect Events tools were used to aggregate the traffic fatal accidents data. The Integrate tool snap incident points together within a specific distance, while Collect Events create a new feature class containing a point at each unique location with an associated count attribute specifying the number of accident occurrences (ESRI, 2016). The resultant ICOUNT field is then used as an input field to calculate distance band from neighbours count.

The ICOUNT field must contain various values because this statistic requires some variability in the features being analysed. If all input values were similar, this tool fails to execute.

Calculate distance band, from neighbours count in ArcGIS spatial statistical tools returns three numbers: the minimum, the maximum and the average distance to a specified number of neighbours (ESRI, 2016). The maximum distance is the furthest distance and minimum distance is the closest distance between a feature and its neighbours. The reported average value is the average distance between all the features and their neighbours. The maximum and average values were exploited to find a distance band using the ISA function. Incremental Spatial Autocorrelation (ISA) creates a line graph of those distances and their corresponding z-scores (ESRI, 2016). The magnitude of spatial clustering is indicated by zscores. Statistically significant peak z-scores (+1) indicate distances where clustering of traffic accidents is most pronounced. To ensure that all of the aggregated accidents point has at least one neighbour, the maximum value was used as the Beginning Distance, while the average value was used as the Distance Increment as increasing the distance needs to ensure the growth in number of neighbours. The ISA tool runs the Spatial Autocorrelation (Global Moran's I) tool for a series of increasing distances, measuring the intensity of spatial clustering for each distance (ESRI, 2016). An output graph was generated, whereby the X-axis of the graph represents the distance and Y-axis represents the z-score results. At some particular distance, however, the z-score generally peaks. Peaks reflect distances where the spatial processes promoting clustering were most pronounced. One strategy for identifying an appropriate scale of analysis is to select the distance associated with the peak and often this is the first peak (ESRI, 2016).

Data analysis have been done with the use of ArcGIS Pro 1.2 software is used to map the hotspots locations within the Debre Markos town. It is also used to create graphical representation of magnitude of the hotspots. The location of hotspots identification is based on Kernel Density Estimation. Finally, a map showing hotspots location and magnitude of the hotspots has been generated.

3.5.2 Moran's I

Moran's I is a commonly used indicator for spatial autocorrelation. In this study, global Moran's I (Moran 1950) was used as the first measure of spatial autocorrelation for fatal accidents. Moran's I evaluate whether the output spatial pattern is clustered, dispersed or random, and determine concentrations levels (Prasannakumar *et al*. 2011). The null hypothesis states that the feature values are randomly distributed across the study area. Moran's Index values range from -1 to 1, and a Moran's Index value near +1.0 indicates clustering, an index value near -1.0 indicates dispersion (Korter *et al*. 2014), while "0" implies perfect spatial randomness (Fu *et al*. 2014). The p-value is a probability, which determines whether the observed values were created by random processes or other underlying spatial processes. The null hypothesis can be accepted when the critical z-score values are ±1.65 using a 90% confidence level, and if the p-value is greater than 0.10 (> 0.10). On the contrary, when the critical z-score values are ±1.65 using a 90% confidence level, and the p-value is less than 0.10 (<0.10) then the null hypothesis can be rejected because significant clustering exists beyond

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this region (ESRI, 2016). Very high (+2.58) or very low (-2.58) z-scores, associated with very small p-values (0.01) are found in the tails of the normal distribution and these represent clustering or dispersion at a 99% confidence level (Figure 3.2). High z-scores associated with small p-values indicate significant hotspots (shades of red in Figure 3.2), while low z-scores associated with small p-values indicate significant cold spots (shades of blue in Figure 3.2) (ESRI, 2016)

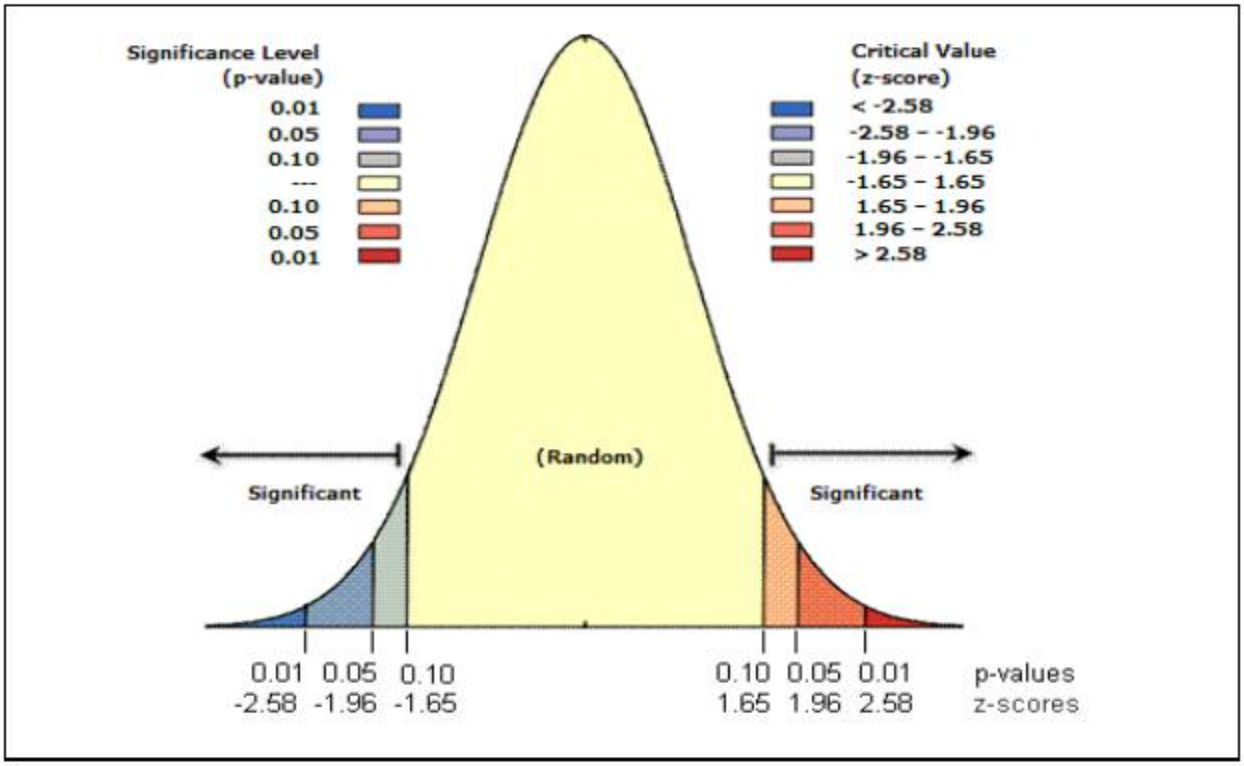

Figure 3. 2 Normal Distribution of Global Moran's I values (Source: ESRI, 2016).

The locational proximity of data events was measured as a direct distance between two points while the inverse distance weighting method was used as a measure of locational proximity among neighbouring points (Rukewe *et al*. 2014). Since each data point is analysed in terms of its neighbouring data points defined by a distance threshold, it is necessary to find an appropriate distance threshold where spatial autocorrelation is maximised (Prasannakumar *et al*. 2011). The Spatial Autocorrelation tool was run with different distance thresholds determined by ISA for each year. Moran I-Index is expressed mathematical using the following equation:

$$I = \frac{N \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(X_i - \bar{X})(X_j - \bar{X}}{(\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}) \sum_{i=1}^{n}(X_i - \bar{X})^2} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \, eq(1)$$

where *n* is the number of all fatal accidents in the study area, *xi* and *xj* are the observations at locations of *i* and *j*, $\bar{x}$ is the mean of *x*, and *wij*, an element of spatial weights matrix *w*, is the spatial weight between locations of *i* and *j*.

3.5.5 Hotspot Analysis: Getis-Ord Gi* statistic

The Gi* statistics is a family of statistics that have a number of attributes that make them attractive for measuring dependence in a spatially distributed variable especially when used in conjunction with the Moran's I and Anselin Local Moran's I (Truong and Somenahalli, 2011). Getis and Ord (1995) assert that the Gi* statistics deepen the knowledge of the process that give rise to spatial dependence and enhance detection of local pockets of dependence that may not be detected when using the global statistic. The Gi* statistic is mathematically expressed by the following equation:

$$G_i^* = \frac{\sum_j^n W_{ij}(d).Y_i - W_j^*.\bar{Y}}{S.\{[nS_{1i}^* - W_j^{*2}]/(n-1)\}^{1/2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..eq(2)$$

Where, *n* is the total number of fatal accident occurrence, *S* is the standard variance of the fatal accidents occurrence ratio, when the distance from location *j* to *i* is within distance *d*, then *Wij (d)* = 1*;* otherwise *Wij (d)* = 0 and *Sij, Wi**. The higher the value of *Gi** is, the greater the influence of location I is at a given distance *d*, indicating that location *i* is a hotspot of the study area.

The Getis-Ord GI* function looks at each feature within the context of neighbouring features (Erdogan *et al*. 2015). The output of hotspot analysis tool is z-score (-1.96 to +1.96) and pvalue (± 0.01 to ± 0.10) for each feature. These values represent the statistical significance of the spatial clustering of values, given the conceptualisation of spatial relationships and the scale of analysis (Erdogan *et al*. 2015). A statistically significant positive (1.96) z-score and small p-value (0.05) for a feature indicates a spatial clustering of hotspots, whereas a statistically significant negative (-1.96) z-score and small p-value (0.05) indicates a spatial clustering of coldspots (Erdogan *et al*. 2015; ESRI, 2016). The higher the z-score, the more intense is the clustering. A z-score near zero indicates no apparent spatial clustering (Truong and Somenahalli, 2011). The Getis-Ord Gi* function was run for fatal accidents in the study area for the period 2015-2020. The maximum distance threshold obtained through ISA for each year was used in the Getis-Ord Gi* hotspot analysis.

3.5.4 Kernel Density Estimation (KDE)

KDE is a non-parametric method that involves introducing a symmetrical surface over each point feature, assessing the distance from the point to a reference location based on a mathematical function, and subsequently, adding the value of all the surfaces for that reference location (Levine, 2004). According to Silverman (1986), density estimation is a procedure to create an estimate of the density function from the observed data using the following mathematical expression:

$$f(x) = \frac{1}{nh^d}\sum_{i=1}^{n} K\frac{(x - x_i)}{h} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..eq(3)$$

Where *n* is the total number of features, *h*, which controls the size of the neighbourhood around *x*, is the smoothing parameter. The function K is called the kernel and it controls the weight given to the observations {*xi*} at each point *x* based on their proximity. Though several studies exist on traffic accident hotspot detection and analysis, Xie and Yan, (2013) point out that, the kernel density estimation (KDE) approach is the most widely adopted method. Kernel density hotspots with the populated field as GiZScore were performed with the Kernel density calculator function available within the ArcMap software spatial analyst tool at a search radius determined by ISA for each year under review. It calculates the magnitude per unit area from each hotspot features using the populated GiZScore field (Deepthi and Ganeshkumar, 2010). A number of different kernel functions are available, such as Gaussian, Quartic, Conic, negative exponential and Epanichnekov (Gibin *et al*. 2007). This research employed the default Kernel function, Epanechnikov kernel. This kernel function is the most efficient in minimising the mean integrated squared error.

Hotspots can be categorised into six classification schemes: equal interval, defined interval, quartile, natural breaks, geometric interval and standard deviation. In the natural breaks scheme, the classes are based on natural categories inherent in the data and based on Jenks algorithm (Deepthi and Ganeshkumar, 2010). This algorithm is a common method of classifying data in a choropleth map, a type of thematic map that uses shading to represent classes of a feature associated with specific areas. This algorithm generates a series of values that best represent the actual breaks observed in the data, as opposed to some arbitrary classification scheme; thus, it preserves true clustering of data values. Further, the algorithm creates *k* classes so that the variance within categories is minimised (Manepalli *et al*. 2011). The break points are identified by the class breaks that best group similar values and maximise the differences between the classes. The features are divided into classes and creates boundaries that correspond to relatively big jumps in the data values (Manepalli *et al*. 2011). This classification scheme was best suited to the present study in which the output of the Kernel density function is a raster file displaying the areas of low, low-medium, medium, mediumhigh and high densities of accident occurrence. Lighter shades represent locations with a lower traffic accident density, while darker shades represent locations characterised by the highest traffic accident density.

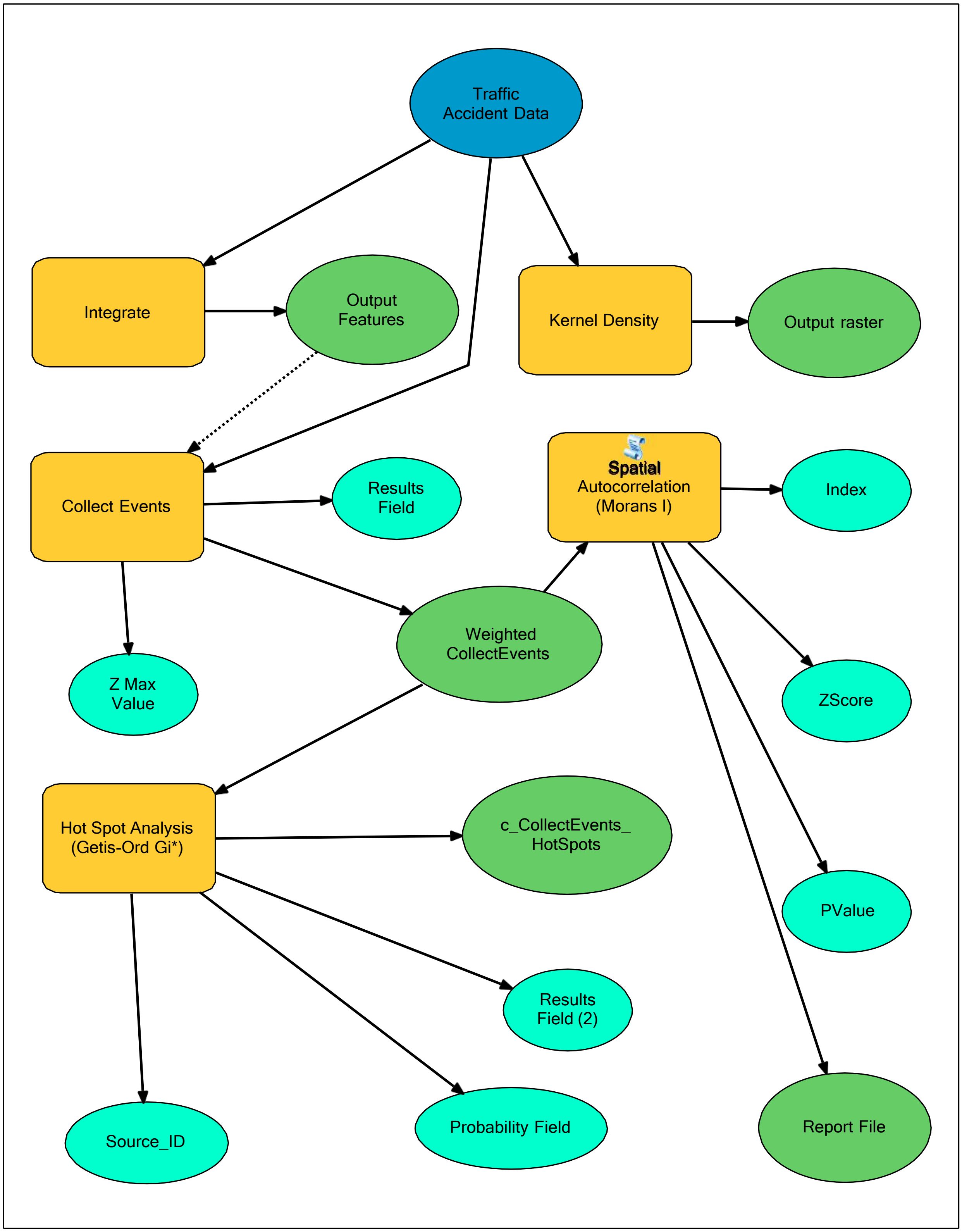

Figure 3.3. Flow chart of the methodology for the study

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

Road traffic road accidents are a combined outcome of human behaviour, vehicular and road environmental induced factors. The Department of Road and Transport, and other government bodies are responsible for monitoring and ensuring that the goal of road traffic death reduction is achieved by 2025.

Hence, this study aimed to analyse patterns and trends of road traffic road traffic accidents at a local level within the Debre Markos town for the period 2008 E.C.-2012 E.C.. The results presented in this chapter also aid in determining the effectiveness of corrective measures implemented by the Department of Transport at a local level on the reduction of road accidents occurrence.

4.2 Database preparation

The recording system in Debre Markos police department is manual and tiresome and difficult to organize for analysis. The following can be used in .dbf file format in ArcGIS 10.4.

ID	YEAR	X COORD	Y COORD	TYPE VEH	DAY	SEVERITY	AGE	CAUSE	DRIVER AGE	Road Surface	STREET	SEX	DESCR

Figure 4. 1 Database system for Debre Markos road traffic accident

4.2 Road Traffic Road Traffic Accidents by year

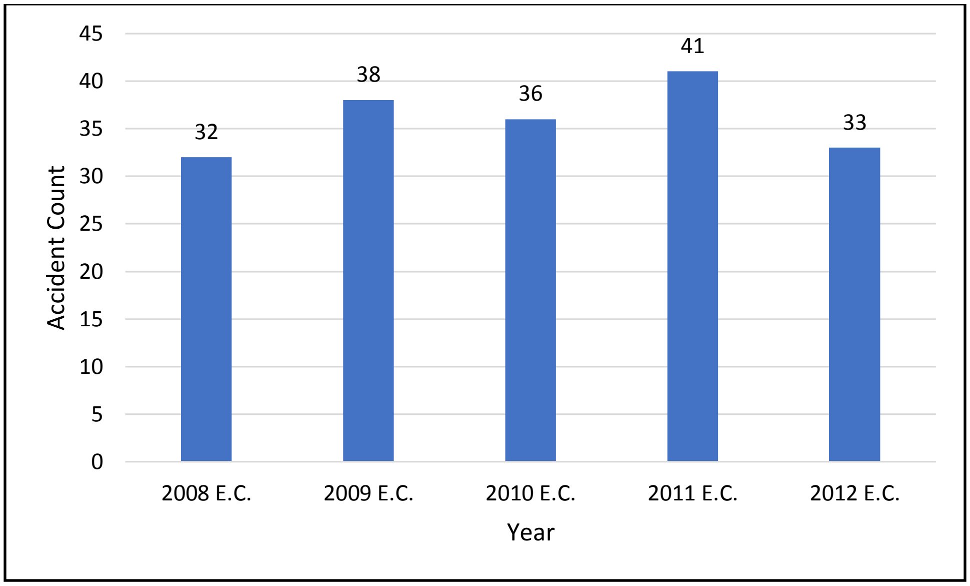

Figure 4. 2 Road Traffic Accidents occurred from 2008 E.C.-2012 E.C.

Figure 4.1 shows the composition of road traffic accidents within the Debre Markos from 2008 E.C.-2012 E.C. during which a total of 180 accidents occurred. On overall, there was a slight increment in road traffic accidents from 2008 E.C.-2012 E.C. with an average of 36 road traffic accidents being recorded annually. The year 2008 E.C., which marks the first year of the decade of action for road safety and road traffic accidents recorded the lowest accidents (32), followed by 33 in 2012 E.C. and 36 in 2010 E.C.. In 2011 E.C., a total of 41 accidents were recorded within the study area while 38 were recorded in 2009 E.C. The research findings also show that the year 2011 E.C. recorded the highest accidents within the Debre Markos Town, followed by 2009 E.C.

4.3 Road traffic Accidents by severity

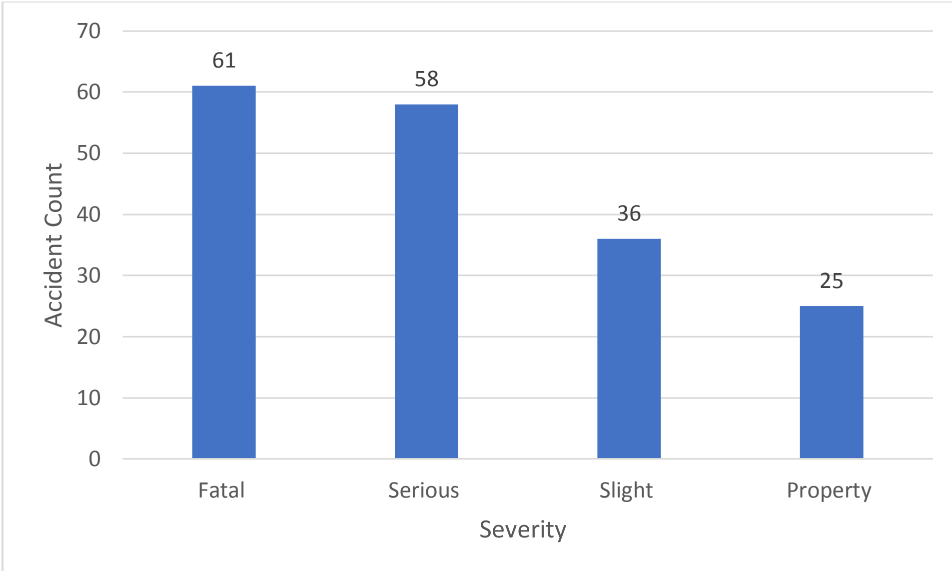

Figure 4. 3 Road traffic Accidents by severity from 2008 E.C.-2012 E.C.

The highest frequency of serious injuries and slight injuries in the town have been exhibited in the years of 2010 E.C. and 2011 E.C. while the most shocking fatal accidents of road crashes have been unveiled in 2009 E.C. and 2010 E.C. in the town. In general, 147 road users in the town became victims of RTAs every year from 2008 E.C. -2012 E.C.. More specifically, 164.507, and 283 people suffer fatal accidents, serious injury and slight injury every year in the city between 2018 and 2012 E.C.. This disaster shows that victims of fatal road accidents died on the scene or in hospitals. Survivors also suffer from different types of injuries and disabilities which can affect their quality of life. The victims can be passengers, pedestrians, drivers; they can even be the cause of the accident themselves. As these victims suffer, their families and communities will suffer too; they must sometimes carry the burden of caring for the victims. The prevalence of people to RTAs can be a cause for social insecurity and social crisis. Road Traffic Accidents affect the physical and psychological wellbeing of an individual or groups.

4.4 Road traffic Accidents by Day

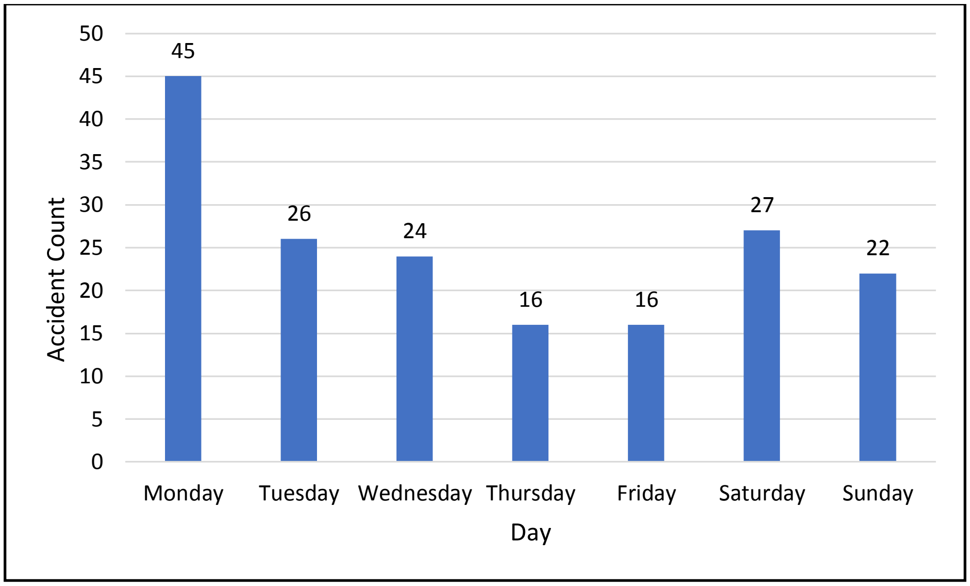

Figure 4. 4 Road traffic Accidents by Day from 2008 E.C.-2012 E.C.

The occurrence of road traffic road traffic accidents by days of the week was examined. The re-sultsreveal that weekends (Monday, Tuesday and Saturday) recorded the highest (54.4%) accidents, while the lowest accidents occurred on Tuesday and Friday equally (8.88%), and that Wednesday recorded accidents (13.3%) and Sunday recorded accidents (12.2%) 2008 E.C.-2012 E.C. (Figure 4.4).

4.5 Road traffic Accidents by time

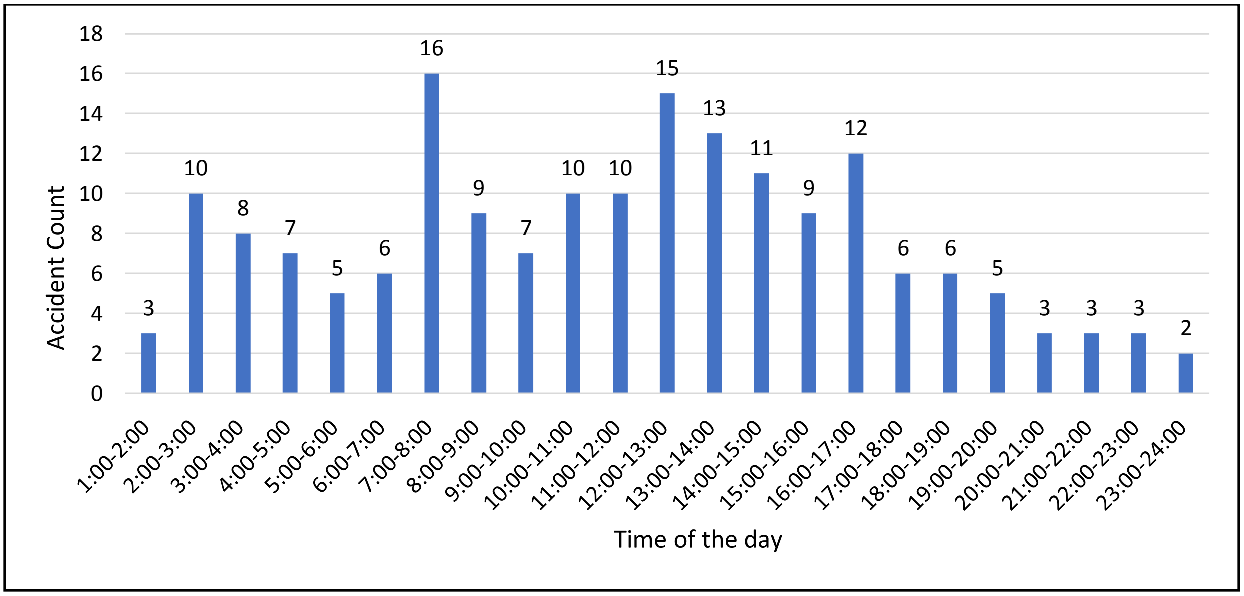

Figure 4. 5: Road traffic Accidents by time of the day from 2008 E.C.-2012 E.C.

In the first stage, 6:00 am-8:00 Pm and 11:00 Pm-14 am local time RTAs severity rates had maximum RTAs severity features for this period and it have peak values from 7:00pm – 8:00pm and from 12:00pm-13:00pm local time, but 20:00am to 24:00am have minimum RTAs severity. And on the other hand, from 2:00-5:00, 8:00-11:00 and 14:00-17:00 have medium RTAs severity records for this period. (See Figure 4.6) Generally Figure 4.6 below illustrates RTAs severity distributed over the hours of the Day. from 1:00- 3:00,RTAs tremendously increased and reached maximum at 3:00,from 3:00 -6:00 RTAs tremendously decreases, from 6:00-8:00 RTAs tremendously increases,8:00-10:00 RTAs tremendously decreases,10:00- 13:00 RTAs tremendously increases and from 13:00-24:00 RTAs tremendously decreases, and reaches minimum levels at 24:00 (12 pm) (see Figure 4.6). Hence, the accidents were highly associated with the number and time of movements of pedestrians, passengers, drivers, and vehicles. Decreasing trends of crashes per hour began with, slight decrease from 12:00 to 17:00(12 am-5 pm), and decreases after 18:00 (6:00 pm)

4.6 RTAs severity data by age of drivers

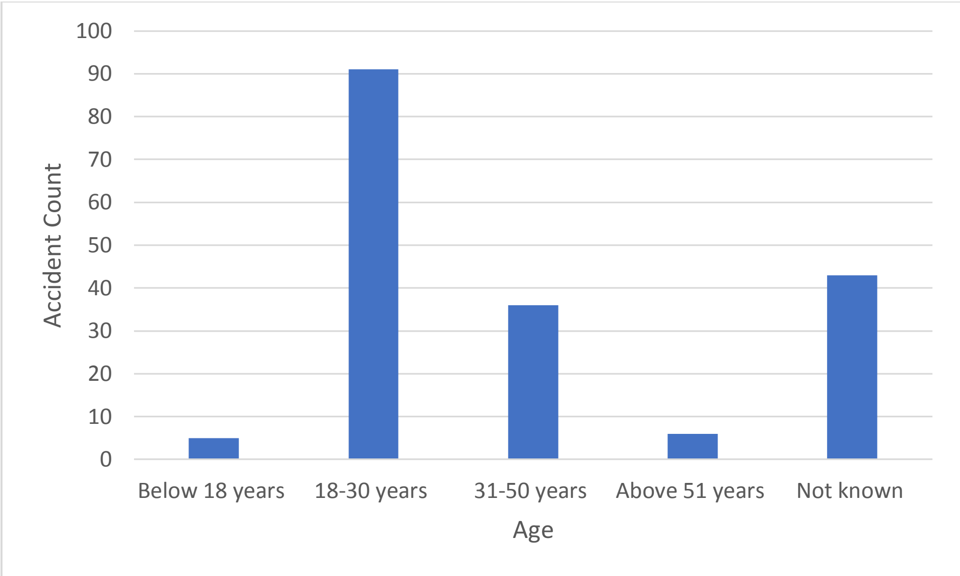

Figure 4. 6: RTAs severity data by age of drivers from 2008 E.C.- 2012 E.C.

From figure maximum accidents (50.56%) of are recorded by drivers with the age of from 18-30 years whereas Lowest accidents (2.78%) are recorded age of below 18 years followed by 3.33% with the age of above 51 years. Drivers with the age of 31-50 years have record of 20% and drivers with the age not known have record of 20%.

4.7 Spatial Autocorrelation Analysis

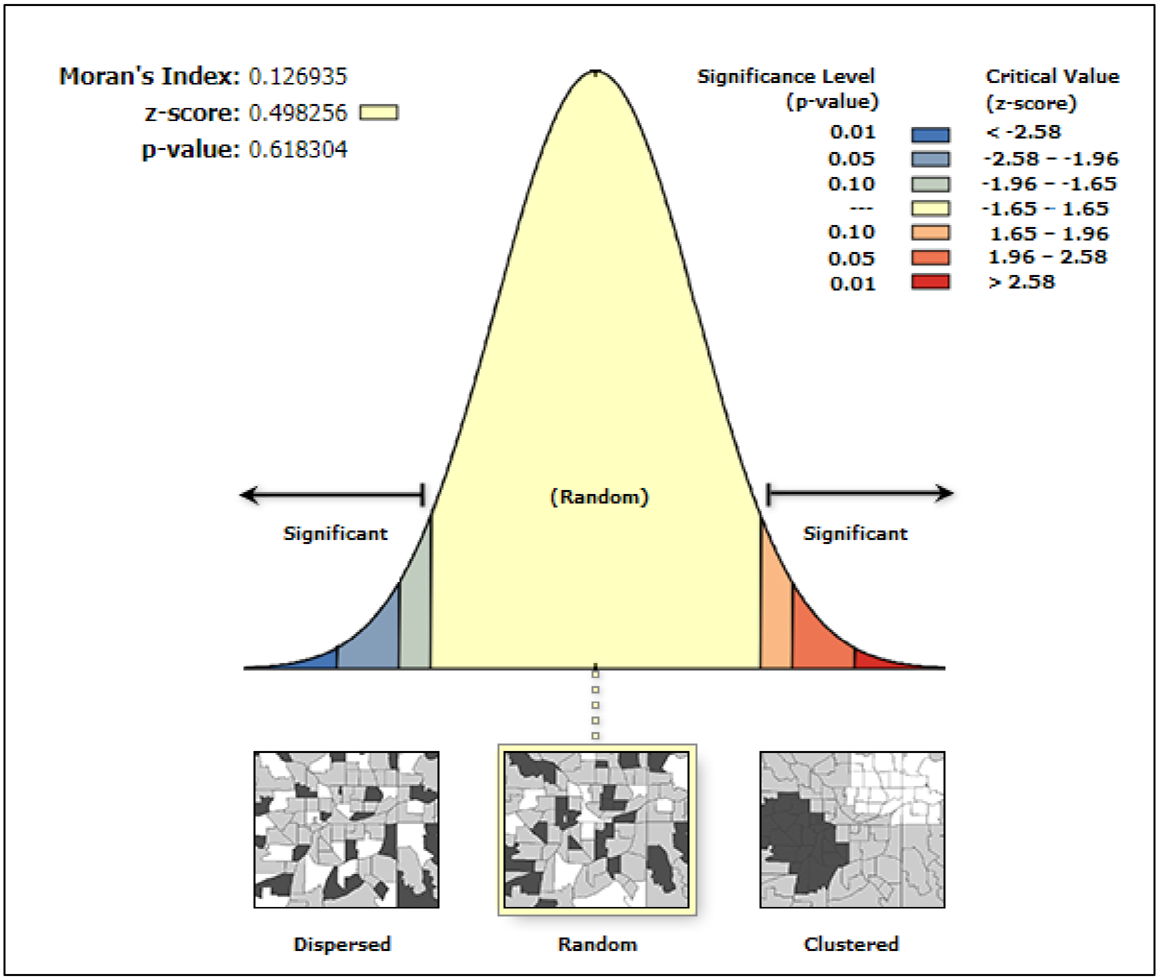

Figure 4. 7: Spatial Autocorrelation Report from 2008 E.C.-2012 E.C.

The analysis shows that Moran's index, z-score, p-value are 0.126935, 0.498256 and 0.618304 respectively. The p-value is *not* statistically significant. It is quite possible that the spatial distribution of feature values is the result of random spatial processes.

4.8 Getis-Ord Gi* hotspot analysis

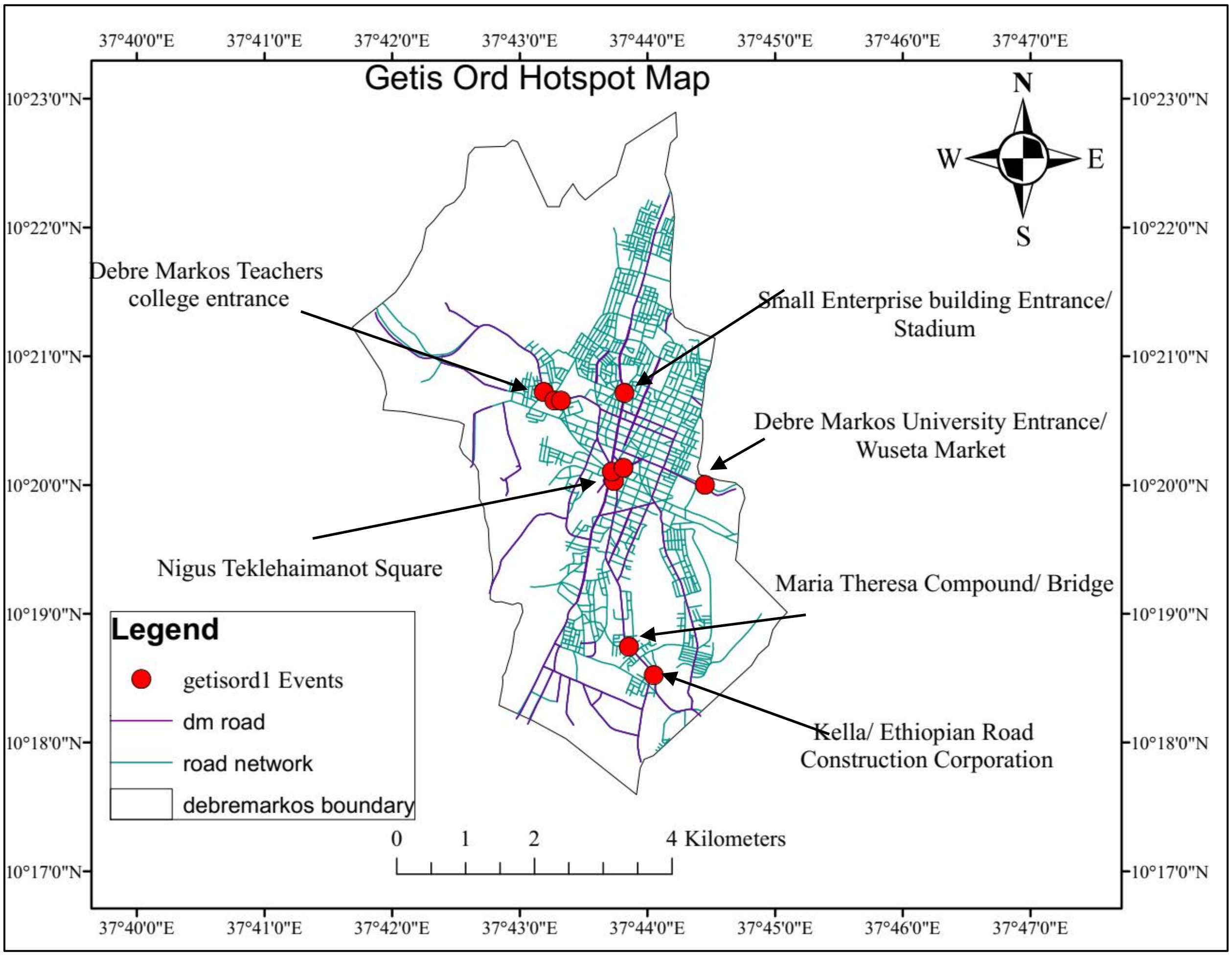

Figure 4. 8: Getis-Ord Gi* hotspot analysis in 2008 E.C.-2012 E.C.

Figure 4.8 shows hotspot locations for road traffic accidents in 2008 E.C.-2012 E.C. based from Getis-Ord Gi* hotspot analysis. Out of 180 accidents recorded in 2008 E.C.-2012 E.C., 10 accidents occurring on 6 locations at a 99% confidence level were identified as statistically hotspots with a z-score ranging from 3.092901184 and p-value of 0.001982101. The areas in which the hotspots for RTA occurred in 2008 E.C.-2012 E.C. were

Debremarkos Teachers College (3 accidents), stadium (1 accident) and Nigus Teklehaimanot Square (3 accidents), Debre Markos University (1 accident), Maria Theresa (1 accident), and Kella(1 accident).

4.9 Kernel Density Analysis

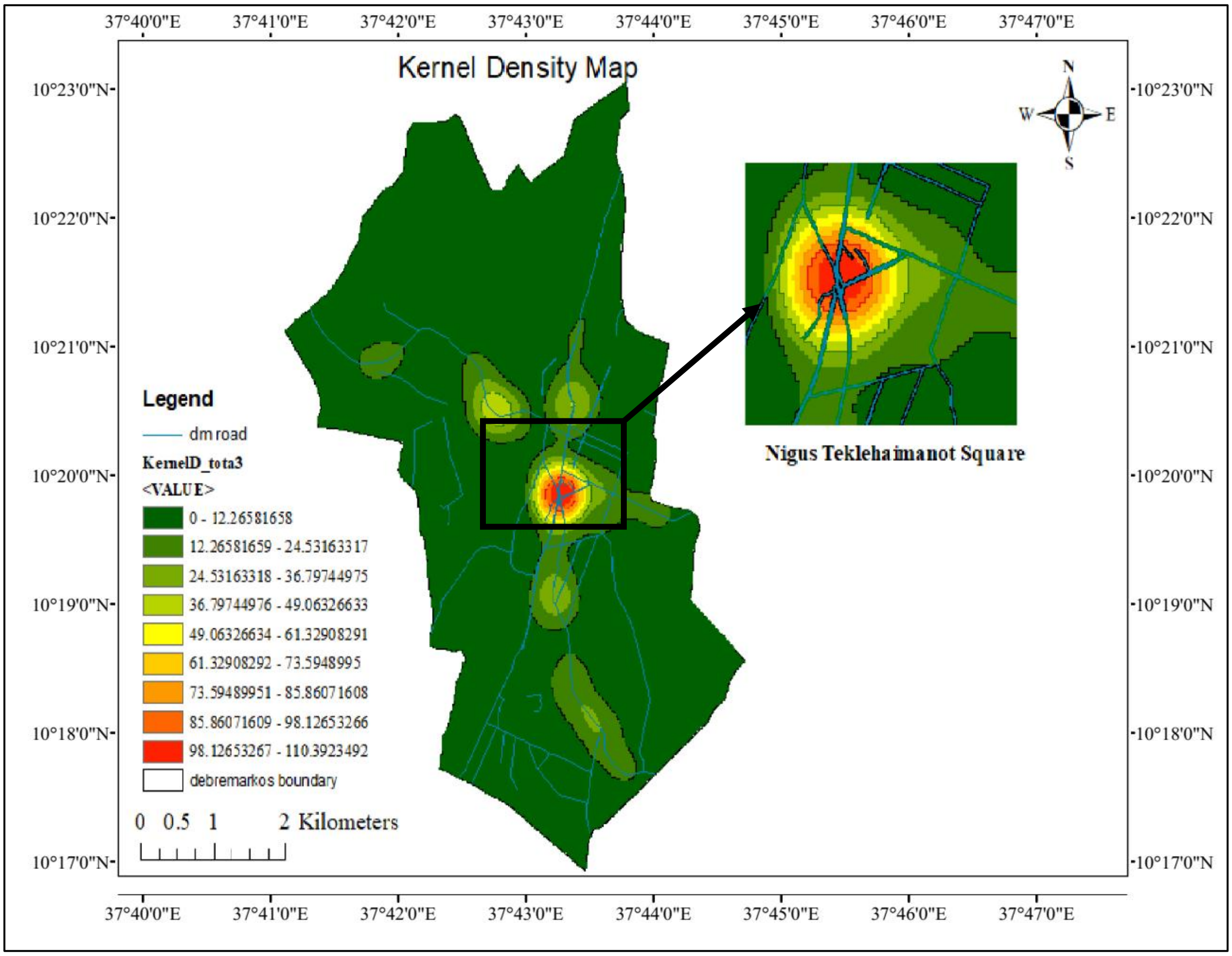

Figure 4. 9: Kernel Density Analysis of RTA in 2008-2012 E.C.

The next step was to determine the spatial spread of road traffic accidents using KDE based on the clusters generated by the collect events tool. The KDE results in Figure 5.14 shows the locations where road traffic accidents are intense based on the kernel function, at an inverse distance and a categorization of inherent data by natural. Hotspot areas identified had a Kernel density value range of 98.13 – 110.39 (Figure 5.14 and its legend). The area is around Gozamin Hotel, Star Business Center, Nigus Teklehaimanot Square and FM International Hotel.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following findings were revealed regarding A GIS Based Approach to Identify Road Traffic Accident Hotspots in Debre Markos Town. The database is modeled to address all conditions and for making ready for further research and analysis.

The accident types incorporated: fatalities, serious, slight injuries, and property damages. Regarding the RTAs severity types, high fatality rates were observed at 33.89% of the total. Corresponding values in respect of: serious injuries, slight injuries and property damages were calculated at 32.22%, 20%and 13.89% respectively.

The results of the research confirmed that RTAs with regard to fatalities, serious injuries and light injuries on the Study Road mostly are recorded drivers age categories between 18 and 30 years. Generally, most of the road traffic accidents have been occurred at age of adultness. The results of the study revealed high RTAs occurred on Monday followed by Tuesday and Saturday.

RTAs varied by hours of the days considered, therefore, the findings of research revealed that crashes reached maximum when pedestrians, passengers, and drivers' frequency of movement increased. Accordingly, most of the highest RTAs in this road segment and at selected Black spot areas during 7:00-8:00 in day light time; 12:00-33:00 evening.

The areas in which the hotspots for RTA occurred in 2008 E.C.-2012 E.C. were Debremarkos Teachers College, stadium and Nigus Teklehaimanot Square, Debre Markos University, Maria Theresa, and Kella.

According to kernel density analysis, the most dangerous location or black spot is around Nigus Tekehaimanot Square.

5.2 Recommendations

- There is need to develop a GIS web-based hotspot location application (app) for road traffic fatal accidents which will be regularly updated as fatal accidents occur.
- There is need for further research on each of the identified contributing factor associated with road traffic fatalities to provide detailed information essential for the revision of the present road traffic policies and road safety awareness programmes aimed at reducing road accidents and fatalities.

REFERENCES

Affum, J.K. and Taylor, M.A. (1997). SELATM – A GIS based program for evaluating the safety benefits of local area traffic management schemes. *Transportation Planning and Technology, 21*, 93–119.

Amare, S.M., and Assegidew,Y.W/Y. (2015). Identifying the Hot Spot Areas of Road Traffic Accidents. *Jordan Journal of Civil Engineering, 9*.

Anderson, T. (2009). Kernel Density Estimation and K-means Clustering to Profile Road Accident Hotspots. *Accident Analysis and Prevention*, 359-364.

Bello, T. (2005). A Stratified Traffic Accident Analysis Case Study: Town of Richardson. *Masters in Geographic Information Sciences*.

Berhane, G. (2015). *GIS Based Assessment of Road Traffic Accidents in Debre Markos (Nazerth) Town.*

Booth, A.J., Fishery-Aquatic GIS Research Group, (2004). Spatial statistic and aquatic geographic information systems. *In: Proceedings of the Second International Symposium on GIS/Spatial Analysis in the Aquatic Sciences*, (pp. 3–44). Kawagoe-town, Japan.

Camara, Monteiro et al. (2001). Spatial Analysis and GIS: A Primer. (*www.dpi.inpe.br/gilberto/tutorials/spatial_analysis/spatial_analysis_primer.pdf*).

Choudhary, Ohri et al. (2015). Identification of Road Accidents Hot Spots in Varanasi using QGIS. *Proceedings of National Conference on Open Source GIS: Opportunities and Challenges Department of Civil Engineering, IIT(BHU).* Varanasi.

Christian, Kwesi et al. (2018). Identification of Road Traffic Accident Hotspots in the Cape Coast Metropolis, Southern Ghana Using Geographic Information System (GIS). *International Journal of Scientific & Engineering Research, 9*(10).

Deepthi, J.K and Ganesh, K. B. (2010). Identification of Accident Hot Spots: A GIS Based Implementation for Kannur District, Kerala Implementation for Kannur District, Kerala. *International Journal of Geomatics and Geosciences, 1*(1).

Elvik, R. (2002). Optimal Speed Limits: The Limits of Optimality Models. *Transportation Research Record, 1818*, 32-38.

Erdogan, Ibrahim et al. (2008). Geographical information systems aided traffic accident analysis system case study: town of Afyonkarahisar. *Accident Analysis and Prevention , 40*, 174–181.

ESRI. (2016). Environmental Systems Research Institute; ArcGIS Pro 1.2 Help 10.4. Redlands, CA.

Ferreira, J.R. and Ferreira, J.C. (2011). Geo-referencing road accidents with Google. *The electronic journal information systems evaluation , 14*, 27-36.

Gibin, Longley et al. (2007). Kernel Density Estimation and Percent Volume Contours in General Practice Catchment Area Analysis in Urban Areas. *Proceedings of the Geographical Information Science Research Conference.*

Gundogdu, I. (2010). Appling Linear Analysis Methods to GIS-Supported Procedures for Preventing Traffic Accidents: Case Study of Kenya. *Safety Science, 48*, 764-769.

Hirasawa, M. and Asano. (2003). Development of traffic accident analysis system using GIS. *In: Proceedings of the Eastern Asia Society for Transportation Studies , 4*, 1193-1199.

Holló, P. et al. (2010). Road Safety Performance Indicators and their Explanatory Value: A Critical View Based on the Experience of Central European countries. *Safety Science , 48* (9), 1142-1150.

Jobin, P. D. (2015). Analysis of road traffic accident hotspots along zaria-kaduna expressway, kaduna state, nigeria".

Jones, et al. (1996). The Application of K-Function Analysis to the Geographical Distribution of Road Traffic Accident Outcomes in Norfolk, England. *Social Science and Medicine , 42* (6), 879-885.

Khan, Qin et al. (2006). Spatial Analysis Of Weather Crash Patterns In Wisconsin. *85th Annual Meeting of the Transportation Research Board.* Washington, USA,.

Kim, Yamashita et al. (2004). Using K-Means Clustering Algorithm to Examine Patterns of Pedestrian Involved Crashes in Honolulu, Hawaii CDRom TRB. Washington D.C., USA.

Lagarde, E. (2007). Road traffic injury is an escalating burden in Africa and deserves proportionate research efforts. *PLoS medicine*, *4*(6), 967-971.

Levine, N. (2004). CrimeStat III: A Spatial Statistics Program for the Analysis of Crime Incident Locations. *The National Institute of Justice.* Washington, DC.

Levine, Kim et al. (1995). Spatial Analysis of Honolulu Motor Vehicle Crashes: I. Spatial Patterns. *Accident Analysis and Prevention , 27* (5), 663-674.

Liang, Mo'some et al. (2005). Traffic accident application using geographic information system. *Journal of the Eastern Asia Society for Transportation Studies* , *6*, 3574-3589.

Lim, Y.L. and Law,T.H.. (2005). Traffic accident application using geographic information system. *Journal of the eastern Asia society for transportation studies, 6*, 74-89.

Manepalli, U.R. and Bham, G.H. (2011). Crash Prediction: Evaluation of Empirical Bayes and Kriging Methods. *3rd International Conference on Road Safety and Simulation.* Indianapolis, IN.

Nyoni, R. (2017). A GIS Based Approach To Identify Road Traffic Road traffic Accident Hotspots In The Greater Durban Town from 2011 - 2015. *Submitted in fulfilment of the academic requirements for the degree of Master of Science in the School of Agricultural, Earth and Environmental Sciences*. University of KwaZulu-Natal, Westville campus.

Sabel, Kingham et al. (2005). Road traffic accident simulation modeling-a Kernel estimation approach. *In: Presented at SIRC 2005 (November), The 17th Annual Colloquium of the Spatial Information Research Centre.* University of Otago, Dunedin, New Zealand.

Shankar, Mannering et al. (1995). Effect of roadway geometrics and environmental factors on rural freeway accident frequencies. *Accident Analalysis and Preventation, 27*(3), 371-389.

Silverman, B. W. *Density Estimation for Statistics and Data Analysis*. New York: Chapman and Hall, 1986

Thomas, I. (1996). Spatial data aggregation: exploratory analysis of road accidents. *Accident Analysis and Preventation*, *28*(2), 251-264.

WHO. (2009). *"Global Status Report on Road Safety: Time for Action".* Geneva.

WHO. (2015). *World Report on Road Traffic Injury Prevention.*

World Life Expectancy. (2018, ecember). etrieved ecember Tuesday, 04 , 2018, from (*https://www.worldlifeexpectancy.com/ethiopia-road-traffic-accidents*).

Xie, Z. and Yan, J., (2013). Detecting Traffic Accident Clusters with Network Kernel Density Estimation and Local Spatial Statistics: An Integrated Approach. *Journal of Transport Geography*, *31*, 64-71.

APPENDIX

Appendix: Actual and compiled RTAs data of from Debre Markos town. (Source- Debre Markos Police Department)

Table A- 1: RTAs severity Data by year

Accident Seg-ment	Types of Severity				
	Fatal	Serious	Slight	Property	Total
2008	11	12	6	3	32
2009	15	12	5	6	38
2010	8	12	9	7	36
2011	12	13	10	6	41
2012	15	9	6	3	33
Total	61	58	36	25	180

Table A- 2: RTAs severity Data by causes of RTAs

Causes of RTAs Severity	Types of Severity				Total
	Fatal	Serious	Slight	Property	
Alcohol	0	1	0	0	1
Addiction	0	0	0	0	0
By driving left side	1	2	1	1	5
By no giving primary driver	2	2	0	4	8
Overtaking problems	1	1	3	3	8
By no give 1st for pedestrians	16	14	7	0	37
Passing in up and down grade	0	0	0	0	0
Passing in curves	0	0	0	0	0
over speeding	32	23	21	16	92
Turing without rule	0	2	0	0	2
Ignoring traffic light	0	0	0	0	0
Ignoring stop sign	0	0	0	0	0
Stopping without rule	0	0	0	0	0
Sleeping/Fatigue	0	0	0	0	0
Thinking	0	0	0	0	0
More lighting	0	0	0	0	0
Excess loading	3	1	1	0	5
Road failer	0	0	2	0	2
Pedestrian failer	2	4	0	0	6
Other	2	4	1	0	7
Not known	2	4	0	1	7
Total	61	58	36	25	180

Table A- 3: RTAs severity data by sex

Sex	Types of severity				Total
	Fatal	Serious	Slight	Property	
M	57	47	33	23	160
F	0	3	2	0	5
Not known	4	8	1	2	15
Total	61	58	36	25	180

Table A- 4: RTAs severity data by age of drivers.

Age of Drivers	Types of severity				Total
	Fatal	Serious	Slight	Property	
Below 18 years	2	1	1	1	5
18-30 years	35	19	23	14	91
31-50 years	16	9	8	3	36
Above 51 years	0	2	2	2	6
Not known	30	8	2	3	43
Total	61	58	36	25	180

Table A- 5: RTAs severity data by Time of the Day

Time of the Day	Amount of Severity
1:00-2:00	3
2:00-3:00	10
3:00-4:00	8
4:00-5:00	7
5:00-6:00	5
6:00-7:00	6
7:00-8:00	16
8:00-9:00	9
9:00-10:00	7
10:00-11:00	10
11:00-12:00	10
12:00-13:00	15
13:00-14:00	13
14:00-15:00	11
15:00-16:00	9
16:00-17:00	12
17:00-18:00	6
18:00-19:00	6
19:00-20:00	5
20:00-21:00	3
21:00-22:00	3
22:00-23:00	3
23:00-24:00	2
Total	180

Table A- 6: RTAs severity data by Day of the week

Day of the Week	Amount of Severity
Monday	45
Tuesday	28
Wednesday	24
Thursday	16
Friday	17
Saturday	28
Sunday	22
Total	180

Table A- 7: RTAs severity data by Land use

Land Use	Types of severity				Total
	Fatal	Serious	Slight	Property	
Rural Village Area	23	15	14	12	64
Agricultural Area	5	7	7	4	23
Around School	3	2	3	0	8
Around Industrial Area	2	0	0	1	3
Around Religious Area	2	1	0	0	3
Around Market Area	3	3	3	0	9
Around Recreational Area	2	5	1	0	8
Around hospital Area	1	1	0	0	2
Around government office	5	4	1	2	12
Around Residential Area	12	15	6	4	37
Other	3	5	1	2	11
Total	61	58	36	25	180

Table A- 8: RTAs severity data by Road Geometry

Road Geometry	Types of severity				Total
	Fatal	Serious	Slight	Property	
Straight	39	44	31	19	133
Slight Upgrade	8	9	0	2	19
Highly Upgrade	3	2	1	1	7
Straight Up and Down	1	0	0	0	1
Slight Reverse Curve	5	1	1	1	8
Exactly Reverse Curve	1	0	0	0	1
Juntel Up Hill	1	0	0	0	1
Juntel Down Hill	3	1	3	1	8
Undefined	0	1	0	1	2
Total	61	58	36	25	180

Table A- 9: RTAs severity data by road intersection type

Table A- 10: RTAs severity data by lighting conditions

Road Intersection Type	Types of severity				Total
	Fatal	Serious	Slight	Property	
No Intersection	47	46	30	24	147
Y-Intersection	6	4	1	0	11
T-Intersection	3	0	1	0	4
Roundabout	1	1	2	0	4
Four leg Intersection	1	3	0	0	4
Five leg Intersection	0	0	0	0	0
Rail crossing	0	0	0	0	0
Other	3	4	2	1	10
Total	61	58	36	25	180

Lighting conditions	Types of RTAs severity				Total
	Fatal	Serious	Slight	Property	
Day light	41	51	23	20	135
Dawn	6	1	0	2	9
Dusk	1	1	1	1	4
Night with good light	1	4	8	2	15
Night with poor light	2	0	1	0	3
Night with no light	7	1	3	0	11
Un specified	3	0	0	0	3
Total	61	58	25	36	180

Table A- 11: RTAs severity data by vehicle service year

Vehicle Service Year	Types of RTAs severity				Total
	Fatal	Serious	Slight	Property	
Up to 1 year	7	2	3	1	13
1 -2 year	4	10	4	1	19
2 -5 year	15	28	18	11	72
5 -10 year	8	8	9	6	31
> 10 year	5	3	0	2	10
Not known	22	7	2	4	35
Total	61	58	25	36	180

Table A- 12: RTAs severity data by experience of drivers

Experience of Drivers	Types of RTAs severity				Total
	Fatal	Serious	Slight	Property	
Have not license	2	2	1	0	5
≤ 1 year	5	7	3	2	17
1 -2 year	6	6	8	5	25
2 -5 year	14	17	11	12	54
5- 10 year	8	9	7	5	29
> 10 year	2	3	3	0	8
Not known	24	14	3	1	42
TOTAL	61	58	36	25	180

Figure A- 1: AndroiTS GPS