ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT

The Influence of Street Pattern Configuration on Road Traffic Accident in the Case of Two Cities: Dilla and Debre Birhan, Ethiopia

by

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A Thesis Submitted to the Graduate Studies of Addis Ababa University

Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Urban Design and Development

June, 2024

Addis Ababa, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis prepared for the partial fulfillment of the requirements for the degree of Master of Science in Urban Design and Development entitled **"The influence of street pattern configuration on road traffic accident in the case of two cities: Dilla and Debre Birhan, Ethiopia"** is my original work and has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged.

Flagote Taye Yifru

Signature: ________________________

June, 2024

Confirmation

This thesis can be submitted for examination with my approval as a university advisor.

____

Tibebu Assefa (Associate professor)

June, 2024

APPROVAL AND SIGNATURE

Addis Ababa University

School of Graduate Studies

This is certifying that the thesis prepared by Flagote Taye, entitled ***"The influence of street pattern configuration on road traffic accident in the case of two cities: Dilla and Debre Birhan, Ethiopia"*** & submitted to graduate studies of Addis Ababa University in partial fulfillment of the requirement for the degree of Master of Science in Urban Design and Development Compiles with the regulation of the University and meets the accepted standards for originality and quality.

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ABSTRACT

The purpose of this study is to find out, whether the variation of street pattern configuration impacts the incidence of Road traffic accident (R.T.A.). Dilla and Debre Birhan cities are selected due to their different street pattern configuration and approximate equal number of population. RTA, in Dilla city is the most common type of injury causes and it is responsible for higher percentage of death among suffering patients. Residents believe that, the cause of this accident is the city's grid iron street pattern configuration. Debre Birhan in the other hand has mixed street pattern configuration and has relatively lower accident rate. In order to assess the influence, initially, identifying hotspot areas, then analyzing road maps of each city to get data about street configuration parameters, representing hotspots on each cities' street maps as well as their parametric maps and selecting the most significant parameters to correlating the variables are followed respectively. Street maps of the cities are converted to axial map to analyze the configuration using tool of analysis, called space syntax via software depth map X. This data collaborating with accident risk rate, states their correlation one to another. Consequently, the study provided accident estimation models based on the parameters of street pattern configuration. For Dilla it is explainable by the predictors $F (6, 4) = 19.03, p <0.05, R2 = 0.966$ and for Debre Birhan $F (7, 3) = 1.705, p>0.05, R^2 = 0.799$. Adjusted R value brought the significance level's explainablity of Dilla's RTA by parameters to 91.5% and 33% for Debre Birhan. Finally it's recommended to create awareness about space syntax for those having no prior experience and highlights the importance of considering space syntax while planning and designing road network, is important factor.

Key Words: RTA, Space Syntax, Dilla city road network, Debre Birhan city road network.

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LIST OF ACRONYMS AND ABBREVIATIONS

A.A.	Addis Ababa
CAD	Computer Aided Design
DV	Dependent Variable
GIS	Geographic Information System
IV.	Independent Variable
RTA	Road Traffic Accident
RTC	Road Traffic Crash
SS	Space Syntax
TMO	Traffic Management Office
UNECA	United Nation Economic Commission for Africa
WHO	World Health Organization
WRI	World Resources Institution

CHAPTER ONE

1. INTRODUCTION

Every research is made to enable people get better utilization out of it. Now a days, Road Traffic Accident (RTA) has become the leading killer of young people and is projected to be the 7th leading cause of death by 2030. RTA is defined as an incident on a way or street open to public traffic, resulting in one or more persons being injured or killed and involving at least one moving vehicle. Therefore understanding causes behind it, should be carefully considered. From the three major causes of RTA, since both driver-based and vehicular based factors can often be controlled, this research will mainly focuses on the uncontrolled factors which is related to the road related factors especially on road pattern configuration. Two cities Dilla and Debre Birhan were taken to analyze road traffic accident with respect to their street pattern configuration using space syntax.

1.1 Background of the study

According to World Health Organization (WHO) data published in 2020, RTA death in Ethiopia reached 31,564 or 5.60% of the total deaths. The age adjusted death rate is 42.41 per 100,000 of population. This makes Ethiopia to be the 19th in the world RTA. Here Table 1 shows previously recorded data of RTA in Ethiopia.

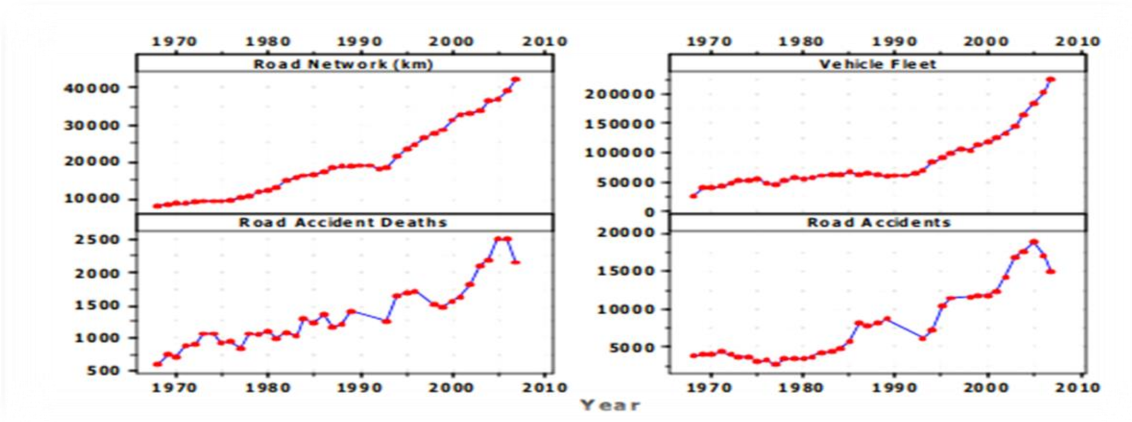
Table 1 – Early annual traffic data of Ethiopia from the year 1993 -2002 G.C.

Year G.C.	1993/ 1994	1994/ 1995	1995/ 1996	1996/ 1997	1997/ 1998	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	% increase 93-02
Fatality	1077	1257	1335	1314	1313	1263	1274	1261	1327	23.20
Serious	1100	1403	1618	1618	1762	1642	1771	1679	1712	55.63
Minor	1100	1263	2044	2044	2444	2173	2120	-	8.63	-
Property	2706	3279	5553	5553	7783	6560	6666	-	15.12	-
Total	6063	7202	10500	10529	13302	11638	11831	2940	3063	-

Source – Traffic management office, 2009

RTA is a serious problem that occurs periodically. Analysis on RTA put forward that the accidents in the past eleven from 2007/2008 to 2017/2018 G.C., were more than 291,577, counting 912,956 km road network and developed motorized vehicles were 68,100. The variation of road network coverage in km was estimated 25,914 and motorized vehicle were 563,003 respectively. Below fig. 1 shows historical RTA alteration through years.

Fig.1- RTA in Ethiopia with respect to time of the year, population number and speed.



Source: (Federal Police Commission and UNECA, 2009)

Between the years 2010 and 2018 the trend of crash shows an increase by about 9 percent on average (UNECE, 2021). Ethiopia's Federal Police Commission reported 3,628 fatal crashes that took place between the year 2019 and 2020. In 2021 and 2022 this rate was reported to be 3,149 (WRI, 2023).

One of Ethiopian city known for higher motorized activity with higher number of RTA is Dilla city. RTA in Dilla city is the most common type of injury causes that is responsible for higher percentage of death among suffering patients. Even though the cause for the occurrence of the accident varies, drives argue that the reason behind it, is related to the street pattern configuration in the other hand, RTA in Debre Birhan is lower than RTA of Dilla even though, both have resembling population number.

Causes of RTA, according to the journal by Global tint written in 2023, can be summarized in to three main categories as driver-related, vehicle-related and road environment-related factors. Driver-related factors are related the physical, mental & temporal status of the driver/the pedestrian. Vehicle-related factors are related to the specifications, age, serviceability and maintenance of the vehicle itself. Road environment factors are related to exposures like weather conditions, pavement types, geographical slopes, street patterns configuration and hierarchy as well as existing urban infrastructures are the major factors.

There are several ways to know if a city has high or low level of traffic accidents. One way is to use spatial data science to predict traffic accident hotspots. Another way is to look at the road traffic injury death rates which are highest in the African region and lowest in the European region. The standard measures used in assessing road safety interventions are fatalities and seriously injured which is referred as severity index rates (WHO, 2023).

The study conducted by Tesfaye in Dilla city, indicated that RTA is the most common type of injury cause and it is responsible for higher percentage of deaths among suffering patients (Tesfaye, 2020).The other study conducted by Tadesse in hospitals of southern Ethiopia supports this experience numerically, out of the total 423 road traffic accident, 213 (50.4%) of RTA was caused by motorcycles (Tadesse, 2018).

Tadesse also stated that the existence of poor road conditions like loose gravel, steep descent, and rough road was responsible for 44.6% of motorcycle accident injury. The odds of motorcycle accident injuries were 50% and 52% less likely to occur during sunny and foggy weather conditions respectively compared to rainy weather conditions relative to the external causes of RTA (Tadesse, 2018).

In this study the RTA’s relation to one of the city’s morphological element, street configuration were investigated by selecting two towns in Ethiopia to know that weather street configuration is a cause for RTA or not.

1.2 Problem Statement

In the present days while living in a city demands movement from one place to another, utilizing different modes of transportation is inevitable. Due to this, transportation related accidents are relatively frequent in side cities compared to countryside. The rate even the rate varies from cities to cities. The reason for the variation can have different reasons and its reason related to street pattern configuration has given low attention. To illustrate this aspect more two cities Dilla and Debre Birhan are considered.

RTA in Dilla city is the most common type of injury causes and it is responsible for higher percentage of death among suffering patients. Even though the cause for the occurrence of the accident varies, drives argue that the reason behind it, is related to the street pattern configuration. To strengthen their argument, they state that the collisions occurring at intersections is due to its street pattern configuration.

In the other hand, RTA in Debre Birhan is comparatively lower than RTA of Dilla even though, both have resembling population number. Investigating whether there exist relationship between street pattern configuration and RTA in both cities of which, one has grid iron street pattern configuration and the other having mixed type of street pattern configuration proceeds.

1.3. Objective of the study

- **Main objective :**
  To identify the influence of street pattern configuration on road traffic accident.
- **Specific objectives :**
  1. To determine road traffic accident rates of the cities and their hot spots.
  2. To compare the rate of road traffic accident occurring due to street pattern configuration.
  3. To predict upcoming road traffic accident rate of the cities.

1.4. Research question

- **Main research question :**
  What is the impact of street pattern configuration on road traffic accident?
- **Specific research questions :**
  1. What are road traffic accident rates of both cities and locations their respective hotspots?
  2. How to compare the rate of road traffic accident occurring due to street pattern configuration?
  3. How to predict road traffic accident rate of the cities?

1.5. Significance of the Study

For the perspective of the societies or the residents, it creates understanding whether there is relationship among street pattern configuration parameters and RTA, then take measures to keep their safety. For researchers and academia, the study can be used as a resource for further study. For government bodies, firstly for those having no awareness towards the concept and relation of R.T.A. and street pattern configuration, it provides a means of understanding. Then using this as a reference, further studies can be made. Lastly, planning and designing can be encounter using the study as a reference.

1.6 Scope of the Study

The scope is bounded with in context of the current jurisdictional boundary of Dilla and Debre Birhan city. Thematically, on the influence of street pattern configuration on road traffic accident indicating parameters and in time frame of between 2008 to 2023.

1.7 Limitation of the Study

Whenever performing regression analysis, some variables have to be omitted. In this case, driver and vehicle related factors take the major portion and even some of road-environment variables' such as whether condition, land use type, pavement type and other urban traits are considered to be constant.

1.8 Organization of the study

The study report has five chapters namely introduction, literature review, research methodology, result & discussion and conclusion & recommendation. The first chapter deals about the basic overview of the paper which includes introduction, background, problem statement, objectives, research questions, significance of the study, scope of the study and limitation of the study. The second chapter deals with the review of literature. Theoretically, reviews about Road traffic accident (RTA). Contextually, it reviews local RTA literatures. The third chapter deals with research methodologies. It begins by describing study areas & then research design was discussed. Sampling techniques, methods of data collection & analysis on street configuration parameters & accident indicating indexes individually. The fourth chapter explains, results found through summary of questioner, interpretation of data from government bodies and software analysis result of G.I.S. and Depth map x. It starts by pointing out the hot spots of RTA and then it investigate the influence of street configuration on accident indicating indexes and discussing the result found and finally the correspondences and alterations of the study with other studies are discussed. The fifth and the final chapter deals with the conclusion and recommendation of the research given with respect to the study finding.

CHAPTER TWO

2. LITERATURE REVIEW

The literature review section of the study goes through earlier theoretical and contextual literature related to road traffic accident and space syntax. The review covers different definition of traffic accident from most reliable sources and terms related to RTA specifically with respect to definition related to the context of urban design and development, causes of road traffic accident, analyzing tool of space syntax.

2.1. Theoretical Review

2.1.1. Road traffic accident (RTA)

Some of the sources like World Health Organization define Road traffic accident as, a fatal or non-fatal injury incurred as a result of a collision on a public road involving at least one moving vehicle (WHO, 2018), the other source Safe Car Guide, defines road traffic accident as "an accident that occurs on a way or street open to public traffic, results in one or more persons being killed or injured, and at least one moving vehicle is involved and also it defines road traffic accident as a collision between vehicles, between vehicles and pedestrians, between vehicles and animals, or between vehicles and fixed obstacles (Guide, 2004). Even though they defined RTAs in their own ways, the definitions generally have the same meaning.

2.1.2. Causes of road traffic accident

The major causes of RTA are categorized in to three main categories as internal factors, vehicular factors and external exposures.

A. **Driver-related** – this factors are sometimes referred as behavioral factors because this are related to personal character. Driving mechanisms and style , anger management problem, temporary or sudden daily conditions, attention diversions, driving while drunk, wearing belts and generally disobedience of traffic law, rules and regulation can be considered (Globaltint, 2023).

B. **Vehicle-related factors** – these factors are concerned with the vehicle itself to associate overall appearance and functionality. Appearance is accompanying with the vehicle's specification and age where as functionality is associated with serviceability and maintenance (Globaltint, 2023).

C. **Road environment factors –** External factors are also known as environmental exposures that are responsible for occurrence of RTA. It consists of both natural and man-made features. The natural feature is associated to the topography, climatic or weather condition of the area. The man made features include road hierarchy, road pavement, street pattern, existing urban structures, physical obstacles, socioeconomic factors and cultural factors are the main features. (Northernplainsjustice,2020)

- **Topography –**Land forms considered as topography includes hills, mountains, valleys, and plateaus and these can be represented using two dimensional topography representing mechanism to convey information about its physical appearance. The comparative spacing measured between these lines shows the relative slope of the certain land surface (Worldatlas, 2019).

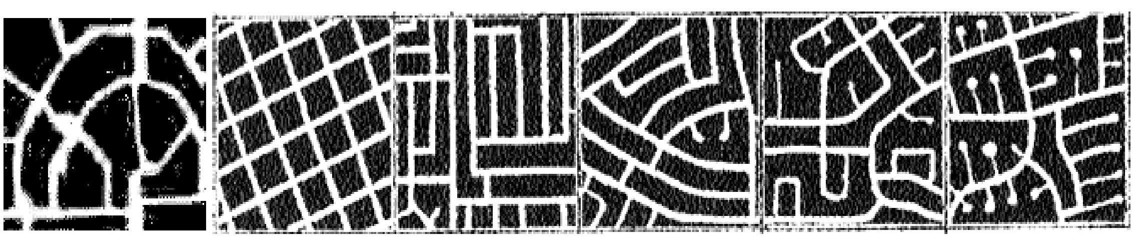
- **Climatic or weather condition** – the climatic condition of urban area can be denoted by different natural and an avoidable factors like dust, fog, rain conditions and so on. Dust can contribute to the occurrence of RTA by blocking clear visual contact towards the upcoming vehicle resulting collision between/ among vehicles. The presence of fog with in the atmosphere can contribute to RTA in the same manner as that of dust by blocking the visual contact. Besides the direct effect of climatic condition, Indirect effect like sun glare from buildings with aluminum and glass cladding and glare from front vehicles, has vast effect in harming the driver safety and health in both temporarily, causing traffic accident and permanently, impairing the sight of the driver (Zou et.al, 2018).

- **Road hierarchy -** The road system has different flow patterns, with some roads designed for faster flow and others designed for slower flow. The functional hierarchy of the road system is based on the level of importance the roads represent to the road system as a whole. This importance can be associated with the number of traffic lanes, with the position of the roads or with the accommodation potential of vehicle flow (Designhub1610, 2021).

- **Road pavement** – Different road finishing materials have different level of slipperiness. Asphalt and tiles have higher tendency of slipperiness since their imperviousness is higher. Whereas cobbles are moderately impervious and gravels are pervious (Parsa, 2020)

- **Road pattern** - When roads are provided to facilitate and interconnect branch roads with main road and aligned in a certain patterns as such as rectangular, radial, hexagonal and the like for proper traffic management it is called road pattern. There are different types of road patterns like radial, grid iron, parallel layout, loop and lollipops. Lollipops on stick and mixed types are hybrids of the former pattern. These different types of configurations are shown below in fig. 2 respectively (Riffat, 2008)

Fig.2.1. Street pattern configuration types



Source: (Southworth & Joseph, 2003 and radial configuration from easy map work ,2011)

Marks explained the accident rate of different street pattern configuration and concluded that grid iron pattern has greater accident rate per year unlike other types of street pattern configuration. (Marks, 1957)

- **Existing urban features** – are features that exist on that specific urban area and have contribution on the rate of road traffic accident. Grid iron pattern unlike other kinds of patterns has more land devoted to streets, as well as the capacity to hold more blocks, intersections, and points of access than the other types. Although the grid maximizes infrastructure costs, this pattern offers the shortest trip lengths and the largest number of route choices of any of the patterns. It also creates the most walk-able neighborhood. This kind of pattern was dominated in the pre-world War II era when pedestrian travel was high, auto ownership was relatively low, and street construction standards were less automobile oriented than they are today (worth & Owens, 1993). Besides having all this characters as grid structure, it is important to consider the land use, demographic aspect, population and vehicular density and infrastructure to visualize its contribution to RTA. Practicing hyper-caution when intersecting should become critical element of safety plan. Often, there's a lot happening on intersections, including traffic that enters and exits from nearly every angle, traffic lights, signals, pedestrian crossings, and more.

- **Physical obstacles –** Physical obstacles in the road are a common cause of a multiple-vehicle crash, especially on main roads and highways. Positive barriers on the main roads and highways are placed to reduce the speed of the approaching vehicle and prevent upcoming accident. This barriers sometimes made out of the standard. This little variation of barriers combined with Speeding can also be the cause of accident. Conjunction is also a reason that makes it difficult for a driver who sees an object in the road ahead to slow down, stop or take fast reaction. Negative barriers are different from positive barriers. It sometimes referred as obstacles simply that can also be the reasons for RTA (Onisr, 2019)

- **Socioeconomic factors and Pedestrian character** – are economic activities that are shaped by social process, These are mostly takes place on the side of the road, whenever there is more activity taking place, the space expand towards the roads and it will be utilized as a place of trade and exchange in most parts of the country but these activities require a place of their own. Jumping over lane separator fences and donkey pathing can be seen as reason to severe RTA (Haghighi et.al, 2020).

2.1.3. Road traffic accident indicating parameters

Accident can be represented in terms of the following terms.

Accident risk: It is the number of accidents per 100,000 people. Simply referred as crash rate, is the number of crashes recorded on a specific area for a specific time.

According to the World Health Organization, The risk of dying as a result of a road traffic injury is highest in the African Region (26.6 per 100,000 population), and lowest in the European Region (9.3 per 100,000) . The average rate was 17.4 per 100,000 people. (WHO, 2015)

Accident severity index: measures the seriousness of an accident. It is therefore defined as the number of persons killed per 100 accidents. Severity index determines the weight of a single crash. So, to accurately identify high or low clustered zones, it is important to incorporate crash severity index in hot spot analysis. The concept of crash severity index is accrediting the higher value to severer crashes based on the expenditures. Many past studies associated crash severity weights in crash hot spot analysis. The crash severity index developed by the Roads and Traffic Authority of New South Wales was utilized in this study. In this system, each crash incident is provided a value of 3.0 for fatal, 1.8 for serious injury, 1.3 for slight injury and 1.0 for property damage. The crash severity index of each zone can be computed by the following equation. (Road Traffic Accidents in New South Wales–1997-Statistical Statement: 1999).

Low-income countries now have the highest annual road traffic fatality rates, at 24.1 per 100,000, while the rate in high-income countries is lowest, at 9.2 per 100,000. (WHO, 2023)

$$SI = 3.0 \times X_1 + 1.8 \times X_2 + 1.3 \times X_3 + 1.0 \times X_4 \quad \text{------------------------------------} \quad \text{Eq. 1}$$

Where X_1 is fatal crashes, X_2 is serious injury crashes, X_3 is slight injury crashes, X_4 is Property-damage-only crashes.

Few of the foremost examples of cities that have used space syntax include, City Changchun, SS proposals included the introduction of a number of spatial linkages which supported an integrated grid with strong regional connections & strong internal structure. City of Jeddah, the previous unplanned Settlements created sleek transitions from city-wide access to local routes inside the settlements; hence reconnecting the settlements to the larger city while preserving their unique character and sense of place.(Spacesyntax.com)

2.1.4. Characters of road traffic accident

Traffic accident can be expressed in terms of three main characters, Space, time street configuration. As explained above, in the topic of external causes of road traffic accident, most of the sub topics fall under the category of street configuration. Therefore the character can be determined in terms of space, time and street configuration (Fikadu, 2021).

i. **Time** – RTA can be highly influenced by seasonal or temporal pattern of the event.
ii. **Space** – the place of occurrence for a certain accident entails as the degree, kind, reason and also time of occurrence.
iii. **Street configuration** – the arrangement of the street with respect to the built environment is considered to be the other physical character to determine road traffic accident. This can be analyzed using space syntax.

2.1.5. Space Syntax as a theory and tool of Analysis

Space syntax (S.S.) is a theory and method for assessing spatial interactions using a range of objective metrics that was developed by Hillier and Hanson. The relationship between each roadway segment and the other public spaces in a constructed environment is measured by space syntax. Each street segment's proximity to other street segments is measured using space syntax. Additionally, each street segment's ability to pass through or between the others is evaluated. Different accessibility potentials are represented by the street networks' to- and through-movement potentials (Van Nes & Yamu, 2021).

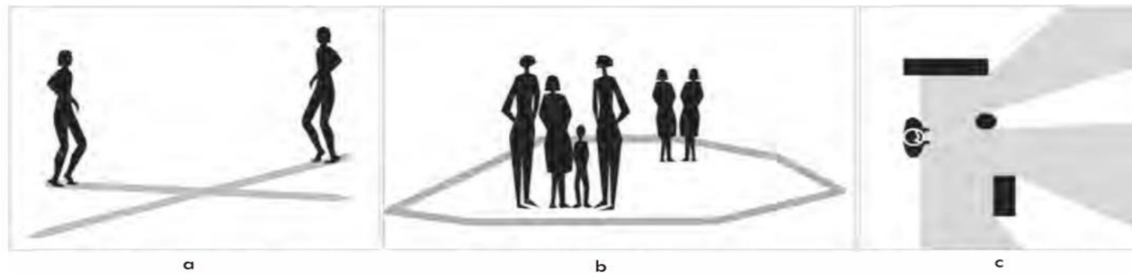


Fig. 2.2: The basic elements of space syntax. The axial line for movement (a), the convex space for interaction (b), the isovist field for orientation(c).(Nes & Yamu,2021 The smallest unit in a street network is the axial line, which disregards "segments," that are the smallest spatial units.

Axial maps do not allow for sophisticated angular examinations. A segment line is derived from axial lines via the intersection of axial lines. Space syntax researchers currently employ segment maps much more frequently than axial maps, sometimes not at all (Shrestha, 2019). The road center line map has recently been used to analyze vast metropolitan areas, entire regions, and even entire countries. When working on a metropolitan or regional scale, the case-based routes are simple to aggregate from the road center line. Sometimes a "hybrid model," which combines axial maps and road center lines, is employed (Nes & Yamu, 2021).

According to Hillier and Dettlaff's study, there is a connection between vehicular and pedestrian mobility and the physical layout of the street network. The SS aims to describe several aspects of links between the morphological structure of artificial environments and social structures and events. Understanding how people interact with space is crucial because it enables to predict how user experience will be impacted by spatial design. According to Hillier and Vaughan, the city is described as the physical layer's penetration into the social layer. A approach for sustainable development that uses spatial syntactic analysis can assist in striking a balance between an area's social, economic, and environmental aspects.

The effect of traffic volumes on traffic safety has been examined by Scholars, but they reported different conclusions. Some studies reported that streets and intersections with high volumes were found to be associated with increased crash incidence (Abdel-Aty & Radwan, 2000), while others found them to be associated with significantly fewer crashes (Obeidat & Al-Hashimi, 2015).

Another study by, (Rifaat et al., 2009) found that contemporary patterns with loops & cul-de-sac were associated with lower crash rates than gridiron patterns. Lovegrove and Sun (2010) also found that irregular patterns were safer than grid, & cul-desac patterns. These studies draw attention to the notion that streets organization within the urban form can either limit or regulate the potential encounters among different vehicles or pedestrians. For example, gridiron patterns might increase the number of traffic causing more accidents to happen unlike limited access patterns.

Researchers in Space Syntax have developed a number of metrics with the aim of defining & analyzing social behavior (Al Sayed, 2014). The most significant are as follows:

1. **Connectivity (complexity):** Density of linkages and directness of links in a path or road network are referred to as connectivity. A network of roads or paths that are well-connected has lots of short linkages, lots of intersections, and not too many dead ends. A more accessible and robust system is produced when connection grows, resulting in shorter travel distances and more route options that enable more direct transit between places. An index called connectivity can be used to measure how well a network of roads connects different locations. .

$$\mathrm{ctrl}_i = \sum_{j=1}^{k} \frac{1}{Cj} \qquad \text{------------------------------------} \qquad \text{Eq. 2.}$$

Where, k = number of direct connections,

Cj = connect value of the directly linked line ‘j’ (Hillier, 1984)

2. **Mean Depth:** Topographical distance is usually expressed by distances, which denote it as "depth or D." Steps are used to measure depth. There is one depth between two intersecting lines. In all other cases, it is one plus the maximum number of lines that need to be coasted to move from one line to the next. The Total Depth, or DT, of a line is the sum of its depths to all other lines on the axial map. The DT Value is difficult to work with and has a tendency to get very huge. As a result, the analysis uses the MD or Mean Depth of the lines.

$$MDi = 1/(n-1)\sum_{j=1}^{n-1} dij, i \neq j$$ ------------------------------ Eq. 3

M distance of the i-th axis from all the other n – 1

3. **Bendiness (Bend density, BD):** The concept of "curviness" or "bendiness" is often defined as the total variance in horizontal direction along a stretch of road (McLean 1989). The quantity of bends on a road per kilometer is known as bend density. This only contains vertices that are not also nodes in its analysis; it does not include the bends at crossings. The following formula can be used to determine bend density (Megan Fowler, 2007):

BD = (Nv-Nn) / (a+b+c+d) -- Eq. 4

where: Nv = number of vertices within the study region;

Nn = number of nodes within the study region; and

a,b,c,d = road link lengths.

4. **Integration:** Using shortest paths, integration calculates the number of turns required from one street segment to all other street segments in the network. There is just one turn needed for the first intersecting segment, two turns for the second, and so forth. This evaluates a street's level of network integration, or centrality. 'Most integrate' street segments are those that need the fewest turns to connect to all other streets; they are typically depicted using brighter hues, such red or yellow.

According to theory, the integration measure indicates how difficult it is to access a street cognitively and is frequently used to "predict" the likelihood of a car collision occurring on that street (Teklenburg & Timmermans, 1993).

$$0 \leq ND_i := \frac{2(MD_i - 1)}{k - 2} \leq 1.$$ -------------------------------- Eq. 5

Where, MDi is given by the total depth divided by

k−1, k is the total number of nodes in the graph

Two Space syntax parameters, Local and Global Integration, specify how a line integrates with the other lines in the graph. By using Relative Asymmetry (RA), it can be quantified. The ratio of the system's actual depths from a given line to its predicted depth is known as relative asymmetry.

5. **Straightness:** Straightness is defined as the same direction throughout its length, having no curvature or angularity. Straightness, originates from the idea that the efficiency in communication between two nodes i and j is equal to the inverse of the shortest path length δi,j . The straightness centrality of node i is defined as:

$$C_i^S = \frac{\sum_{\substack{j \in V \\ j \neq i}} \frac{\delta_{i,j}^{Eucl}}{\delta_{i,j}}}{n-1}$$ -- Eq. 6

Where CSi = Straightness centrality of node i &ij = Cumulative no of straight link between nodes i and j

LijEucl = the Euclidean distance between nodes i and j,

N = all nodes in the network

Vehicle accidents are caused by both very high and very low levels of straightness, which are expressed by the straightness values.

2.1.6. Space syntax and road traffic accident

Academicians have looked into the connection between space syntax and accidents. Road network configuration, as determined by space syntactic parameters including choice, connectivity, and integration, was found in one Sri Lankan study to be substantially correlated with road traffic crashes (RTCs). The study discovered a significant association between RTCs and the local level variance of integration values, connectivity, and global level choice. To build a sustainable built environment, the authors recommended that preventive measures include traffic pattern-specific methods in road network planning and design (Hillier, 2007).

According to a different study, space syntax can be used as a measurement instrument to examine how urban layout affects patterns of automobile and pedestrian traffic. The study suggested that space syntax can be used to identify areas with high accident rates and to develop strategies for improving traffic safety (Bushra et al, 2017)

2.1.7. Land use and road traffic accident

Land use can be a factor that contributes to road traffic accidents. Studies found that traffic accidents on roads in urban centers and public institutions were particularly associated with congested, limited, and centralized commercial land use and unbalanced traffic generation and attraction land use. Other studies also found that most crashes have occurred in commercial and terminal land-use type. (Hillier et.al, 1993).

Areas with high-density residential land use have been found to have higher accident rates than areas with low-density residential land use. Similarly, areas with high commercial land use have been found to have higher accident rates than areas with low commercial land use. This is because high-density residential and commercial land uses are associated with higher traffic volumes and more complex traffic patterns (Hillier & Hanson, 1989).

2.1.8. Road traffic accident Impacts

From the definition, it is understandable that, this problem is rising in number due to the quest and desire of people who are heavily influenced by the needs of motorized vehicles which is related to urbanization leaving all the consequences behind.

The consequence of road traffic injuries has both direct and indirect impact on individual, families, companies, society and even the country at large. It is certainly true that even when only a person is involved in a road traffic accident, the whole household will be affected financially, socially and emotionally. Generally, these impacts can be categorized in to four main groups as property damage, minor body injury and serious body injury and fatal accidents (WHO, 2023)

Property damage accidents in this case causes only material goods destruction and also considered the simplest type of accident that could be expected (Bieber, 2023)

Minor body injury are relatively lighter injuries, harming the body in a way as of cuts, scrapes, scratches, and punctured skin. These types of injuries are often left to heal its self with a little follow up or no follow up at all. Serious body injury which are heavier in nature than that of a minor body injury and it is much more severe demanding more serious, frequent and close follow up. Typically, a serious bodily injury involves noticeable deformity, loss or impairment of the function of a bodily parts or organ and may rise further higher up to substantial risk of death. (Armstrong, 2023).

The last category is fatal accidents. It is irreversible cessation of all biological functions that sustain an organism. It is also the third and the final stage of road traffic accident's impacts. People strive and keep running to win over life. But some time they will be taken by this irreversible cessation (Preventionweb, 2019)

According to WHO, every day more than 3000 people die from a road traffic accidents. Developing countries account for 90% of global road traffic deaths in other term Traffic accidents are still responsible for 1.3 million annual deaths and 50 million injuries all over the world. In Africa this is registered with road-traffic mortality rate of 26.69 deaths per

100 000 inhabitants per annum. This with respect to global rate of 17.5 per 100, 000 population per annum, is considered very high. Ethiopia owns only 2% of the world's vehicles, it contributes 16% to the worldwide death (WHO, 2023)

Impacts rise from urbanization require urbanized solutions, solutions that consider key points designing urban areas like sustainability, safety, convenience, comfort, pleasure, playfulness and beauty. These key points with respect to traffic accident are important to highlight and check what is missing from a certain urban area and to respond accordingly.

The design of urban area, towns, cities, neighborhoods, and social systems greatly influences the social, economic, environmental, and health outcomes of populations. Urban design is intended to be planned and designed to reply for certain urban problems here in this case it should respond to road traffic accident's safety. Cities can design streets and the built environment to be safer, not only in new communities, but also by transforming existing neighborhoods and streets. Considering a comprehensive street network and the hierarchy of its users can reveal opportunities not only around critical transit corridors, but in the surrounding neighborhood streets. This is called a "safe system" approach to traffic safety. It sets targets and works to change the road environment to reduce injuries and fatalities (Bliss & Breen, 2009).

2.1.9. Road traffic accident and time of occurrence

Time's effect on traffic accidents is a complicated topic that depends on a number of variables. A systematic review found that there is conflicting evidence regarding how time affects the probability of traffic accident. The evaluation looked at 24 papers that provide quantitative analyses of time's impact on outcomes related to road safety. Road traffic accidents, injuries, and deaths were the main outcomes of interest. Time transitions were the subject of 12 studies that looked at long-term effects and 17 studies that looked at short-term effects. While the results of the long-term research suggested a favorable benefit of time, the results of the short-term studies showed mixed results. Time, but, cannot be held fully responsible for this since a number of traffic accident risk factors change over time. (Abdissa et al , 2020.)

2.2. Contextual review

There are some researches done on topics related to road traffic accident in Ethiopia but it has no visible attempt to analyze using space syntax. Although the topic of space syntax in the context of Ethiopia, is a recent topic. Here are some reviews of Ethiopian researches in relation to space syntax.

The study entitled Urban conservation of the historic city of Jugol, Ethiopia: a syntactic approach, used space syntax as an analytical tool to alleviate the segregation and absence of accessibility difficulties. The changes in city's structure were found related to Segregation and absence of accessibility. Current expansion of the city off the fence to west, is related to the city's integration core to the west, this weakening city's accessibility. Many options were checked and the alternative that increases the city's accessibility and eases its isolation was identified (Khalil et al., 2016).

Mulushewa in her study that is referred as Identifying Streets from roads of A.A., Using Space Syntax Analysis Tool, she was able to find roads that have the potential to be changed in to street to minimize the conjunction level of Addis Ababa's city roads through the analyzing tool Space Syntax. Then finally, she was able to come up with a certain urban road design proposal that can be done in the future whenever road widening is required (Mulushewa, 2020).

The study that was titled as the spatio-temporal pattern of crime in Arba Minch City, Ethiopia was done in the sense of understanding the conducive environmental and socioeconomic factors by identifying spatial and temporal patterns and hot spots in urban environments of Arba Minch city. Crime hot spots and crime trends in the city were identified after doing emerging hotpot analysis. Auto correlation analysis was made to identify the relation between land use and street pattern with crime and finalized by providing recommendations (Fikadu, 2021).

The research that is called **“**Space- syntax as a tool for place making by restructuring public spaces within mixed-residential areas of Addis Ababa, the case of Meskel flower district.” Argued, the main current problem in that study area is the existence of fewer open spaces when compared to standards. As of Sileshi, “The current existing open spaces are not providing the intended services and most of them are left over spaces without any function and some are even used for emerging slum housing. The general objective of this study is identifying spatial capital of the neighborhoods and redesign open spaces by applying Space- Syntax as an analytical tool (Sileshi, 2021).

The study “Characterizing the Street Network of Adama City for Urban Vitality Using Space Syntax” is intended to illustrate the street network of Adama city and regulate how it affects the city's vitality. The outcome of the analysis demonstrated that Adama is greatly integrated at the center, that shows the center of the city is more vital and invites people. To increase the vitality of the city as a whole and to control disruptive behavior needs urgent enhancement is mainly in required, segregated area (Bogale**,** 2022).

In the previous studies made in Ethiopia were focused on, either road traffic accident or space syntax but not both. This shows that, as there is a gap of knowledge towards the relation between street pattern configuration and RTA. The street pattern configuration will be analyzed using space syntax to investigate, whether there is relation between street pattern configuration of both cities and their respective RTA rate.

CHAPTER THREE

3. RESEARCH METHODOLOGY

This chapter mainly explains how the study was conducted, the applied methods and techniques in data collection, and the reasons as to why they were used according to the research aims and main objectives of the study.

3.1. Description of study area

The study is conducted in two cities Dilla and Debre Birhan. Dilla is the capital of Gedeo zone and located at 356 km away from Addis Ababa, and 90km from Hawassa. The city is located at the co-ordinate approximately 6^0 4' North Latitude and 38^0 10' East Longitude. The shape and growth of the town follows the corridor along the Ethio – Kenya main international route. The city includes three district sub cities/ Kifle Ketema/ and covers an area of 21.4 km^2 of land with average elevation of 1,600 meters above sea level. The population number according to the city administration is estimated to be 120,342.

The other city is Debre Birhan which was initially the administrative city of Semen Shewa zone & now it is established as metropolitan city which is directly response to Amhara region. Debre Birhan is located 130 km away from Addis Ababa & has an elevation of 2,840 m, with a geographic coordinate of 9° 41' 0" North, 39° 32' 0" East. The city covers about 14.28 km^2 and according to city facts.com, it's population by 2030 is estimated to be 127,492.

The street pattern configuration of Dilla has more of grid pattern with very small square and rectangular blocks. Most of the local streets are very narrow. Most of local streets are generally directed to connect to or branch outs from the major streets and also the principal street which crosses the city is very narrow. Where as in the case of Debre Birhan the street configuration is more of organic type having a mixed configuration. There are also more vehicle than that of Dilla and the congestion is relatively higher.

The figure below represents locations of Dilla, Debre Birhan and the capital city, A.A. For more detailed analysis micro level RTA investigation was made.

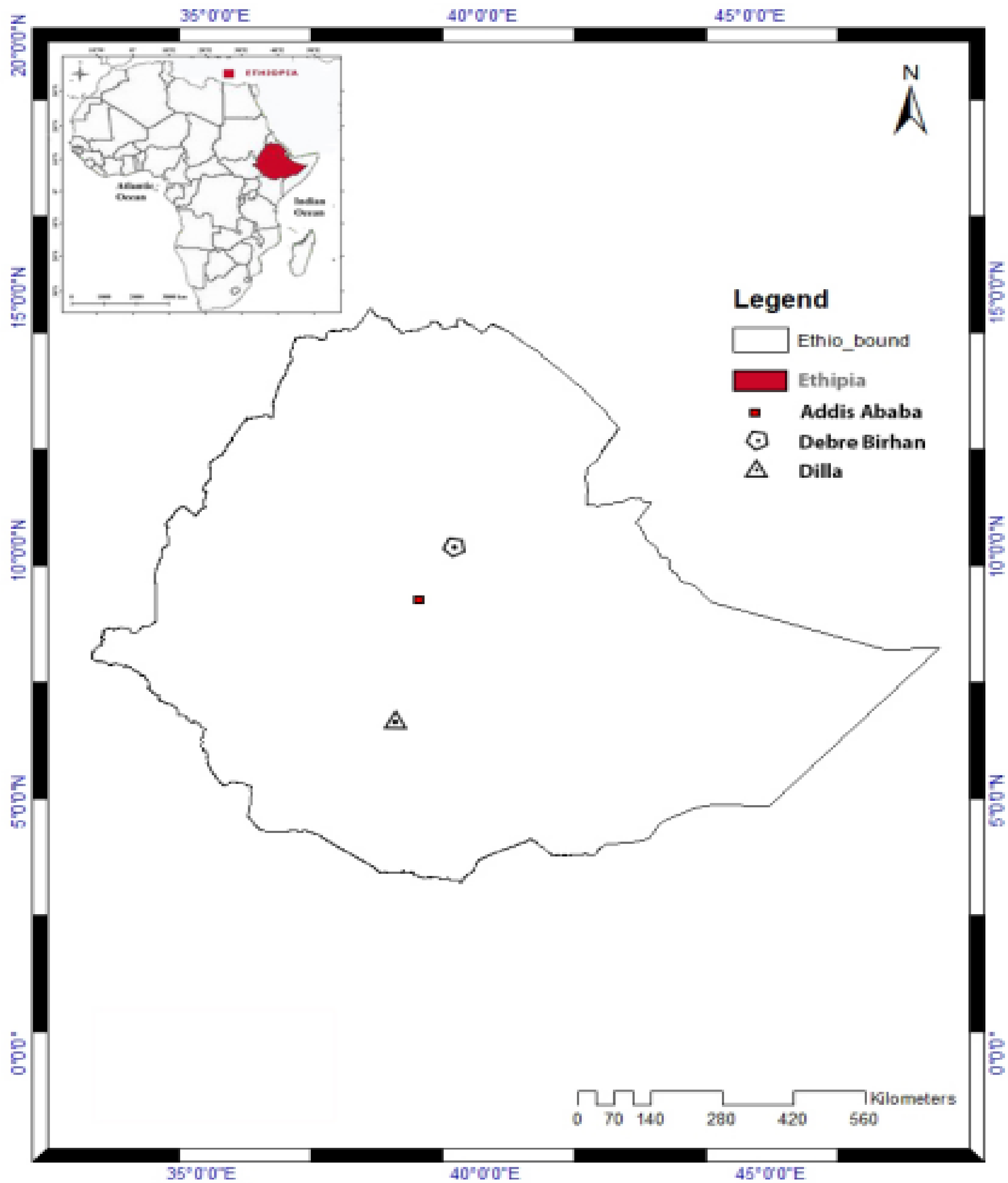


Figure 3.1. Location map of the study areas (Source: illustrated by the author, April, 2023)

3.2. Research Design

Since this study intended to explore the influence of street pattern configuration, it used a concurrent research design means that, the collection of qualitative and quantitative data simultaneously. The overall research design flow is illustrated in figure 3.2 below.

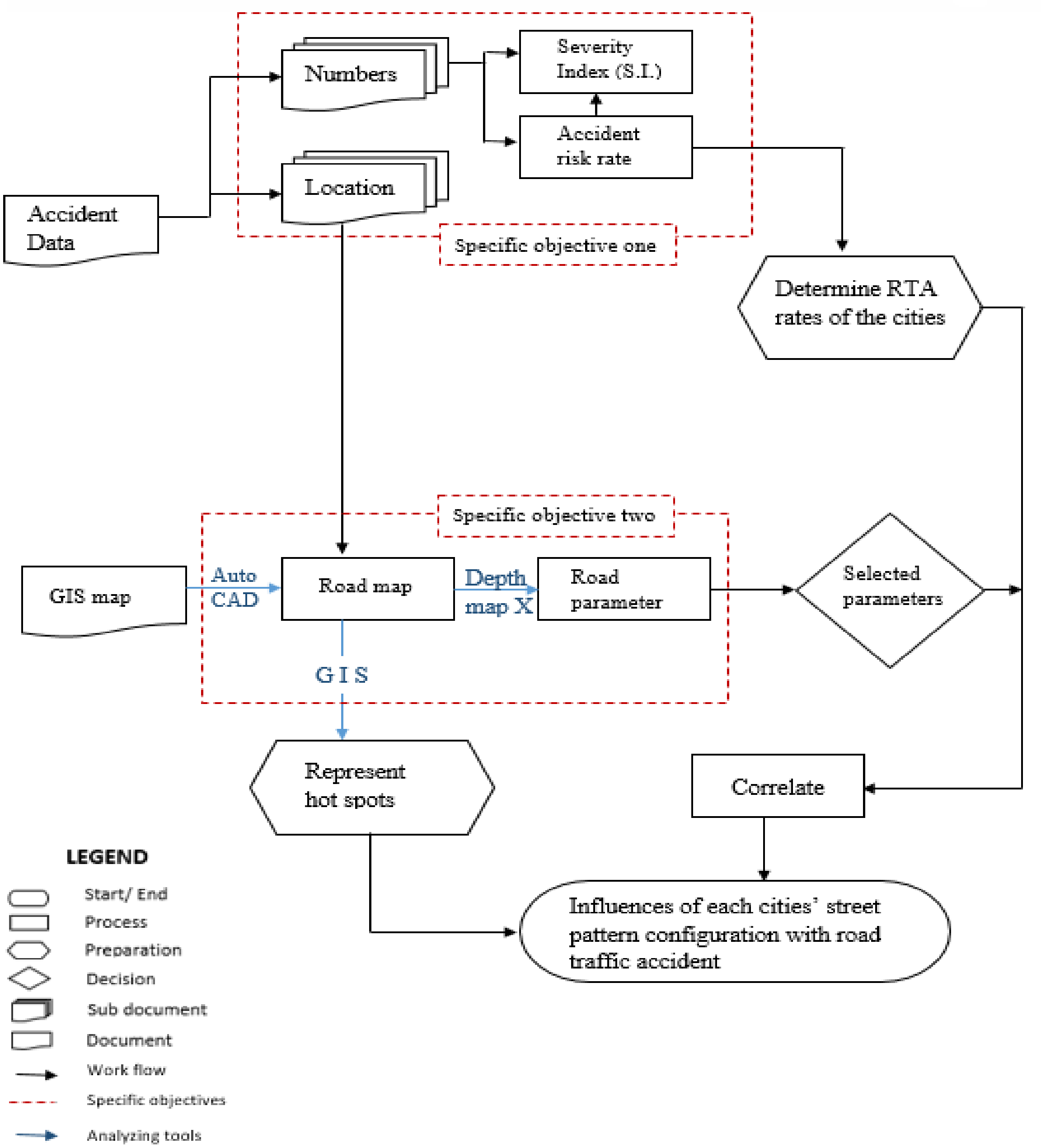


Figure 3.2. Research design flow of the study.

3.3. Data Source

Data concerning hot spots are collected from traffic polices through interview and socio demographic data and spatial data were collected from administrative offices of both cities. This Data were collected from the respective cities administrative office and cities road and transport office (R.T.O.)

3.4. Tool of Data Analysis

Tools of data analysis bases on each specific objective is explained as follows.

1. To analyze the accident risk rate and hotspot locations simple counting was used. Arc GIS is the other tool that used to point out the most frequent traffic accident areas through graphical representation.
2. To analyze the street pattern configuration, first, raw data of each city, in the form of Arch GIS was converted to Auto CAD file. From many layers of the Auto CAD file, only the clipped road maps in dxf file was saved. Depth map X, uploads the dxf file to analyze the street pattern configuration. This provides, important parameters of space syntax.
3. To correlate and formulate SPSS is used.
4. Adobe illustrator and photo shop is used to illustrate and enhance the graphical inputs to change it to descriptive out puts.

3.5. Method of Data analysis

3.5.1 Accident Rate - Measures how many accidents have occurred in an area over a given period of time. Here zones are classified based on availability of proximate number of road infrastructure and the physical appearance of the cities. Table 3.1 below shows what is recorded in Dilla and table 3.2 shows Debre Birhans city’s accident rate.

Table 3.1 Accident Rate of Dilla city from the year 2022/23 G.C.

Record	Fatal	Serious	Light	Property	Total
2022/23	6	2	4	98	110

(Source - Road Traffic office of Dilla city, 2022/23)

Table 3.2 Accident Rate of Debre Birhan city of the year 2022/2023 G.C.

Record	Fatal	Serious	Light	Property	Total
2022/23	38	27	35	4	104

(Source - Road Traffic office of Debre Birhan city, 2022/23)

3.5.2 Accident Risk - refers to the likelihood or probability of an accident occurring. It is the number of accidents per 100,000 people. Here is what is recorded in Dilla in table 3.3. Each zone comprises percentages out of the city and this give the rate of accident risk for every zone.

Table 3.3 Accident Risk of Dilla city of the year 2022/2023

Value	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Min	Max	Mean
Accident risk	25.19	23.83	21.18	5.29	30.45	9.26	17.21	5.29	30.45	18.92
Percentage	19%	18%	16%	4%	23%	7%	13%			
Rank	2	3	4	7	1	6	5			

(Source: Organized by the author, April, 2024)

Table 3.4. Below shows accident risk of Debre Birhan city. As of Dilla's percentage comparison, zones of Debre Birhan also ranked according to their percentage.

Table 3.4 Accident Risk of Debre Birhan city of the year 2022/2023

Value	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Min	Max	Mean
Accident rate	31.82	10.60	22.54	11.93	14.58	19.88	21.21	10.60	31.82	18.94
Percentage	24%	8%	17%	9%	11%	15%	16%			
Rank	1	7	2	6	5	4	3			

(Source: Organized by the author, April, 2024)

3.5.3 Accident Severity - refers to the seriousness or criticality of accidents sustained in a street. It provides insight into the impact of accidents on property, vehicle or people and helps assess the gravity of incidents. Table 3.5 show the severity of accident for a fatal accident with multiple rate of 3, for serious accident with multiple rate of 1.8, for light accident with multiple rate of 1.3 and 1 for property damage.

Table 3.5. Severity Index of Dilla city 2022/23

Record	Fatal	Serious	Light	Property	S.I.
2022/23	6x3	2x1.8	4x1.3	98x1	124.8

(Source: Organized by the author, April, 2024)

The severity index of Debre Birhan is represented in table 3.6 below. Even though the crash recorded in Dilla city is higher than that of Debre Birhan, it does not always mean it has higher severity index

Table 3.6. Severity Index of Debre Birhan city 2022/23

Record	Fatal	Serious	Light	Property	S.I.
2022/23	38x3	27x1.8	35x1.3	4x1	212.1

(Source: Organized by the author, April, 2024)

All, accident rate, risk and severity indexes are helpful to determine hotspots of the cities.

3.5.4. Street pattern configuration analysis

Spatial factor determining the probability of accident occurrence is, the street pattern of urban areas. All streets of Dilla and Debre Birhan city were analyzed using space syntax analysis in Depth map software. Spatial join tool in ArcGIS was used to check the correlation between street configuration and road traffic accident.

Using the space syntax technique, street network analysis has to follow these steps:

i. Get maps of each city.
ii. Clarify their road maps.
iii. Allocate hot-spot regions on the maps.
iv. Identify their clusterness and randomness of the hotspots using GIS.
v. Drawing the longest and fewest axial lines to obtain the axial map on the road maps of each city.
vi. Analyzing the maps using UCL Depth map software, calculating the parameters of street configuration.
vii. Checking the correlations between each of the former values and accident rates.
viii. Select the parameters that are significant to determine the formula.
ix. Forecast the occurrence of R.T.A. of each cities' using street pattern configuration parameters.
    - Observe the pattern and character of the most significant independent variables.
    - Estimate the model
    - Determine the type of statistical technique used to estimate the relation between variables.
    - Evaluate the model
    - Interpret and present the model

Table 3.7. Method of Data analysis summary

Table 3.7. Summarizes the method of data analysis based on specific objective.

Specific objectives	**Types of data required**	**Source of data**	**Software used**	**Analysis**
To determine R.T.A rates of the cities and their hot spots.	Accident rate data	Gathered interview and Traffic Management office.	-Auto C.A.D. - G.I.S.	- Center of Tendency
To compare effects of street pattern configuration based R.T.A. rate of each city.	Road map	Administrative offices of Dilla and Debre Birhan city	-Depth map	- Parametrical values - Statistical test

(Source: Organized by the author, April, 2024)

Table 3.8. Method of Data analysis summary 2

Table 3.8. Summarizes the method of data analysis based on parametrical values and accident rate or simply based on variables. Where IV- Independent variable, DV- Dependent variable.

Variable	Type of Variable	Indicator	Data type	Data Source
Street pattern configuration	IV	Connectivity Total depth Total depth R3 Local integration Global integration Choice Choice R3 Line length Line length R3 Local node Synergy Intelligibility	Quantitative	Government administrative office's road map analyzed to get the indicating parameters
Accident rate	DV	Accident rate	Quantitative	Traffic management office

(Source: Organized by the author, April, 2024)

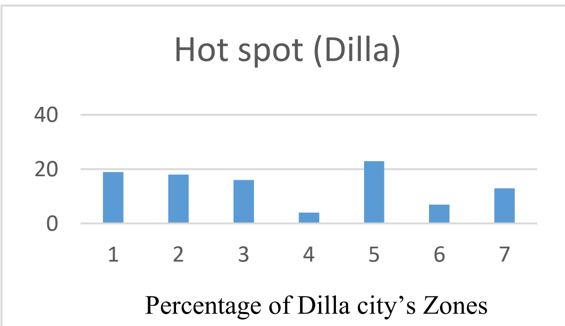
CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Hot spot Analysis

Based on their frequency and distribution of occurrence of accident over the city, hot spots of the Dilla and Debre Birhan are presented as figure 4.1 and figure 4.2.

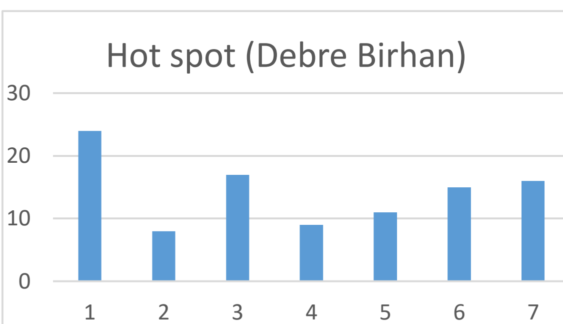
Figure 4.1 denotes that zone 5 has the highest accident risk with percentage of 23% and then zone 1 with 19%, zone 2 with 18%, zone 3 with 16%, zone 7 with 13%, zone 6 with 7% and zone 4 with the least percentage of 4%.



This figure shows that, the percentages of accident risk rate as hot spots among the seven zones of Dilla city, yielding the percentage for each zone out of 100. The hot spots represents the level of exposer towards accident risk.

Figure 4.1 – Accident risk percentage of each zone's hot spot with respect to Dilla

Figure 4.2 indicates that zone 1 has the highest accident risk with percentage of 24% and then zone 3 with 17%, zone 7 with 16%, zone 6 with 15%, zone 5 with 11%, zone 4 with 9% and zone 2 with the least percentage of 7%.



This figure shows that, the percentages of accident rate as hot spots among the seven zones of Debre Birhan city, yielding the percentage for each zone out of 100. The hot spots represents the level of exposer towards accident risk..

Percentage of Debre Birhan city's Zones

Figure 4.2 – Accident risk percentage of each zone's hot spot with respect to Debre

Next Figure 4.3 shows the street pattern configuration of Dilla city and Figure 4.4 shows the street pattern configuration of Debre Birhan city.

Figure 4.5 shows zones of Dilla city specifically illustrated for this study only and Fig. 4.6 shows zones of Debre Birhan city also illustrated for this study only. The color arrays from the darker to lighter brown color pallet to represent hotspot areas ranging from higher to lower RTA.

Like the above figures, Figure 4.7 shows the weight of accident rate of places with in a specific zone of Dilla that is expressed using resembling color. In Figure 4.8 the most significant hotspot areas of Debre Birhan are expressed using the same sequential order as Figure 4.7. but it differs from it because it is represented using only five colors due to data saturation.

For the case of Dilla, there are about 38 known hotspots where this seems very much less in case of Debre Birhan. This is not due to insufficient data rather data saturation, at which collecting additional data no longer provides fresh insights related to the research questions. When data saturate, enough information is gathered to confidently understand the patterns and themes within dataset.

Figure 4.9 and 4.10 below shows, the finding of GIS to determine whether the provided hotspots are really the hotspots of each city with their level of confidentiality or significance.

Figure 4.11 and 4.12 are also representation of spatial statistics data calculated using Z score and P value. It is based on both feature locations and feature values simultaneously and illustrates the graphical representation of the data as dispersed (outlined), random or cluster pattern.

Figure 4.13 and 4.14 represent cluster/ outlier analysis (Anselin Local Moran’s I) that identifies concentration of high values, concentration of low values and spatial outliers

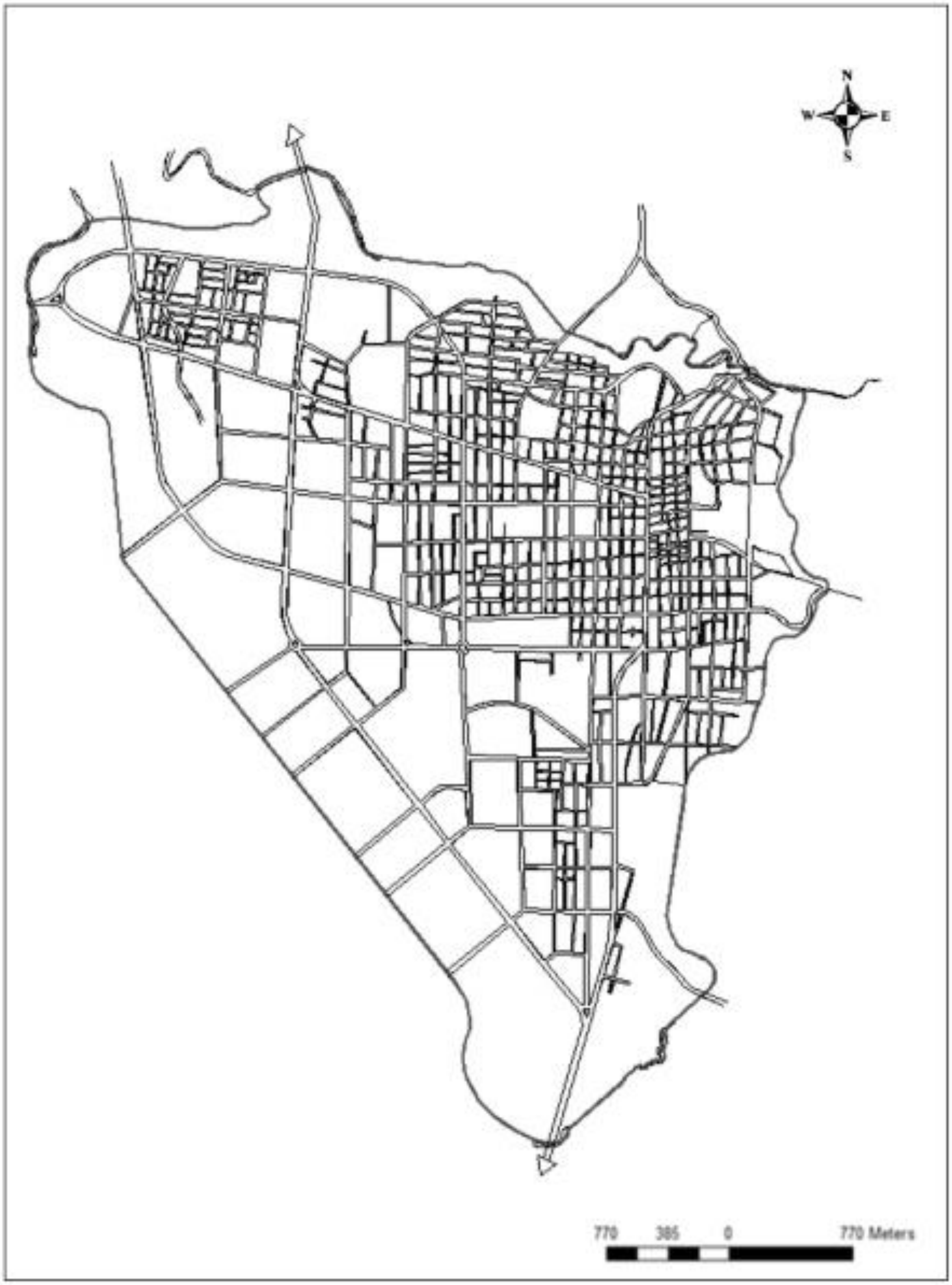


Figure 4.3. Street pattern configuration of Dilla city. (Source: Dilla city administration, 2023)

Figure 4.4. Street pattern configuration of Debre Birhan city. (Source: Debre Birhan city administration, 2023)

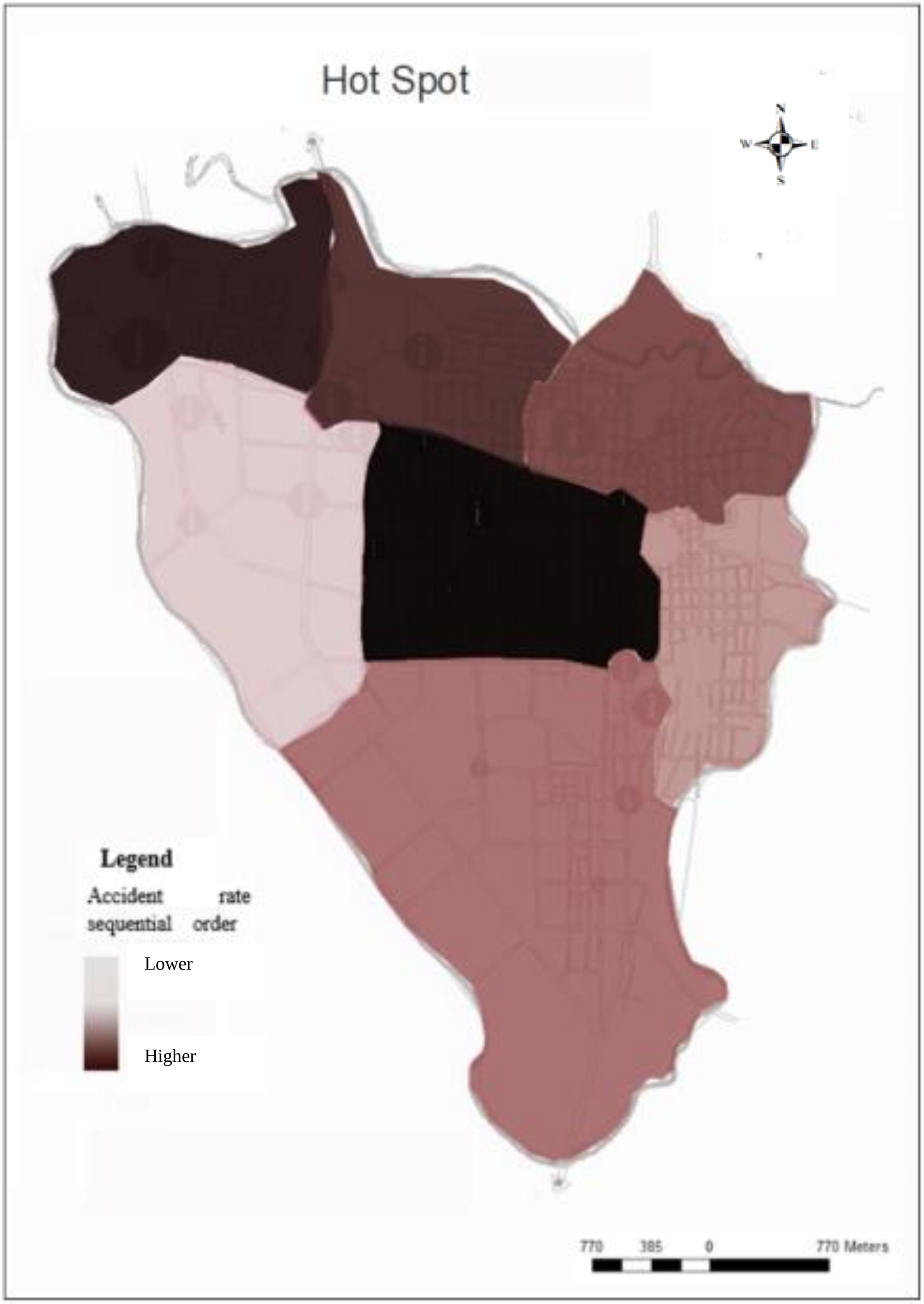


Figure 4.5. Hot Spot of Dilla city with their corresponding zones. (Source: computed from road network map and hotspots of Dilla, 2024)

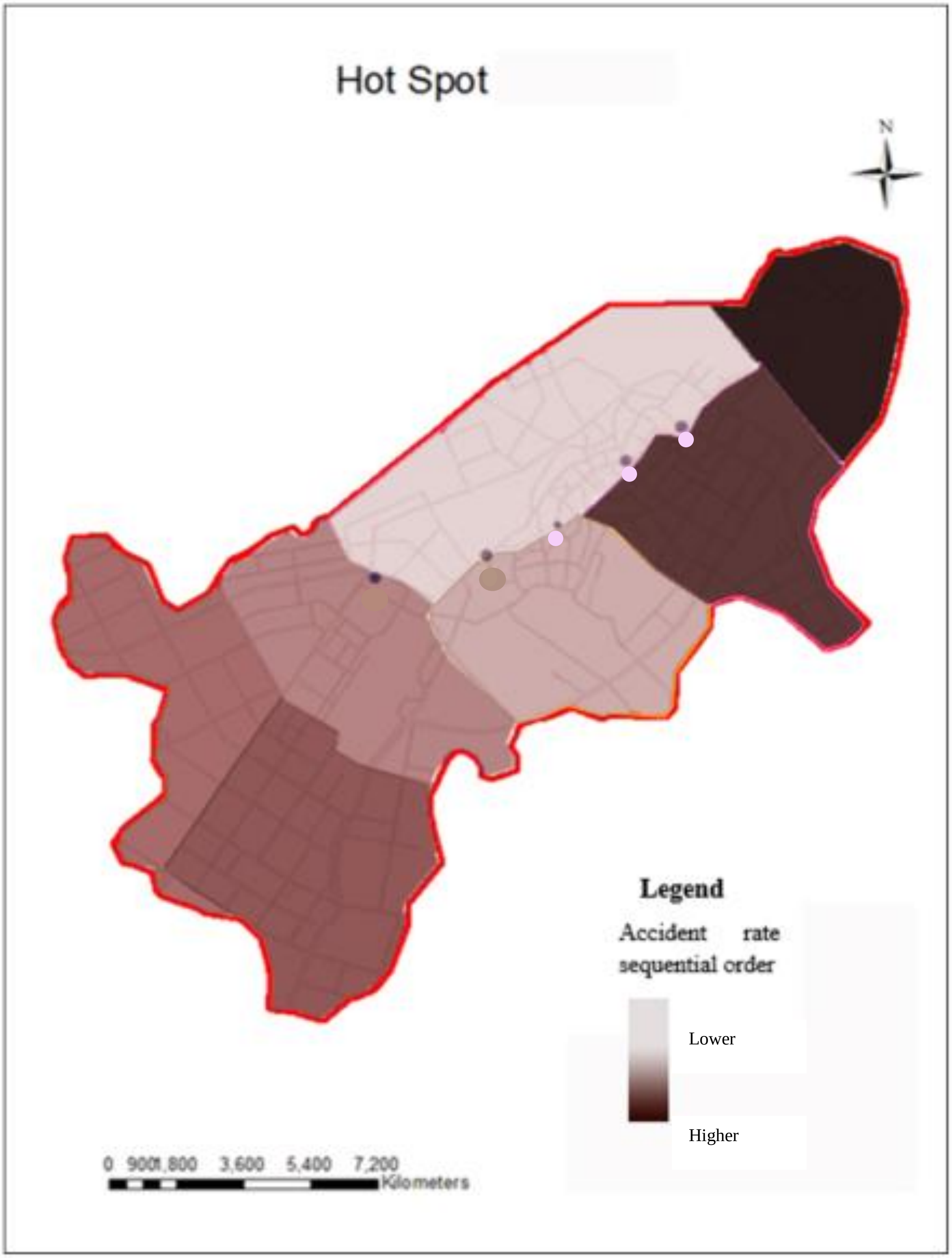


Figure 4.6 Hot Spot of Debre Birhan city with their corresponding zones. (Source: computed from road network map and hotspots of Debre Birhan, 2024)

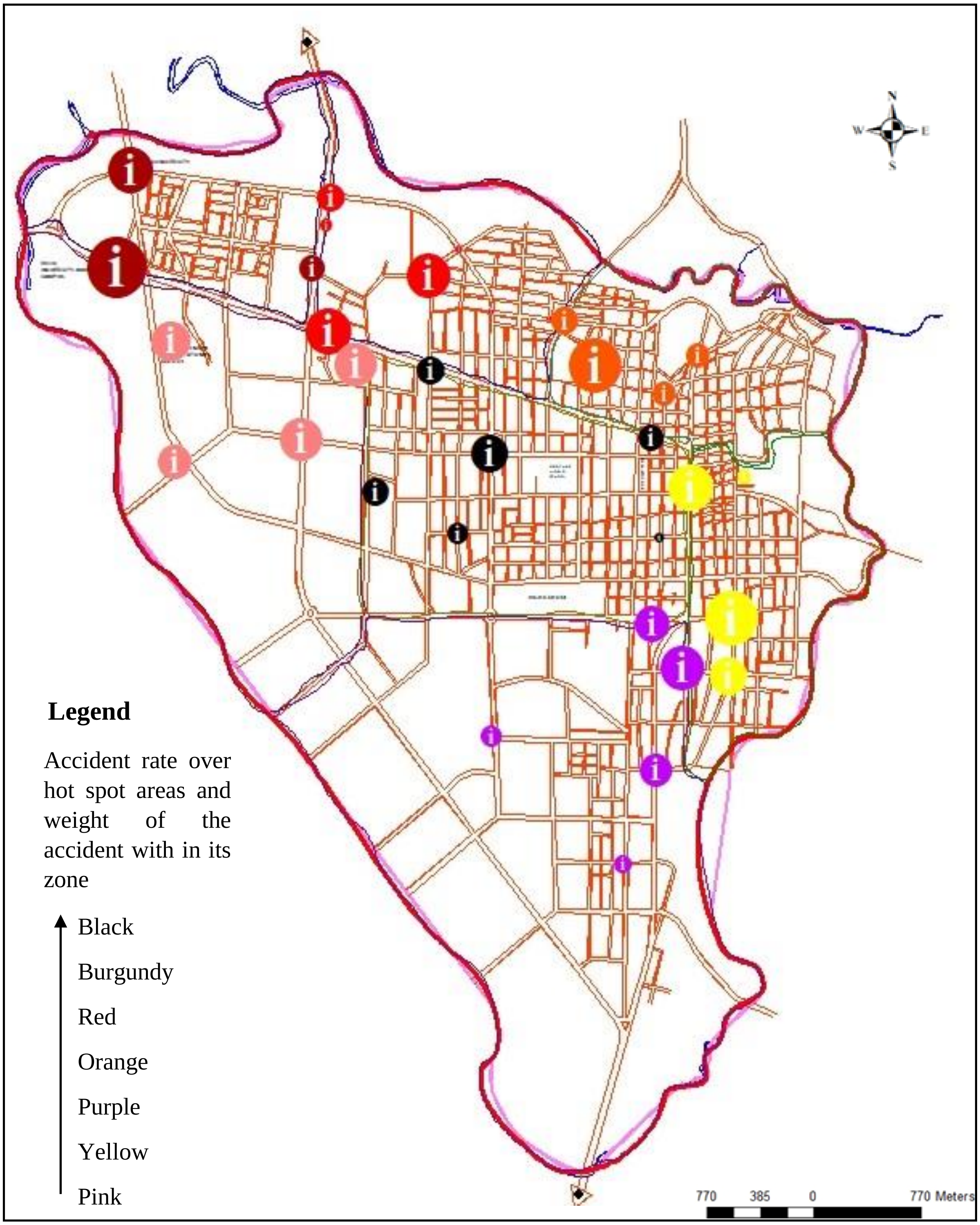


Figure 4.7. Hot Spot of Dilla city. (Source: computed from hotspots of Dilla, 2024)

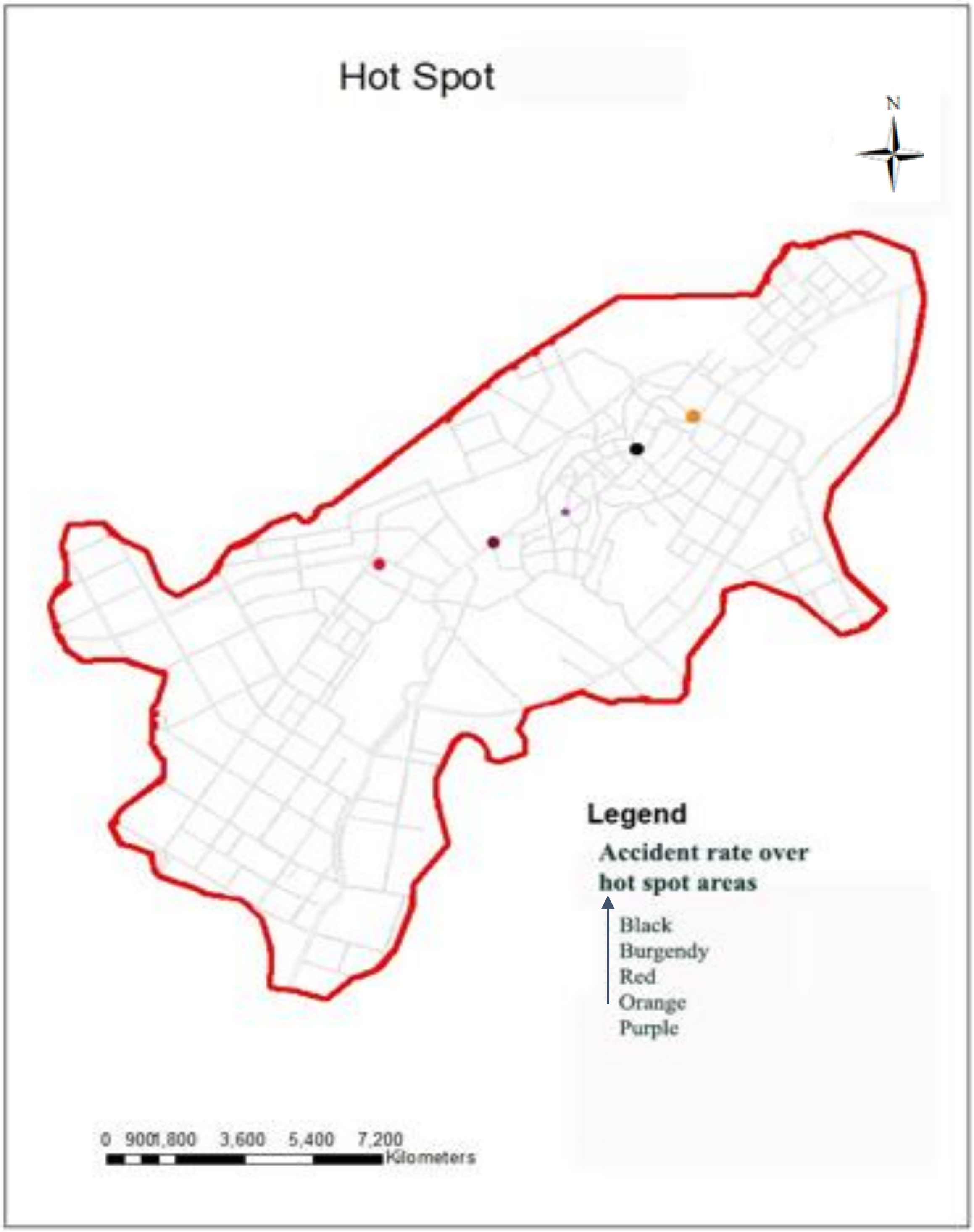


Figure 4.8. Hot Spot of Debre Birhan city. (Source: computed from hotspots of Debre Birhan, 2024)

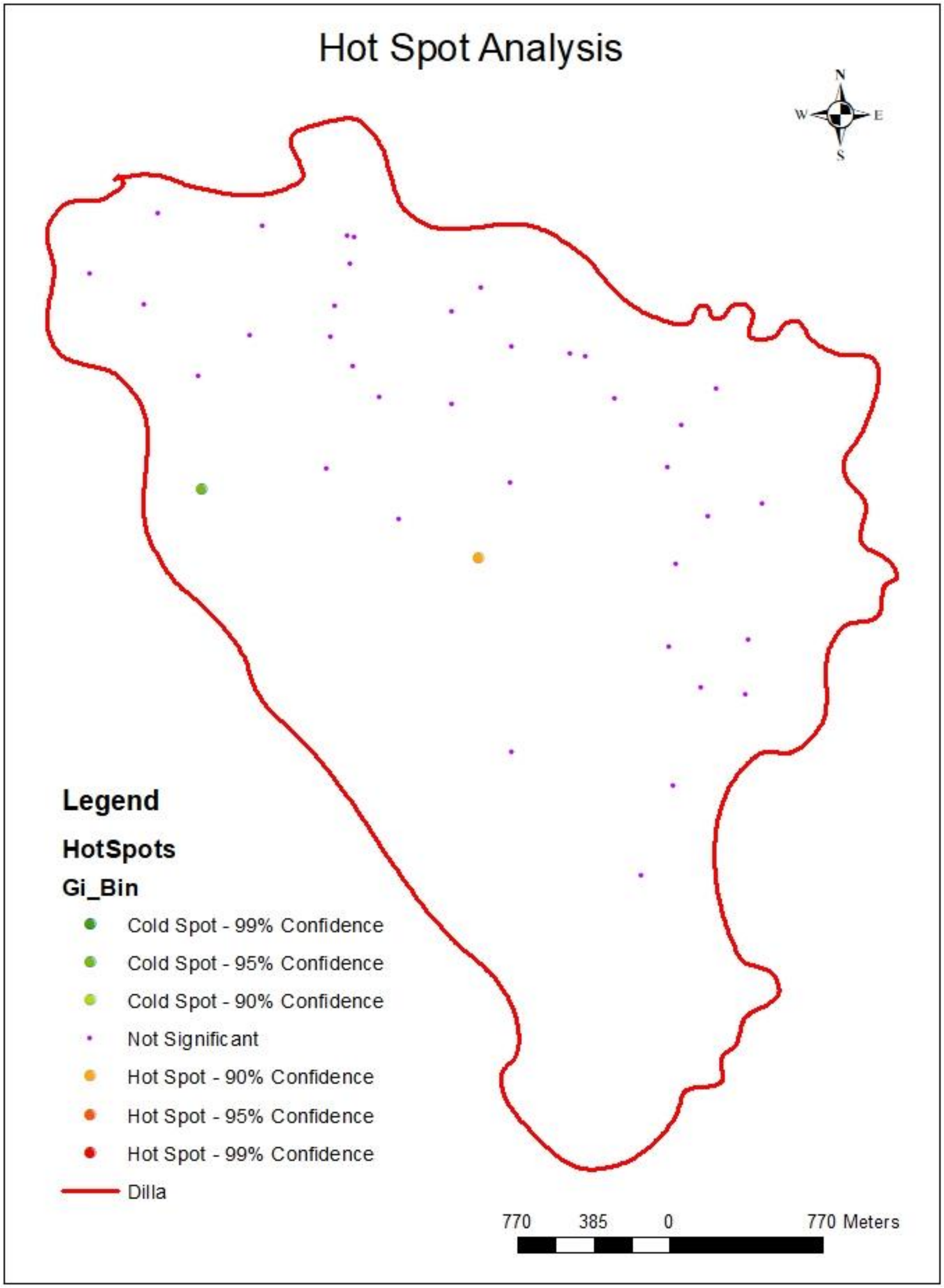


Figure 4.9. Hotspots confidential level of Dilla (Source: computed from hotspots of Dilla, 2024)

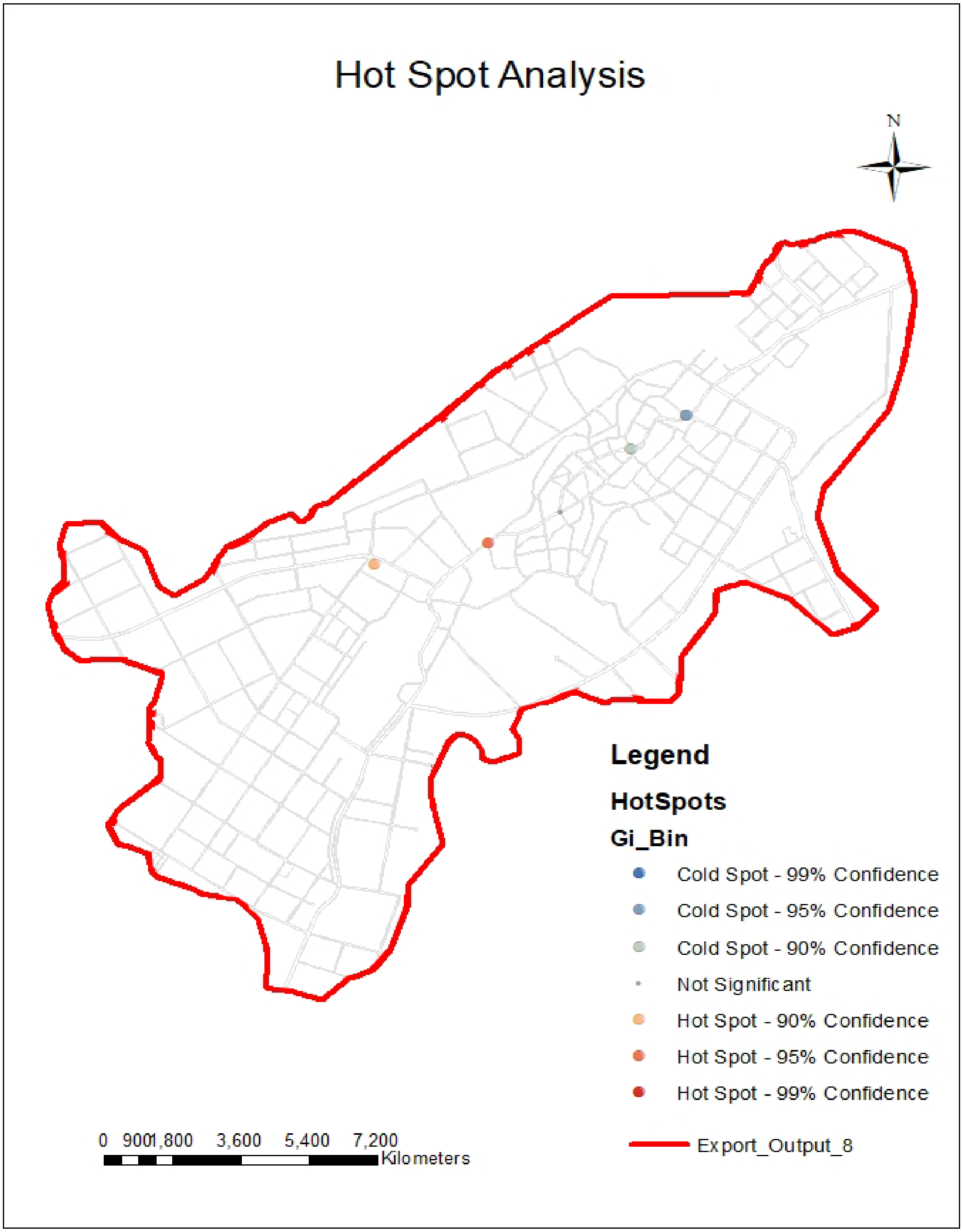


Figure 4.10. Hotspots confidential level of Debre Birhan (Source: computed from hotspots of Debre Birhan, 2024)

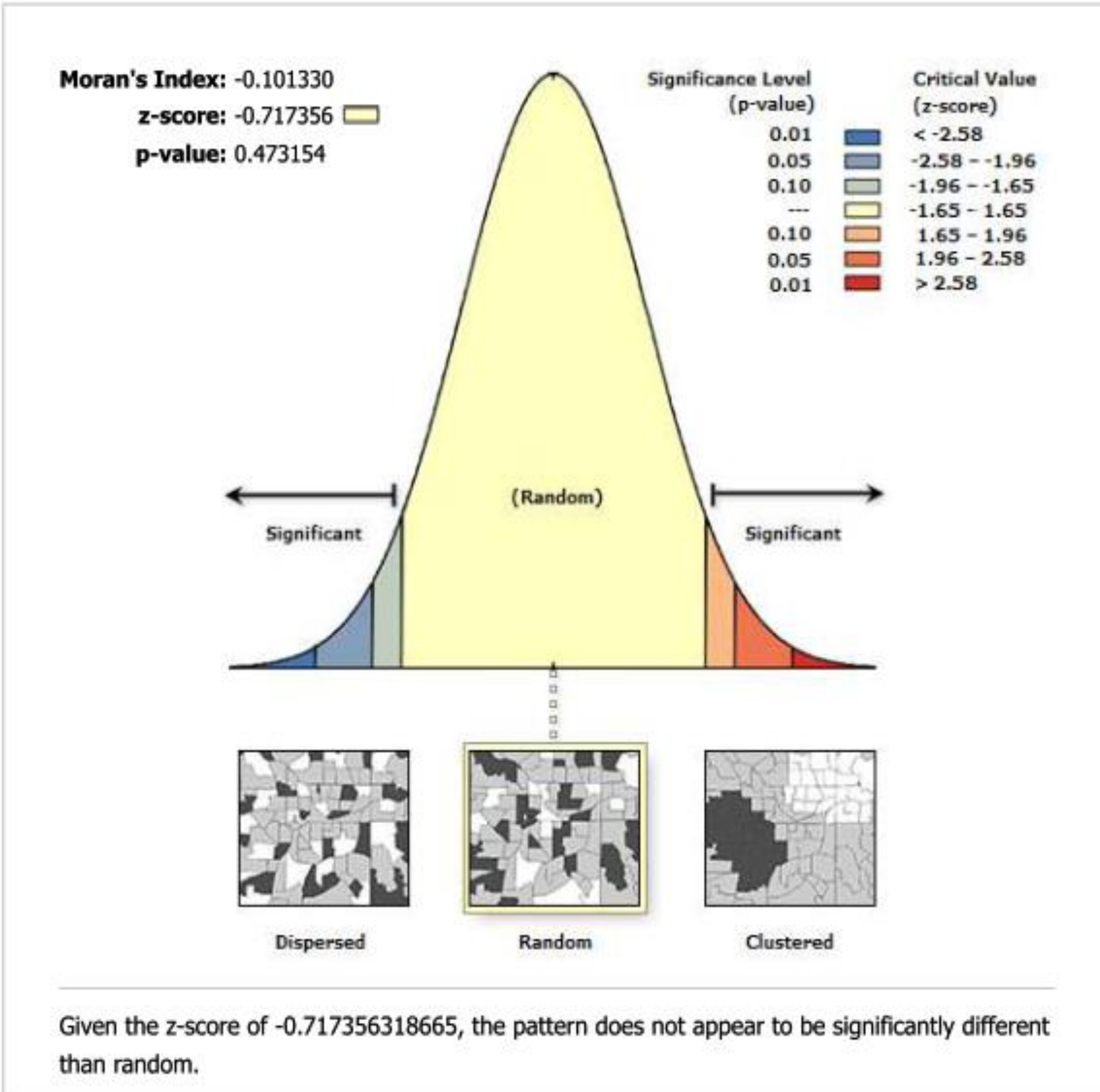


Figure 4.11. Moran's Index, Z-score and P-value of Dilla city (Source: computed from hotspots of Dilla, 2024)

The z-score has indicated that, where the frequency of road traffic accident is compared to the average road traffic accident's mean value. For Dilla city, the Z Score has negative and close value to the mean and it shows that the value is closely below the mean value. This value with respect to the road pattern configuration, the frequency of the road traffic accident appears to be randomly distributed.

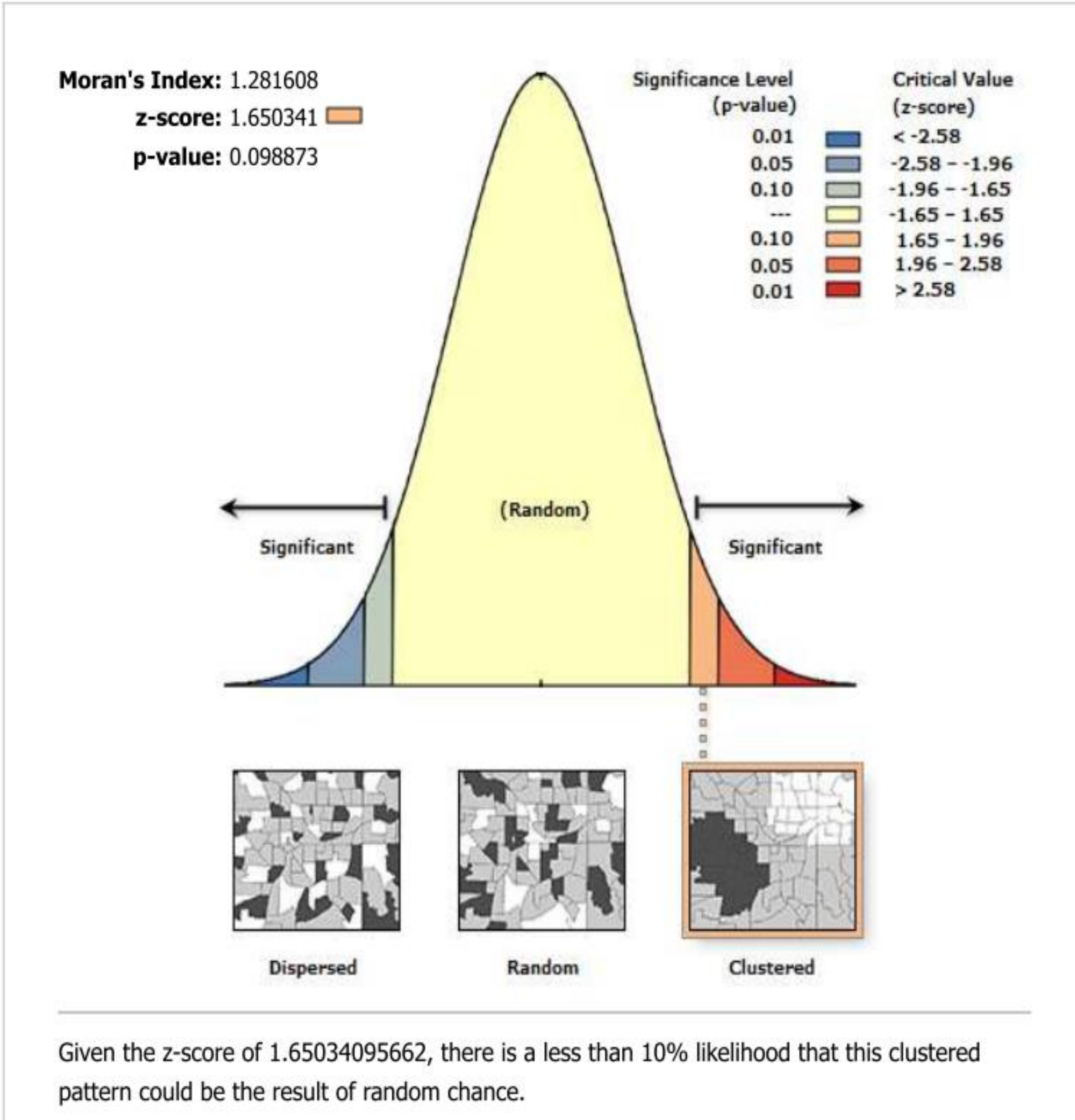


Figure 4.12. Moran's Index, Z-score and P-value of Debre Birhan city (Source: computed from hotspots of Debre Birhan, 2024)

For Debre Birhan city, the Z Score has a positive and value between 1.65 and 1.96, it shows that the value is significantly above the mean value and with respect to the road configuration, the frequency of the road traffic accident appears to be clusterd along a certain road pattern configuration.

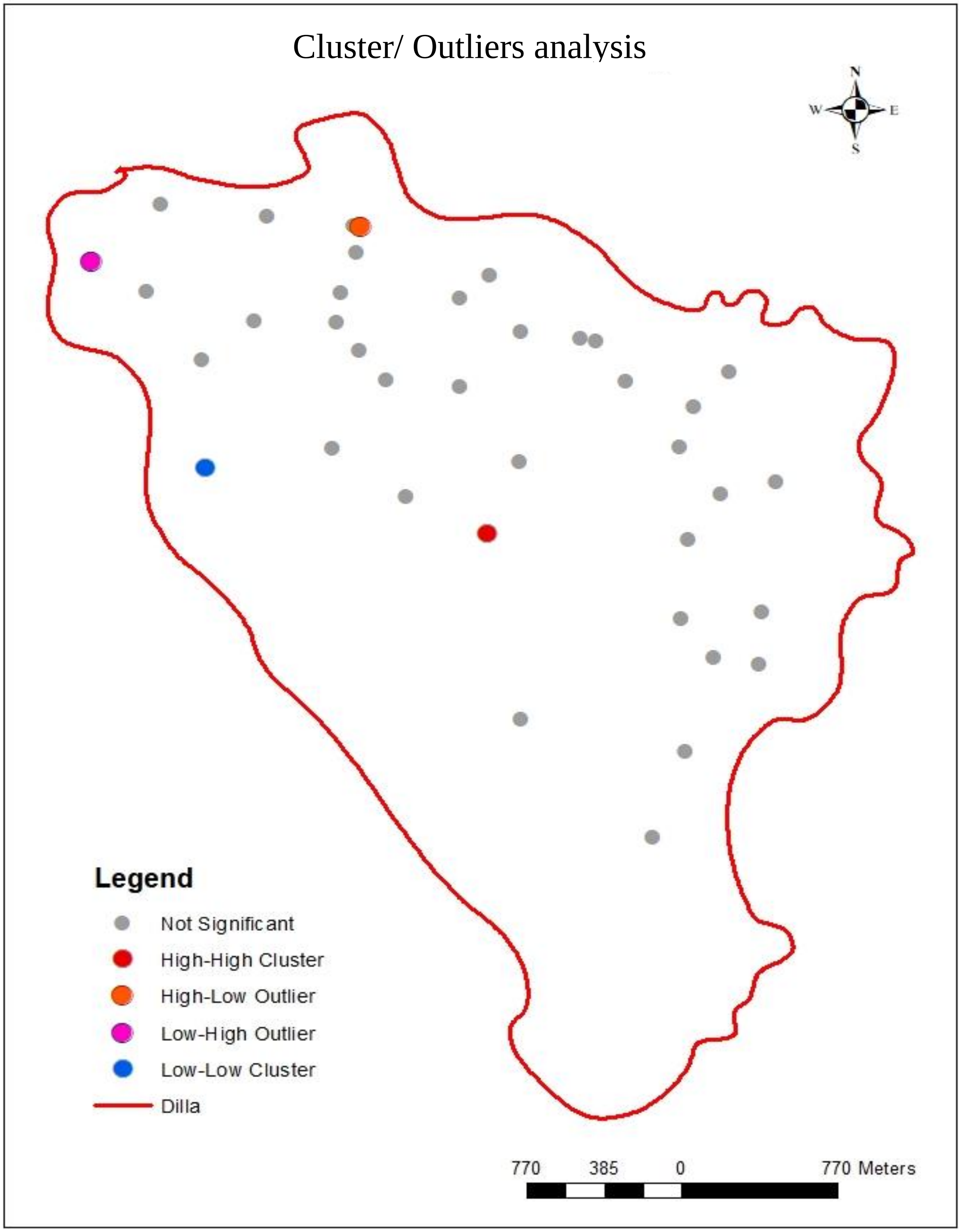


Figure 4.13. Cluster/ outlier analysis of Dilla city (Source: computed from road map of Dilla and its hotspot, 2024)

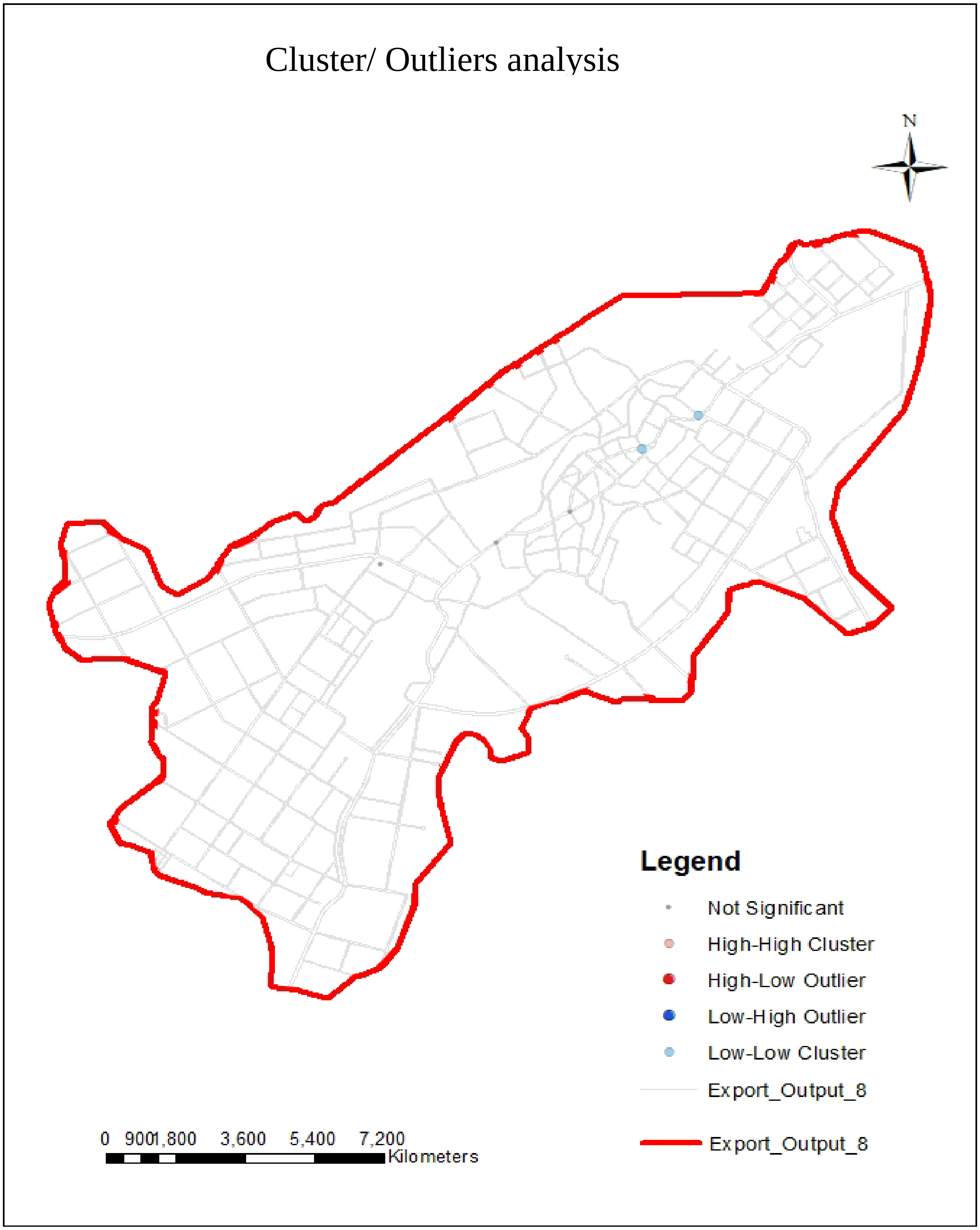


Figure 4.14. Cluster/ outlier analysis of Debre Birhan city (Source: computed from road map of Debre Birhan and its hotspot, 2024)

Figure 4.9 and 4.10 below show, the finding of GIS to determine whether the provided hotspots are really the hotspots of each city with their level of confidentiality or significance. This is highly related with Moran I index since it is determined by P value and Z score

Figure 4.11 and 4.12 are representation of spatial statistics data calculated using Z score, P value and calculated Moran I index. It is based on both feature locations and feature values simultaneously and illustrates the graphical representation of the data as dispersed (outlined), random or cluster pattern. This information further strengthen the finding of cluster/ outlier analysis which is local Moran I

According to Figure 4.13. of Cluster/ outlier analysis, Points represented with red and blue colors shows the points' statistical significance throughout time and $I > 0$, meaning the data point has the same level of high or low attributes as the adjacent points. The attribute values of the points are compared with the average attribute values of all data points. The red point indicates H-H and the blue point shows the L-L clustering.

Points represented with the color orange and purple shows its outliner character and $I < 0$, then the properties of the data point differ significantly from those of adjacent points. The outlier in which a high value is surrounded primarily by low values is (H-L) that is indicated by orange color and the outlier in which a low value is surrounded primarily by high values is (L-H) that in the other hand is indicated by purple color.

On Figure 4.14. Cluster/ outlier analysis of Debre Birhan city, is represented by lighter blue color meaning to show the points are low-low outliner. This indicates that the hot spots of this city are clusters of low value of road traffic accident.

This study, besides the representation performed by GIS like the above, It was analyzed using by depth map x and the result is demonstrated below.

4.15. Road configuration parameters (indexes)

The second types of index generated are, road configuration parameters like connectivity (complexity), total depth, mean depth, integration and choice are the main parameters.

4.15.1 Connectivity (complexity)

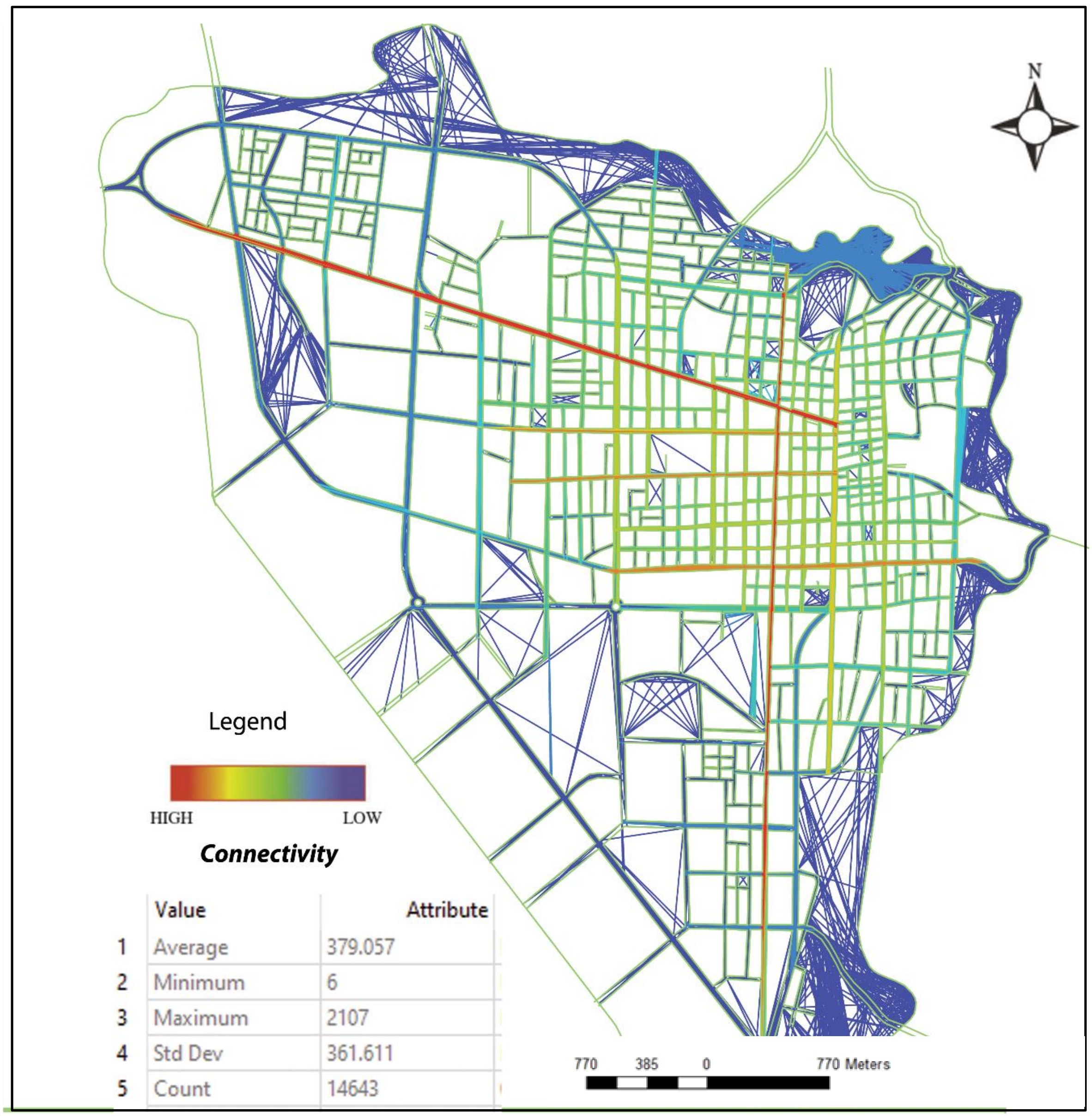
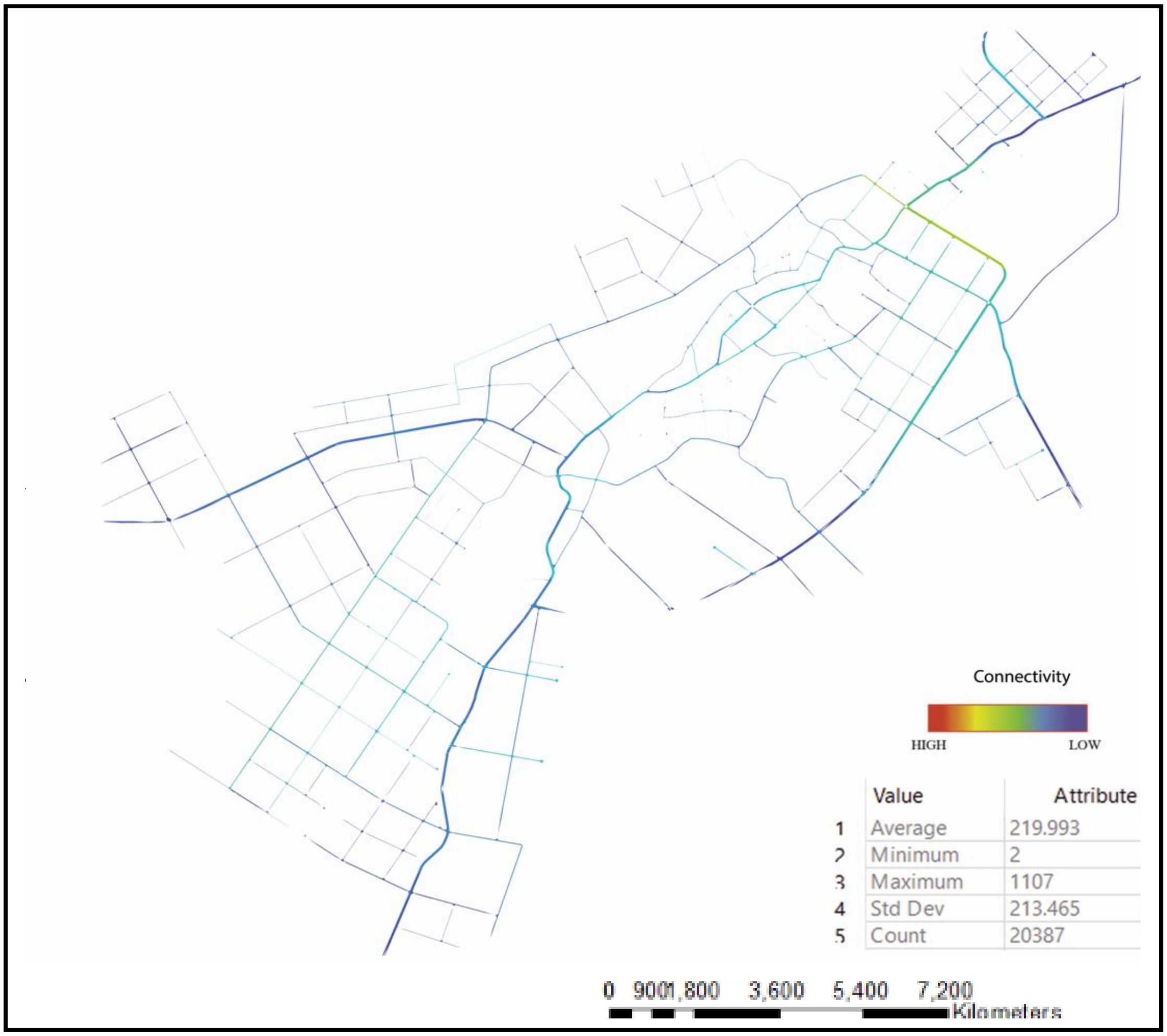


Figure 4.15.1. Street connectivity of Dilla city



	Value	Attribute
1	Average	219.993
2	Minimum	2
3	Maximum	1107
4	Std Dev	213.465
5	Count	20387

Figure 4.15.2. Street connectivity of Debre Birhan city

4.15.3. Total depth R3

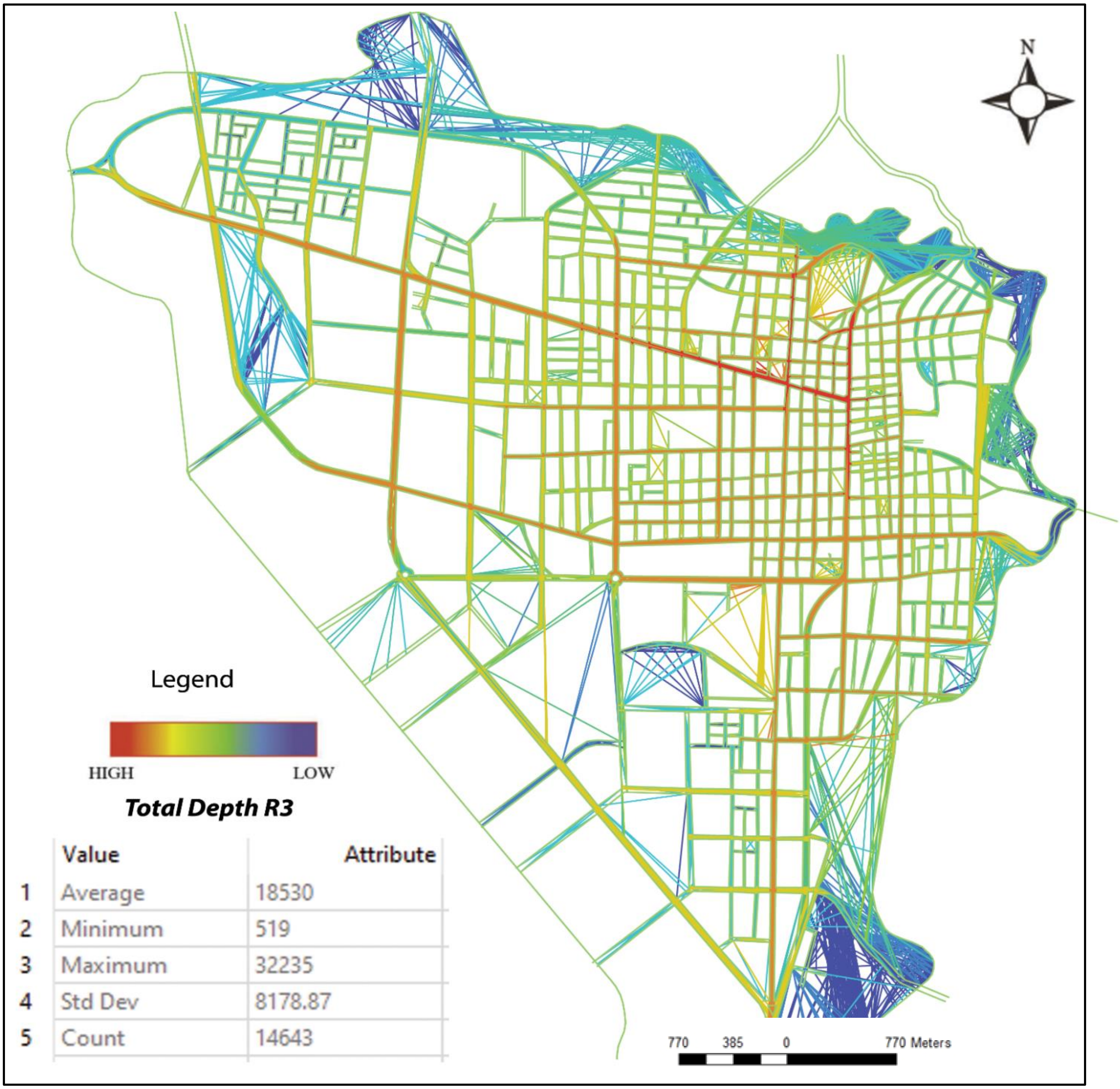


Figure 4.15.3. Total depth R3 of Dilla city

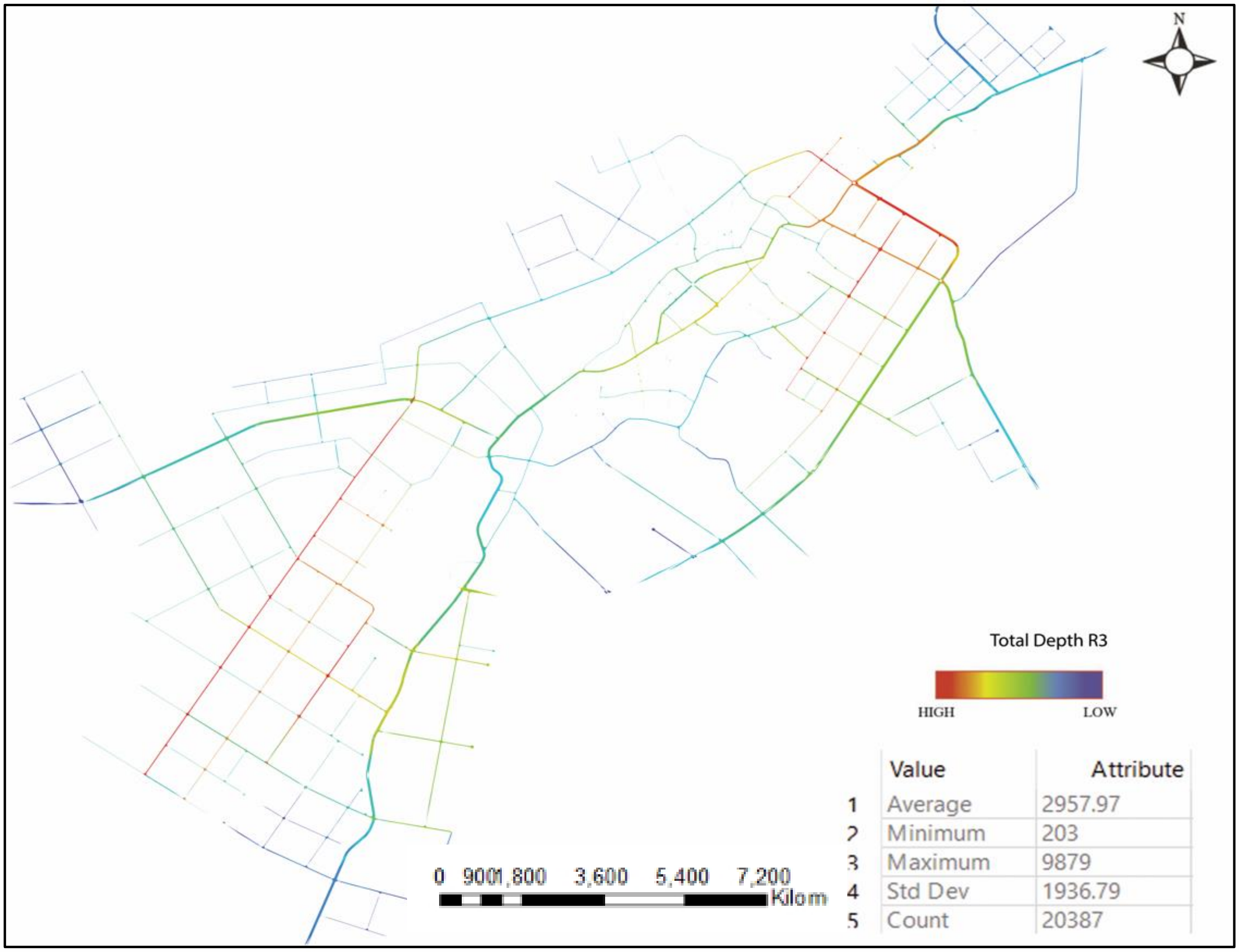
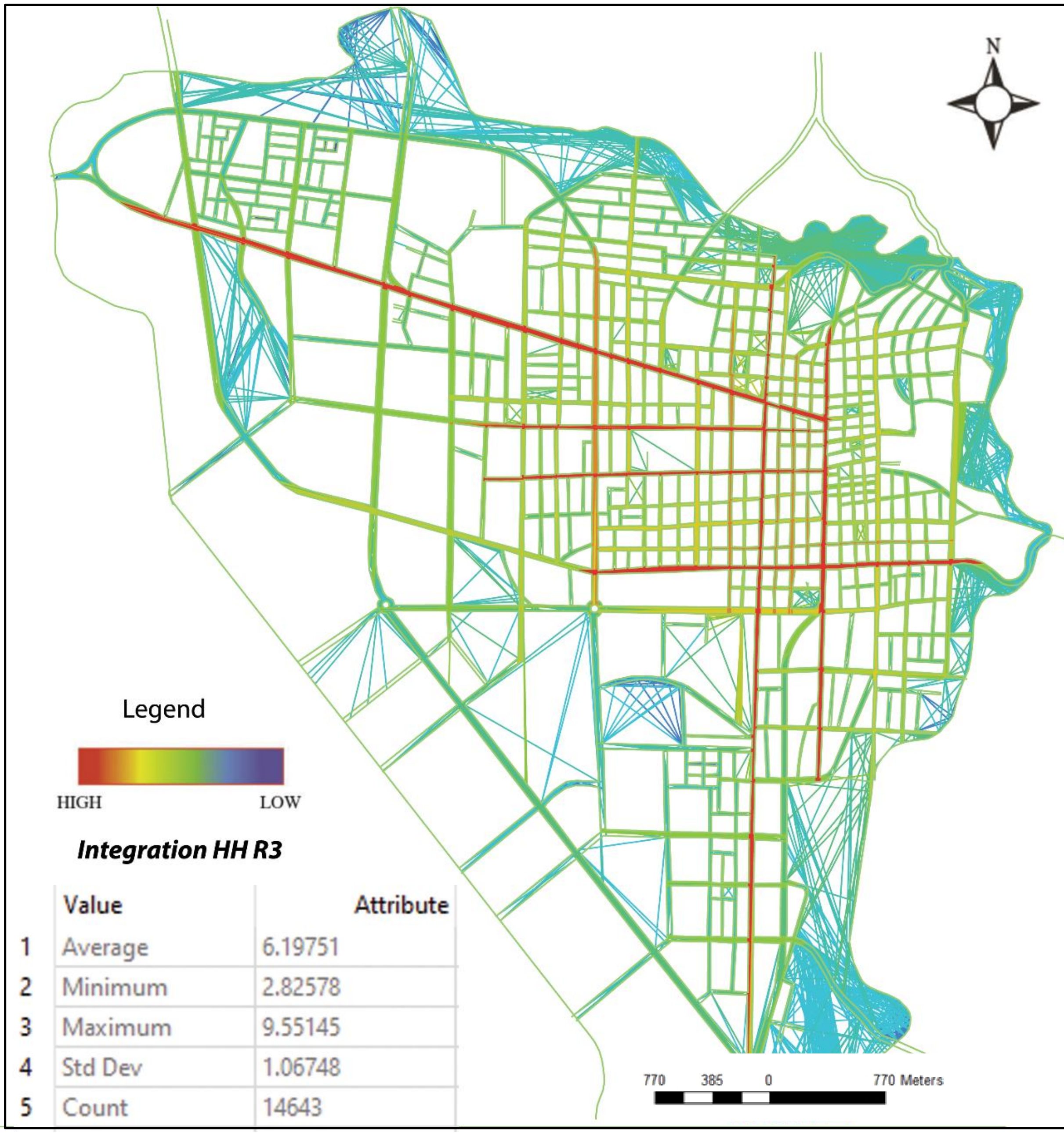


Figure 4.15.4. Total depth R3 of Debre Birhan city

For Dilla city the high value is located in the central part whereas the outer part indications low value as Fig. 4.12. Nevertheless for the case of Debre Birhan the central part is indicated with lower value but most of the outer streets are perceived as higher value as Fig. 4.13. For Dilla 38% of the total street segments have high value, 44 % of the total street segments are moderately placed and 18% of the total street segments are segregated. For Debre Birhan 47% of the total street segments have high integration, 32% of the total street segments are moderately integrated and 21% of the total street segments are segregated.

4.15.5. Local Integration (Closeness)

As described above, Integration in general, measures how many turns one has to make from a street segment to reach all other street segments in the network, using shortest paths.



	Value	Attribute
1	Average	6.19751
2	Minimum	2.82578
3	Maximum	9.55145
4	Std Dev	1.06748
5	Count	14643

Figure 4.15.5. Local integration (R3) of Dilla city

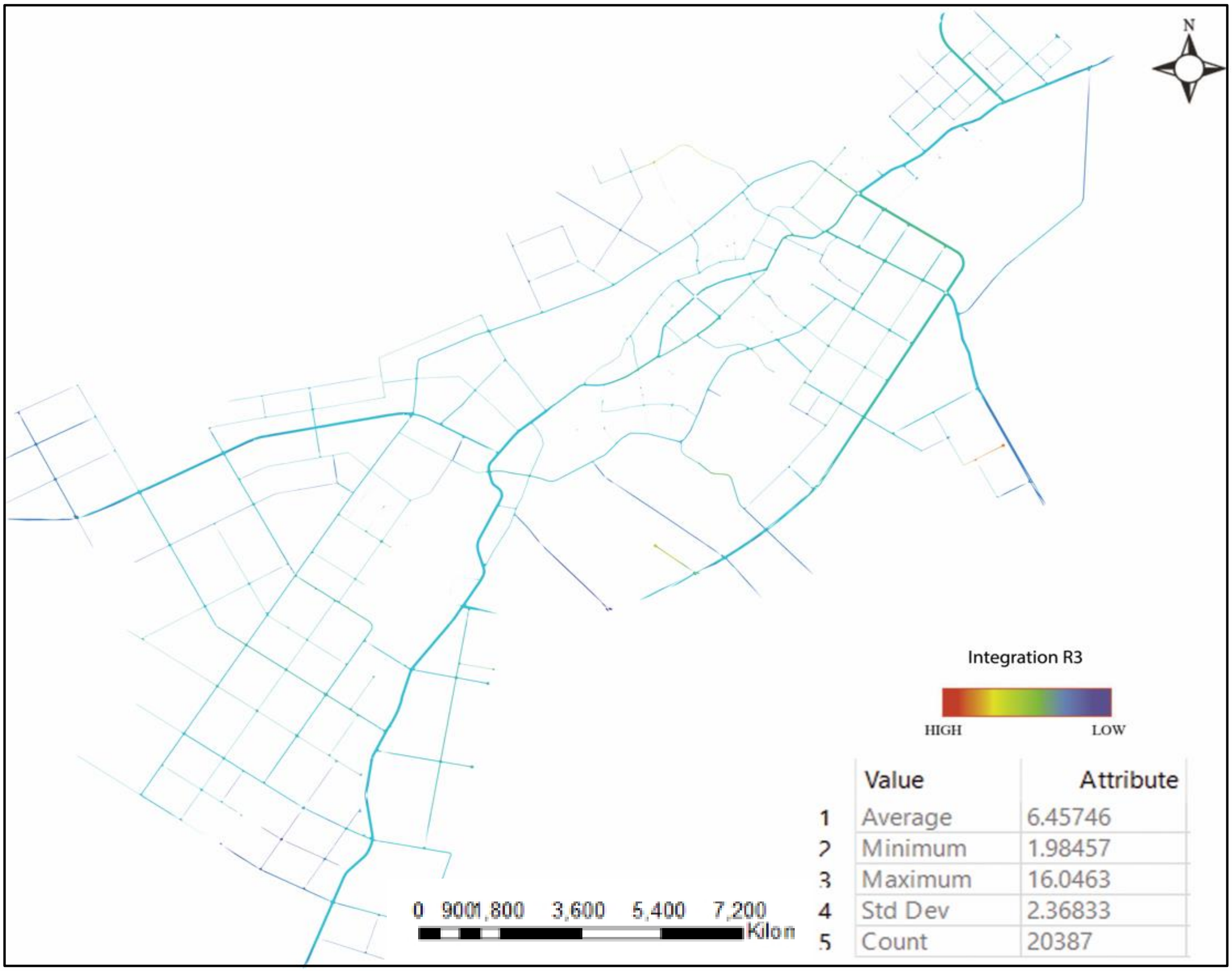


Figure 4.15.6. Local integration (R3) of Debre Birhan city

Here Fig. 4.13 and 4.14. show that the local integration (R3) of cities which is defined as integration values of axial lines at the radius 3 (root plus two topological steps from the root). For the case of Dilla Fig. 4.13 represent a localised picture of integration having higher value at the central part of the city. But for the case of Debre Birhan there is almost no higher and moderately integrated streets in the city. For Dilla 26% of the total street segments have high integration, 72 % of the total street segments are moderately integrated and 2% of the total street segments are segregated. For Debre Birhan 0.5% of the total street segments have high integration, 1% of the total street segments are moderately integrated and 98.5% of the total street segments are segregated.

4.15.7. Global Integration (Closeness)

Axial global integration is defined as the integration values of axial lines at the infinite radius which can be used to represent a picture of integration pattern at the largest scale.

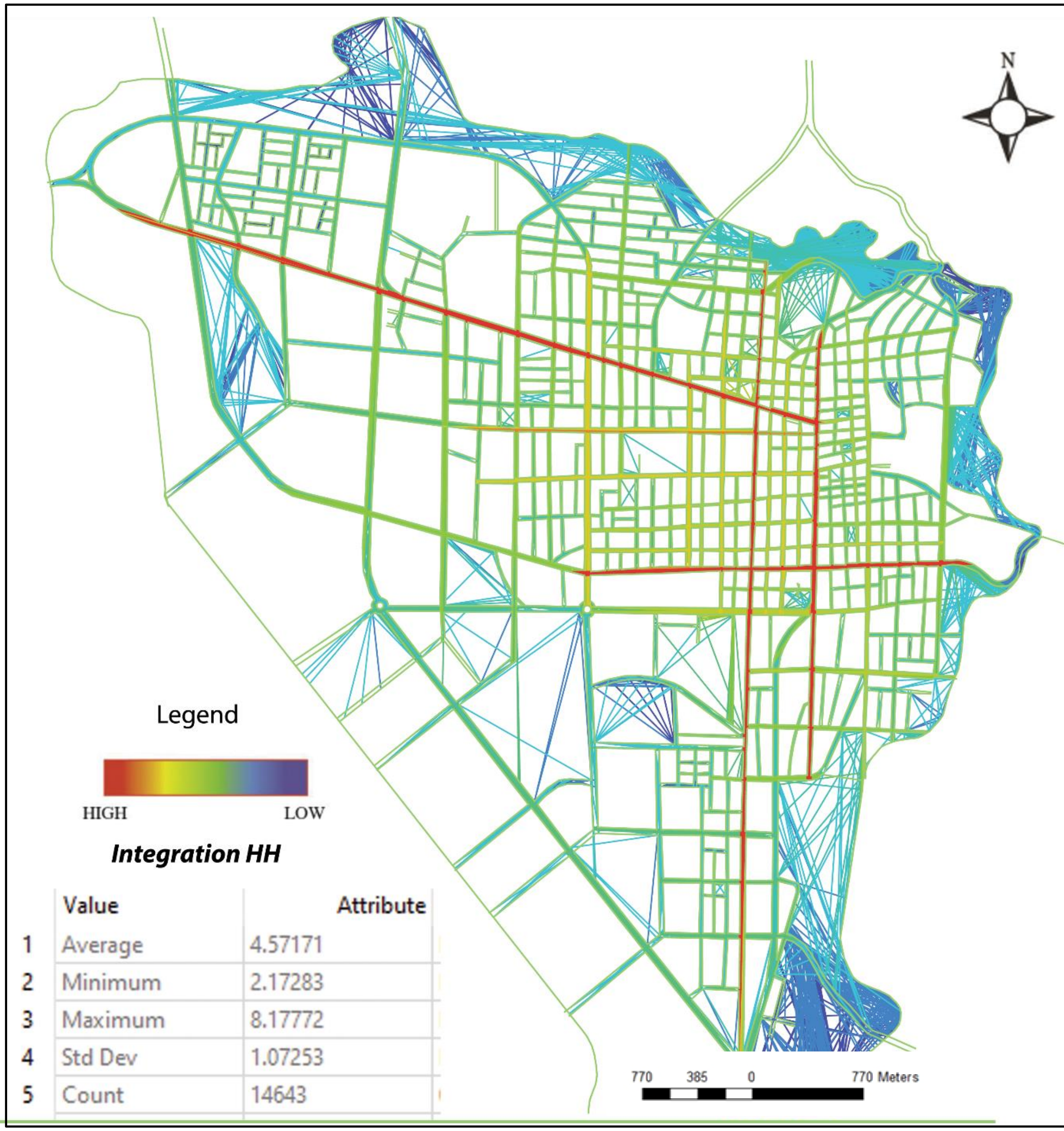


Figure 4.15.7. Global Integration of Dilla city

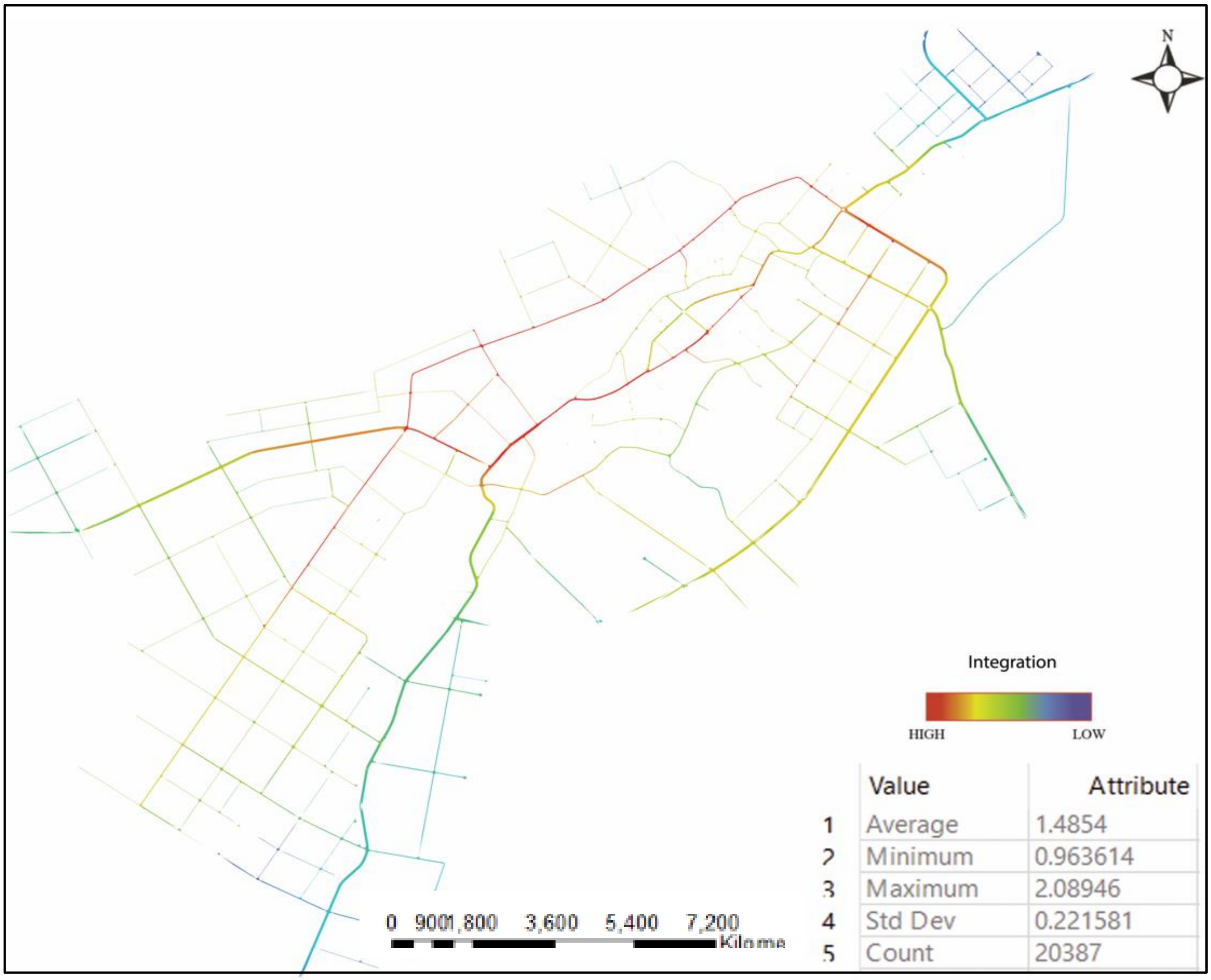


Figure 4.15.8. Global Integration of Debre Birhan city

The set of most integrated streets is collectively known as the „integration core". The integration core is shown in red and orange lines. The segregated streets or less accessible streets are indicated with light blue and dark blue and tend to cover the periphery of the city as shown in Figure 4.15 and 4.16.For Dilla 37% of the total street segments have high integration, 59 % of it are moderately integrated and 4% of it are segregated. For Debre Birhan 86% of the total street segments have high integration, 4% of the total street segments are moderately integrated and 10% of the total street segments are segregated. It has higher value especially in the main roads of the city associated with commercial, recreational, entertainment land use and city exit streets.

4.15.9. Choice (Betweeness)

Choice measures how likely an axial line or a street segment it is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment.

Figure 4.15.9. Choice of Dilla City.

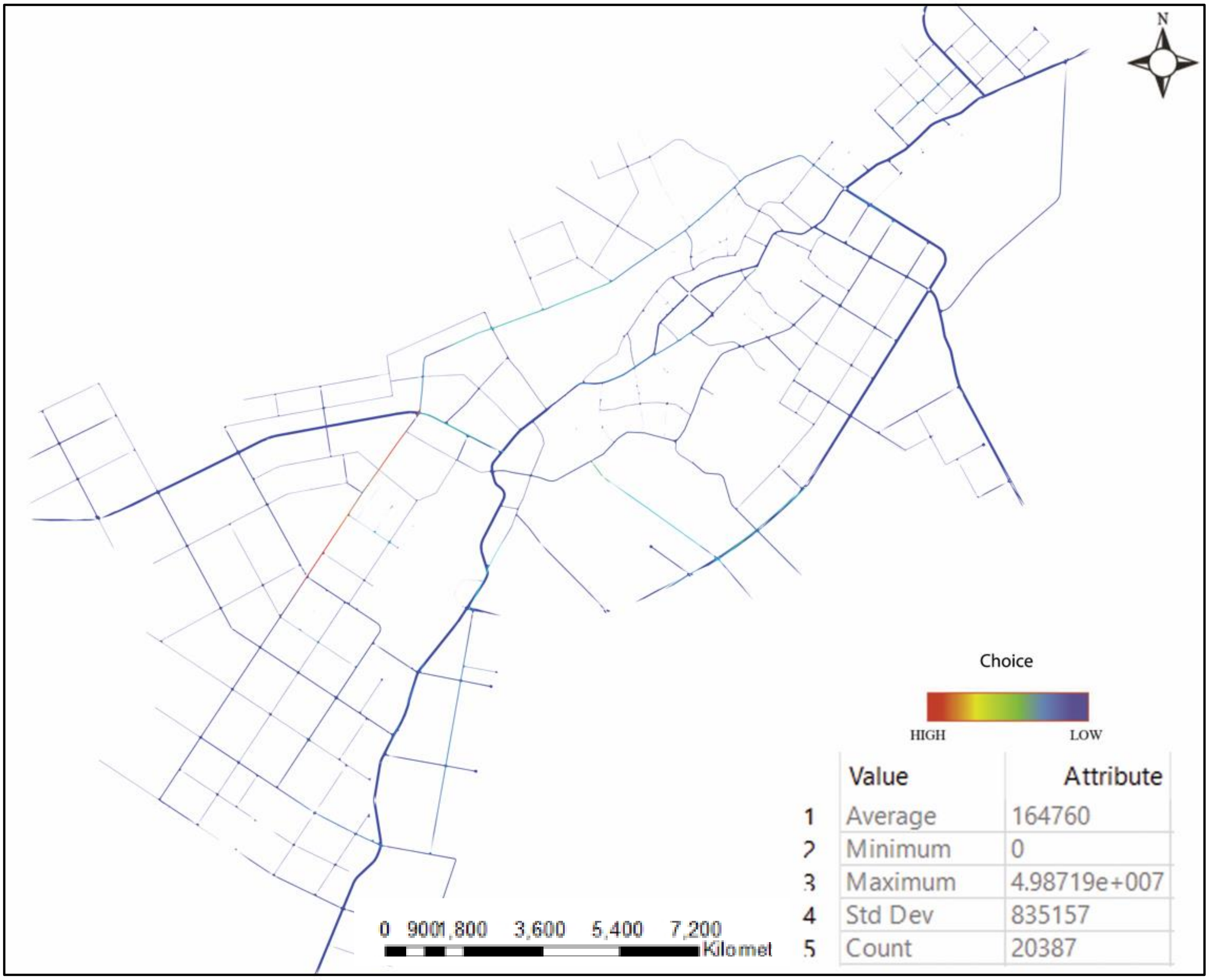


Figure 4.15.10. Choice of Dilla City.

As Fig. 4.17 most streets Dilla are less likely to be chosen where as the vertical and horizontal streets around Meneharial has moderate value and the main exit road of the city has higher tendency to be chosen. 8% of the total street segments have high value, 51 % of the total street segments are moderately placed and 41% of the total street segments are segregated. For Debre Birhan as Fig. 4.18 shows that most of the city’s street are categorized under lower choice group 4% of the total street segments have high possibility to be chosen, 2% of the total street segments have moderately possibility to be chosen and 94% of the total street segments are less likely to be chosen

4.15.11. Line Length

Line length is the total length of a segment of a line.

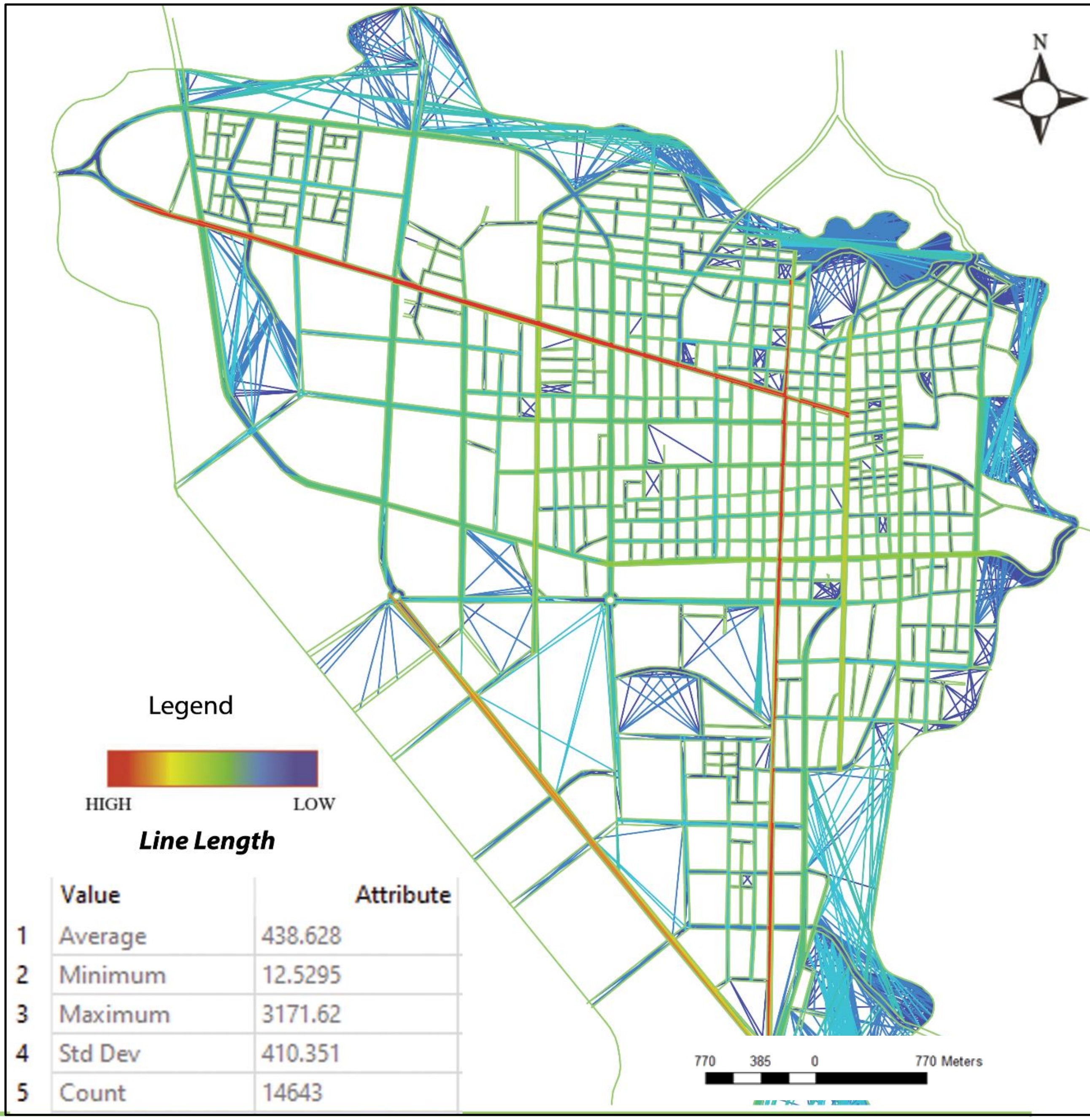
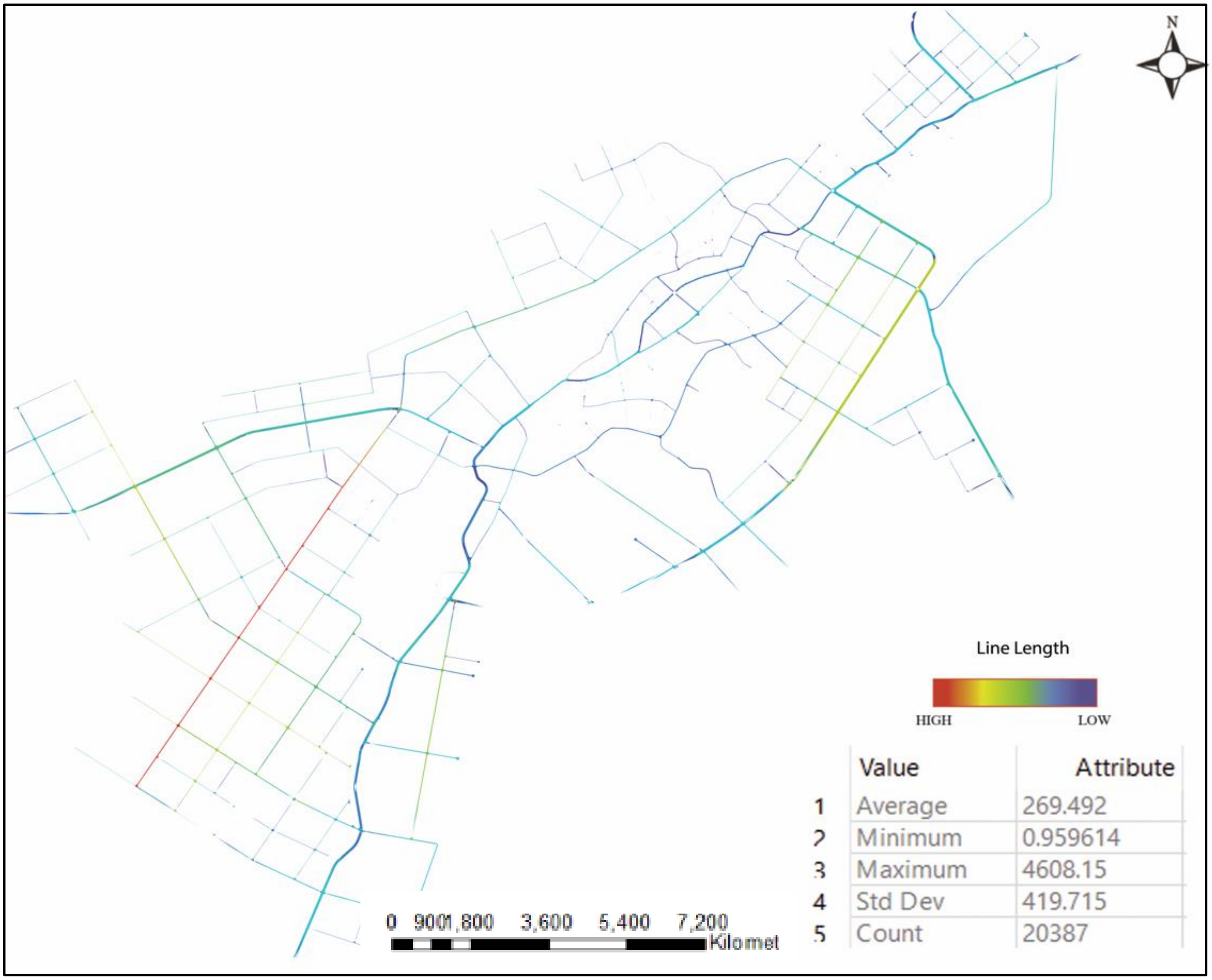


Figure 4.15.11. Line Length of Dilla City.



	Value	Attribute
1	Average	269.492
2	Minimum	0.959614
3	Maximum	4608.15
4	Std Dev	419.715
5	Count	20387

Figure 4.15.12. Line Length of Debre Birhan City.

As per Fig. 40.19, Dilla 12% of the total street segments have high line length, 57 % of it have medium line length and 31% of it have shorter line length. As per Fig. 4.20. Debre Birhan 33% of the total street segments have high line length, 7 % of it have medium line length and 60% of it have shorter line length.

4.15.13. Local Node Count R3

Local nodes represent individual well-perceived local spaces

Figure 4.15.13. Local Node Count R3

Figure 4.15.14. Local Node Count R3

As per Fig. 40.21, Dilla 56% of the total street segments have highly well perceived , 37 % of it have moderately perceived and 7% of it have lower perceived tendency As per Fig. 40.22, Debre Birhan 38% of the total street segments have highly well perceived , 9 % of it have moderately perceived and 53% of it have lower perceived tendency.

4.15.15 Synergy

The level of synergy of the areas is determined by the correlation between local & global integration. Where there is a strong correlation between local and global integration, the area is known to have a high degree of synergy between the local and the whole and it is easy to understand.

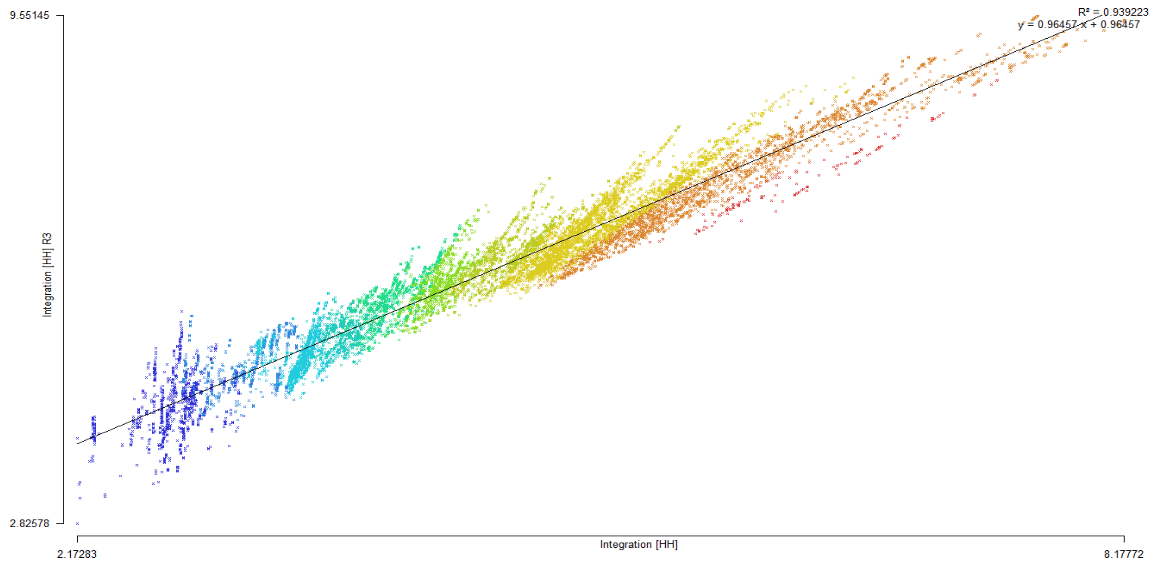


Figure 4.15.15 Synergy of Dilla City

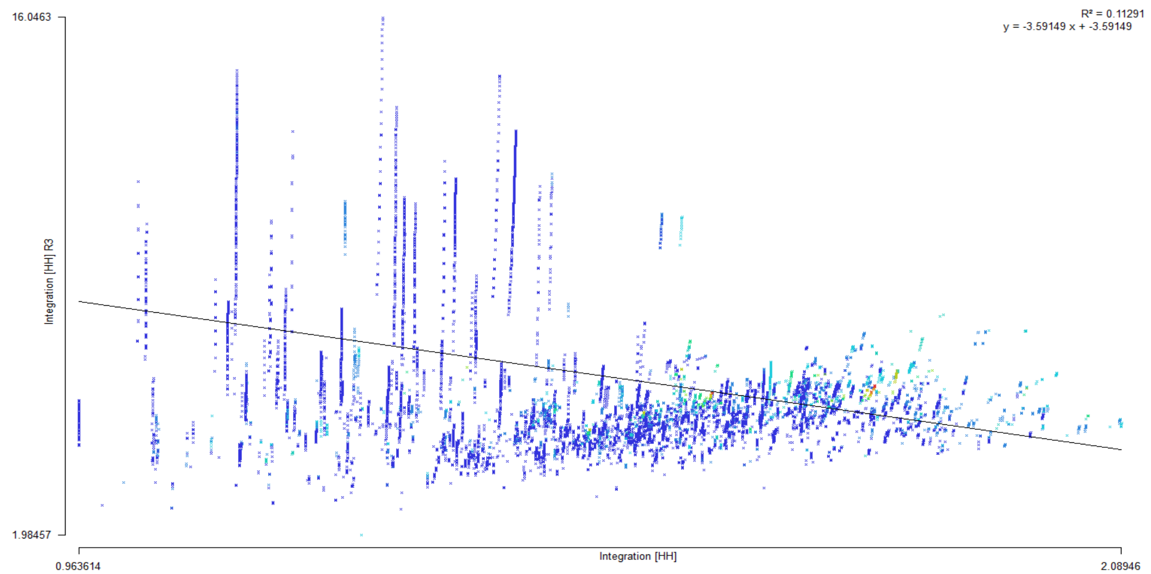


Figure 4.15.16 Synergy of Debre Birhan City

4.15.17. Intelligibility

Intelligibility in refers to the degree to which the number of immediate connections an axial line has is a reliable guide to the importance of that line in the system as a whole.

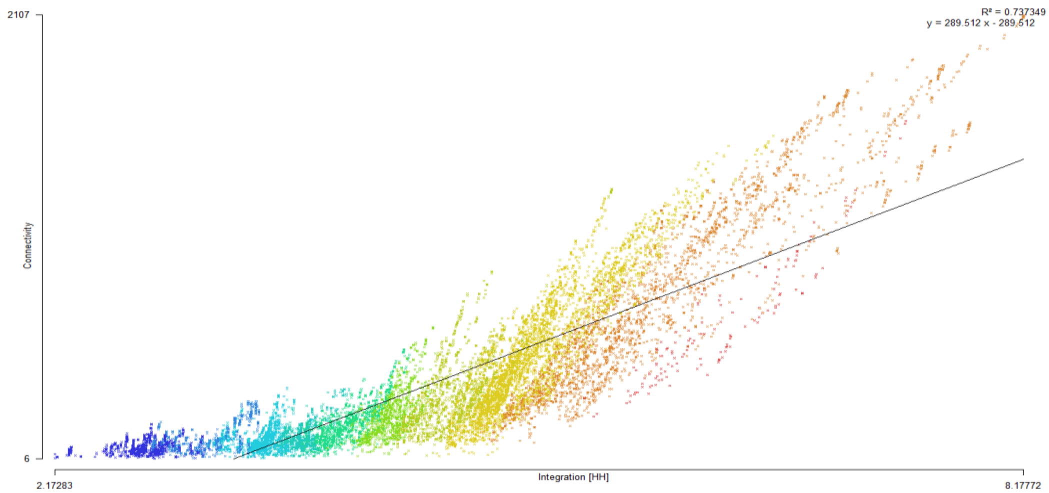


Figure 4.15.17. intelligibility of Dilla City

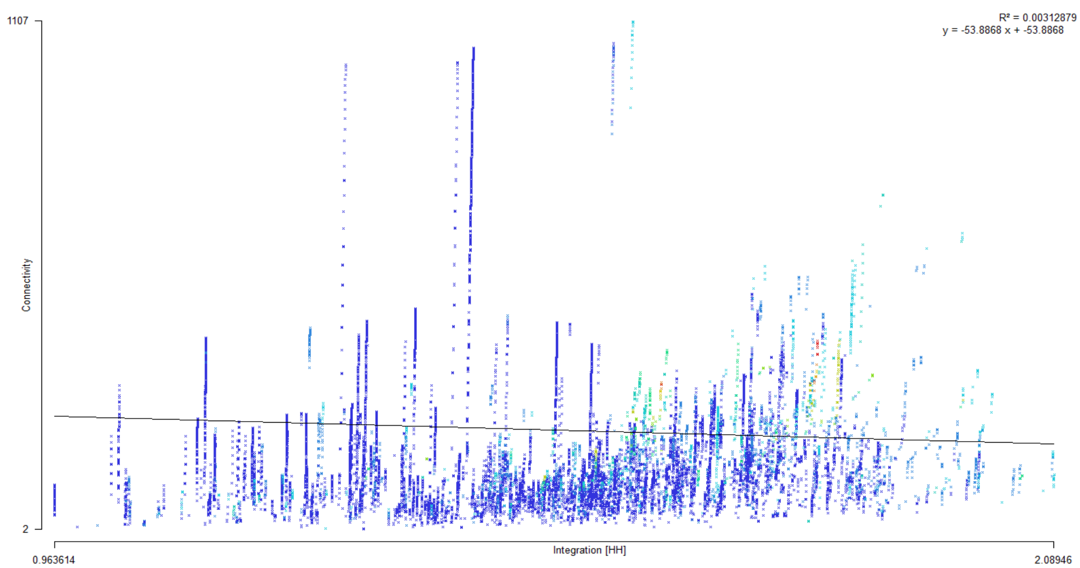


Figure 4.15.18 Intelligibility of Debre Birhan City

This low synergy and intelligibility in Debre Birhan indicates, the spatial configuration is less predictable, less efficient, and more difficult to relate it to RTA

4.16. Correlation Accident rate and configurational parameters of Dilla.

Since the aim of the study is to understand the influence of street pattern configuration on RTA, variables that are related to street pattern configuration are considered as dependent variables, and are expressed using configuration parameters. In the other hand accident rate data is considered as dependent variable. The next step is calculating the correlation and regression of the variables. Figures 4.16.1 to 4.16.10 below shows graphical correlation of each parameter with accident rate in case of Dilla.

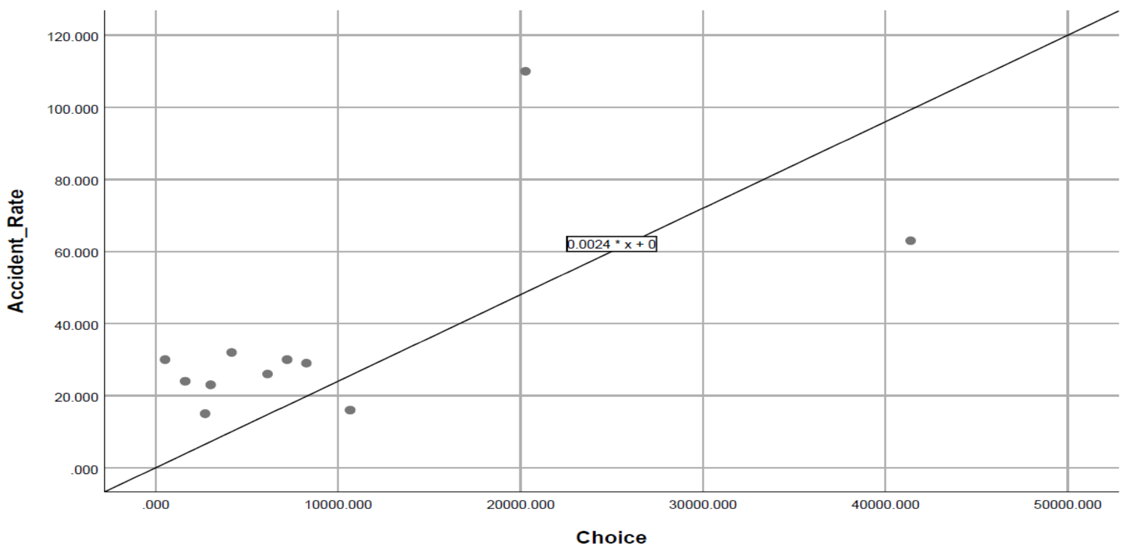


Figure 4.16.1. Correlation between accident rate and choice.

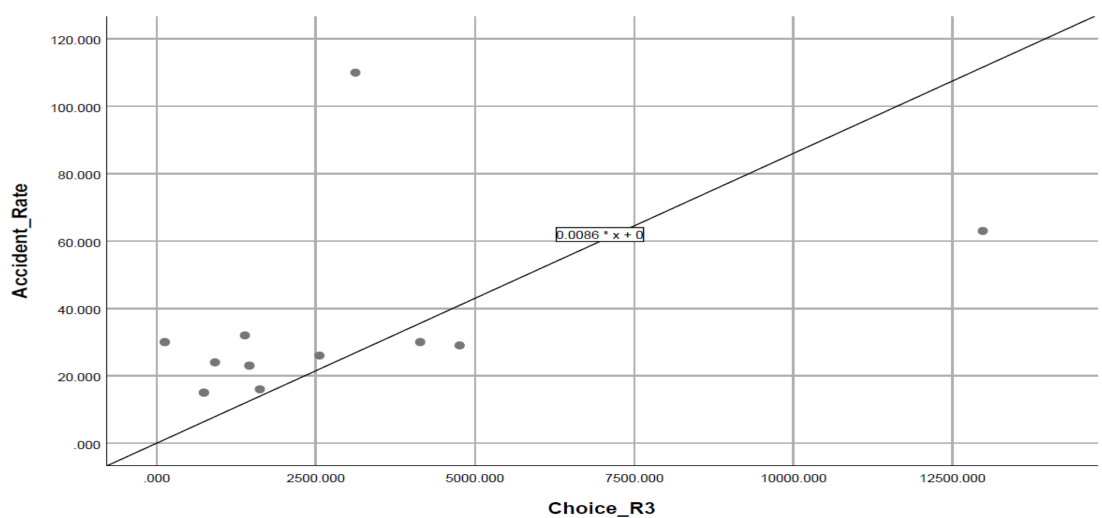


Figure 4.16.2. Correlation between accident rate and choice R3.

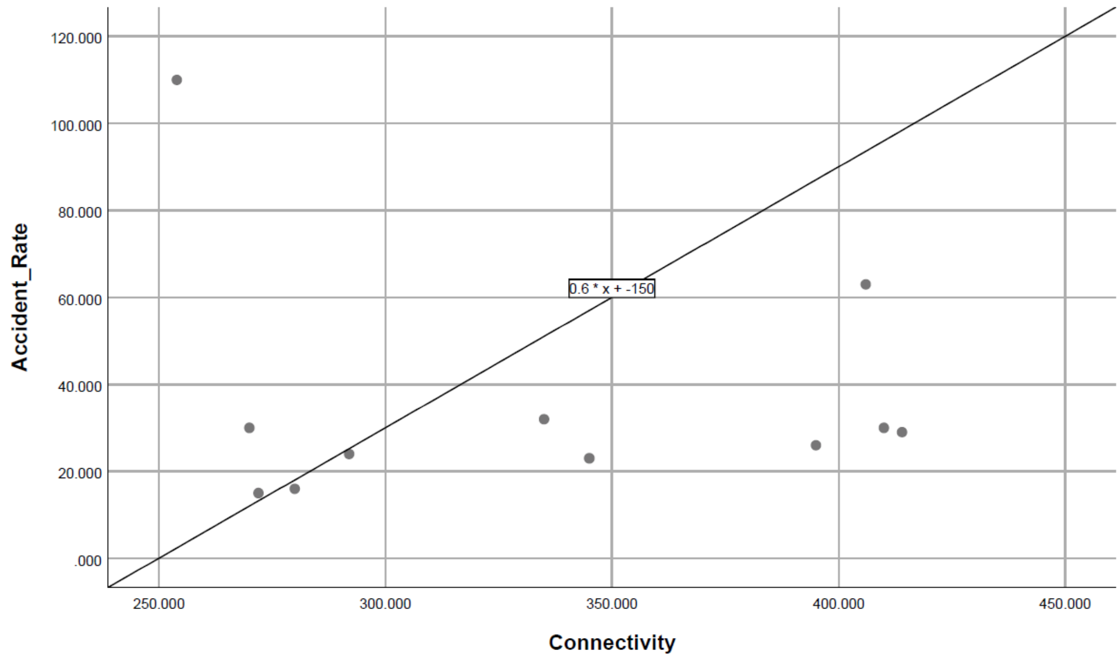


Figure 4.16.3. Correlation between accident rate and connectivity.

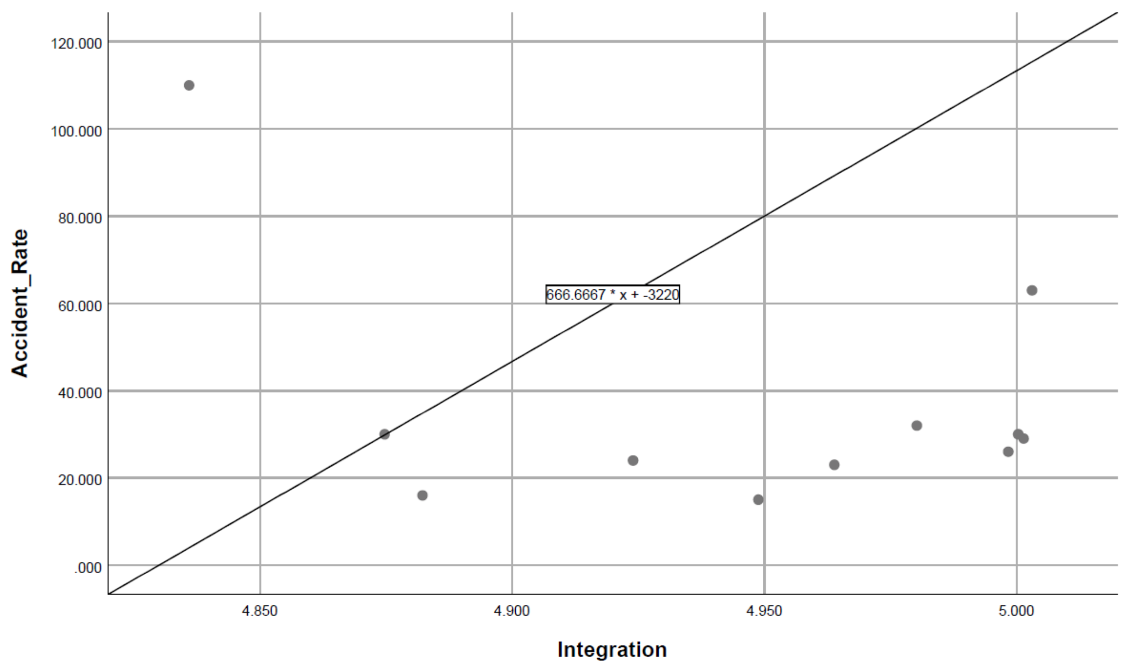


Figure 4.16.4. Correlation between accident rate and integration.

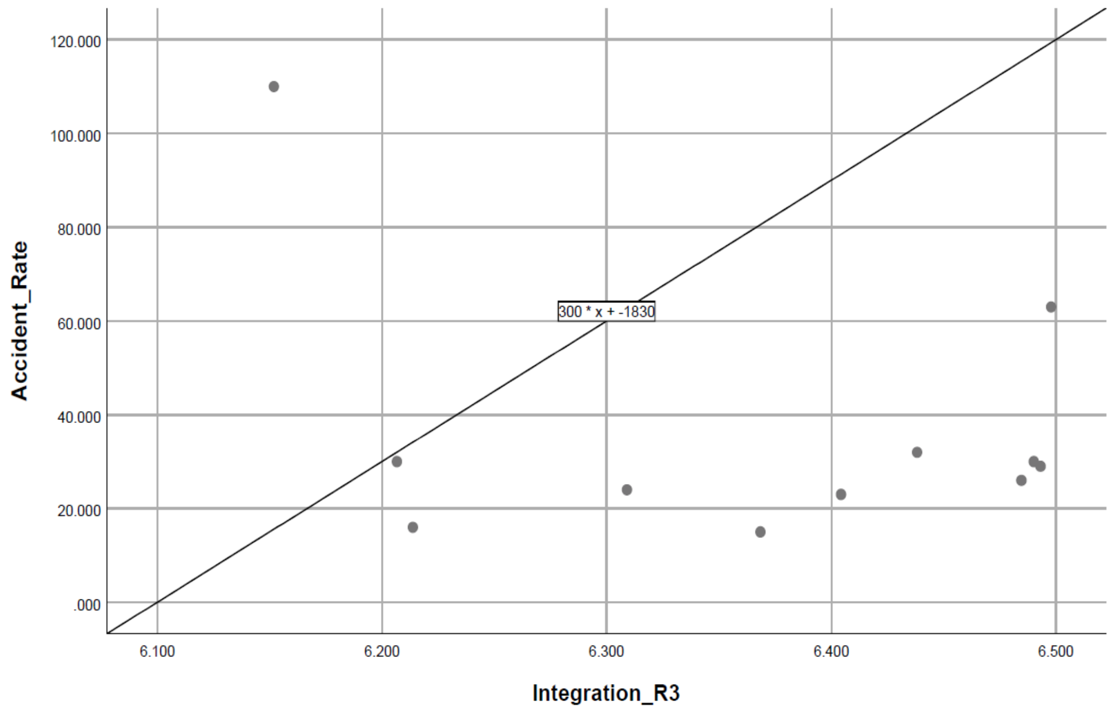


Figure 4.16.5. Correlation between accident rate and integration R3.

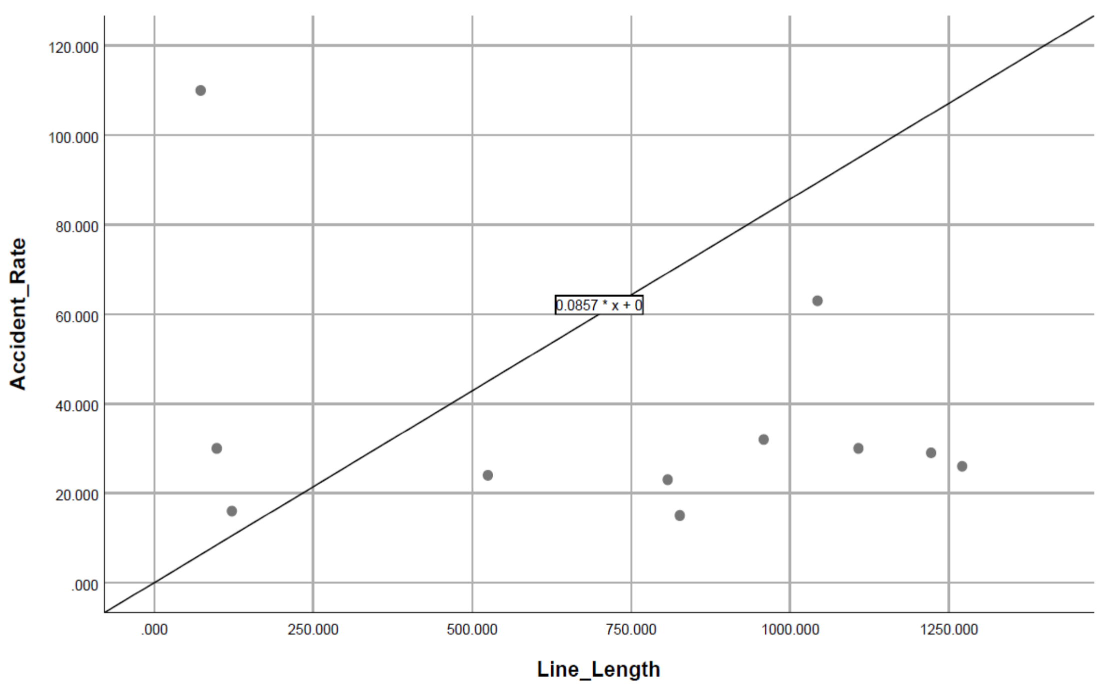


Figure 4.16.6. Correlation between accident rate and line length

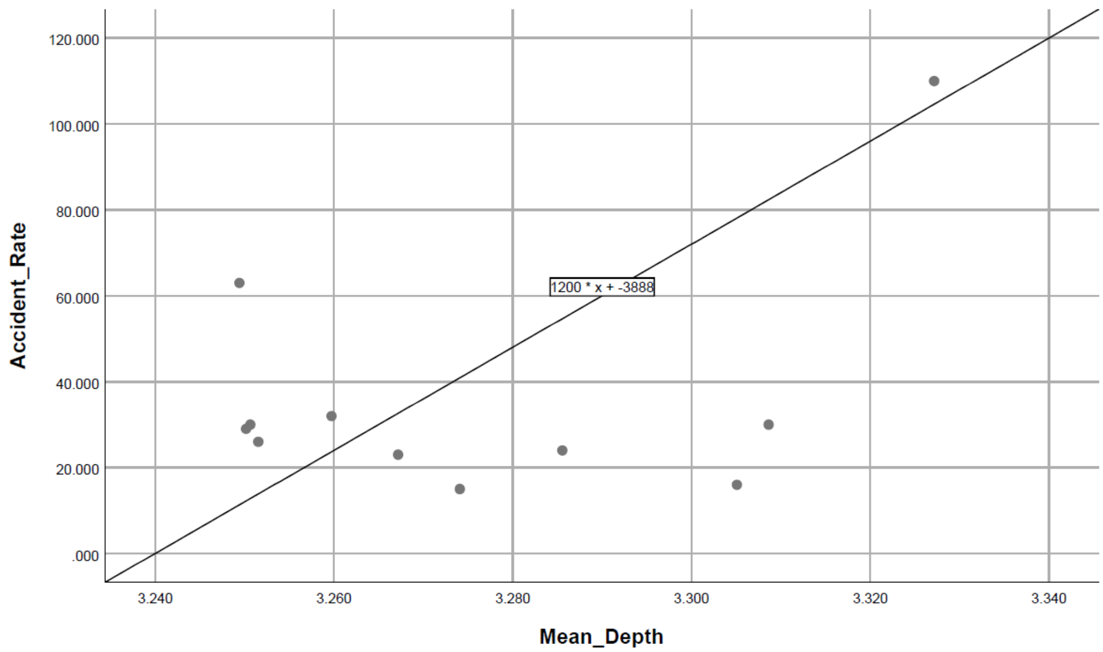


Figure 4.16.7. Correlation between accident rate and mean depth.

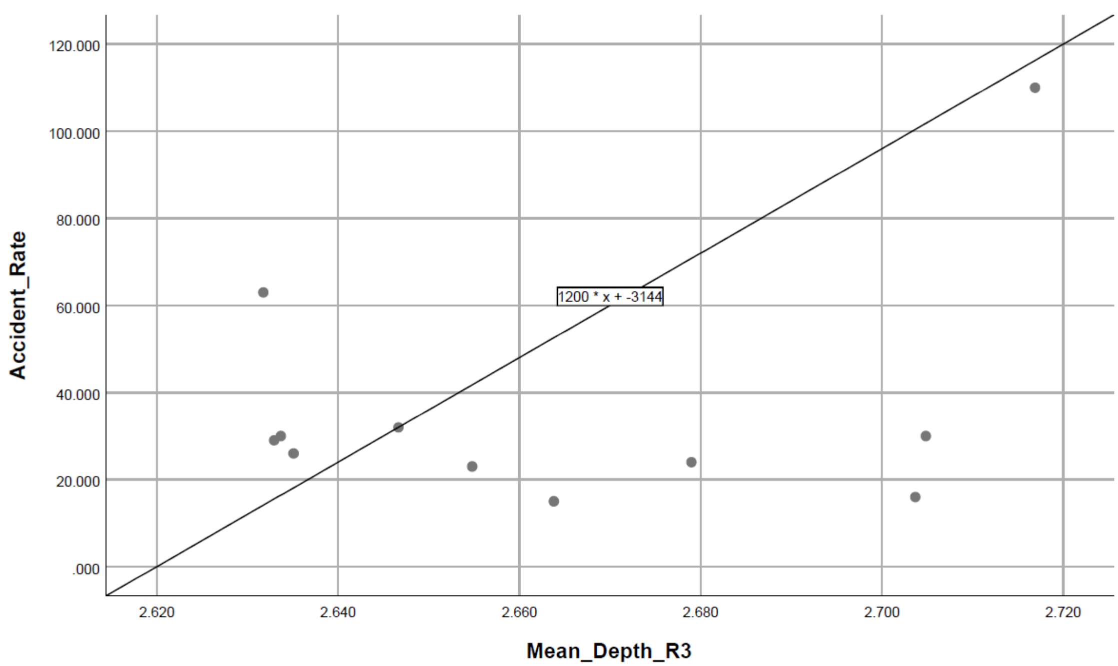


Figure 4.16.8. Correlation between accident rate and mean depth R3.

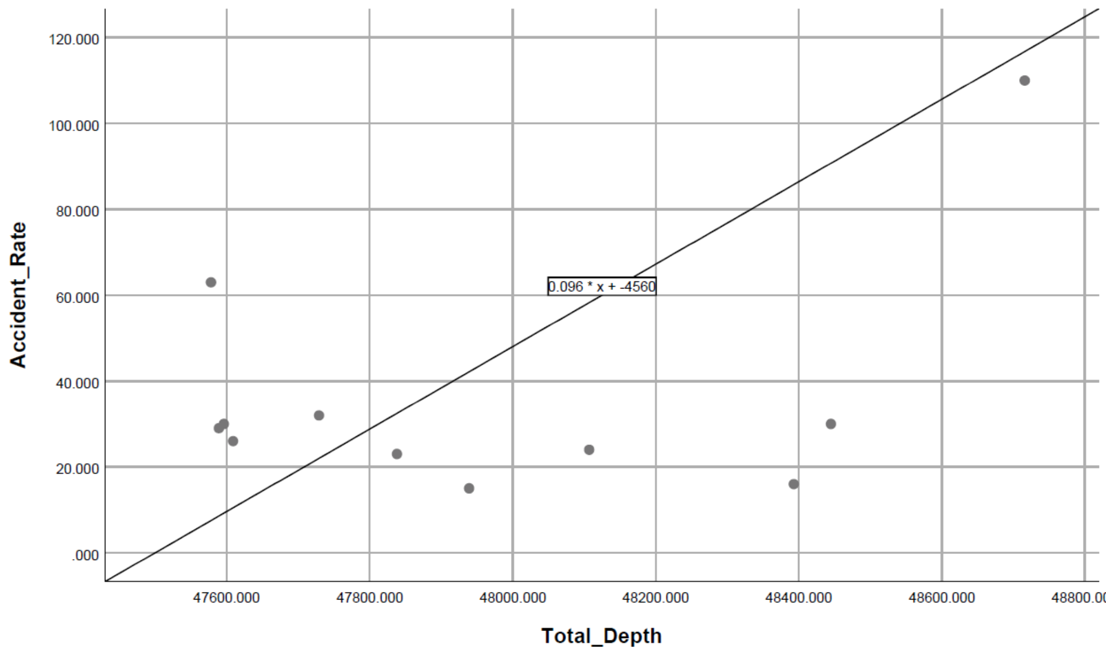


Figure 4.16.9. Correlation between accident rate and total depth

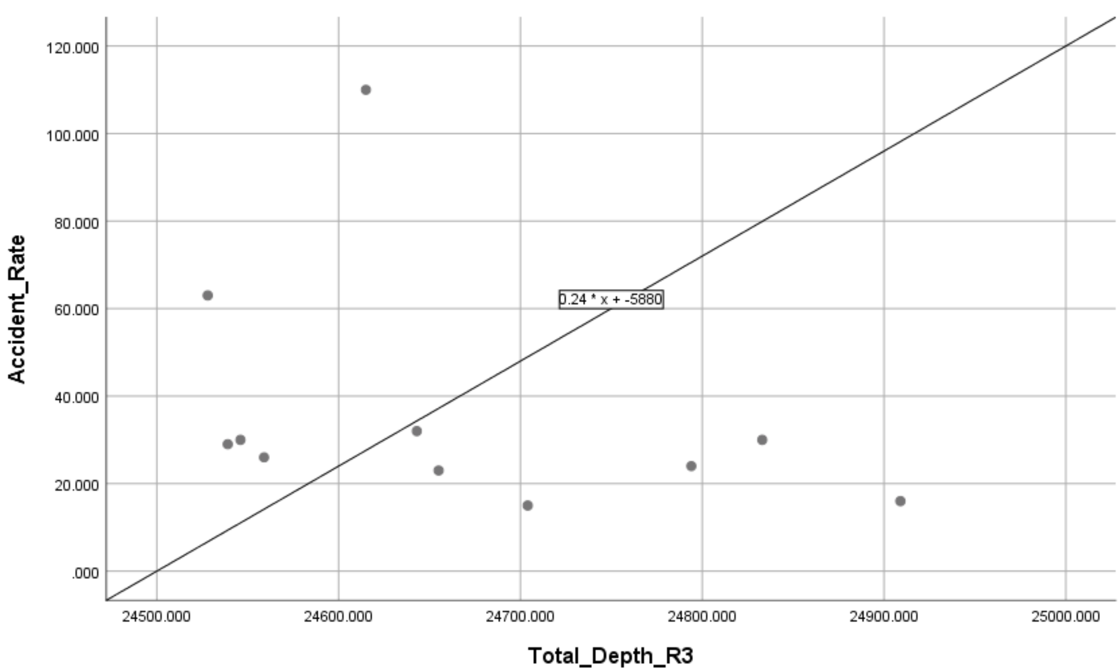


Figure 4.16.10. Correlation between accident rate and total depth R3.

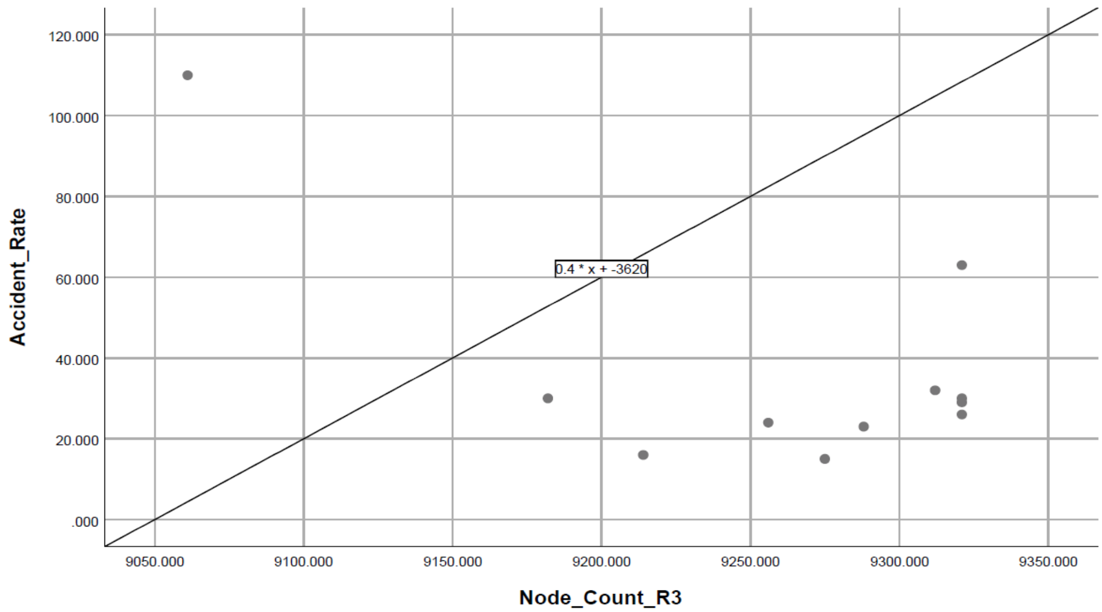


Figure 4.16.11. Correlation between accident rate and node count R3.

4.17. Correlation Accident rate and configuration parameters of Debre Birhan The graph above shows that the considered parameters of Dilla's street and accident rate are positively correlated. Like wise, the correlation for Debre Birhan is also represented by charts 14 to 24 below.

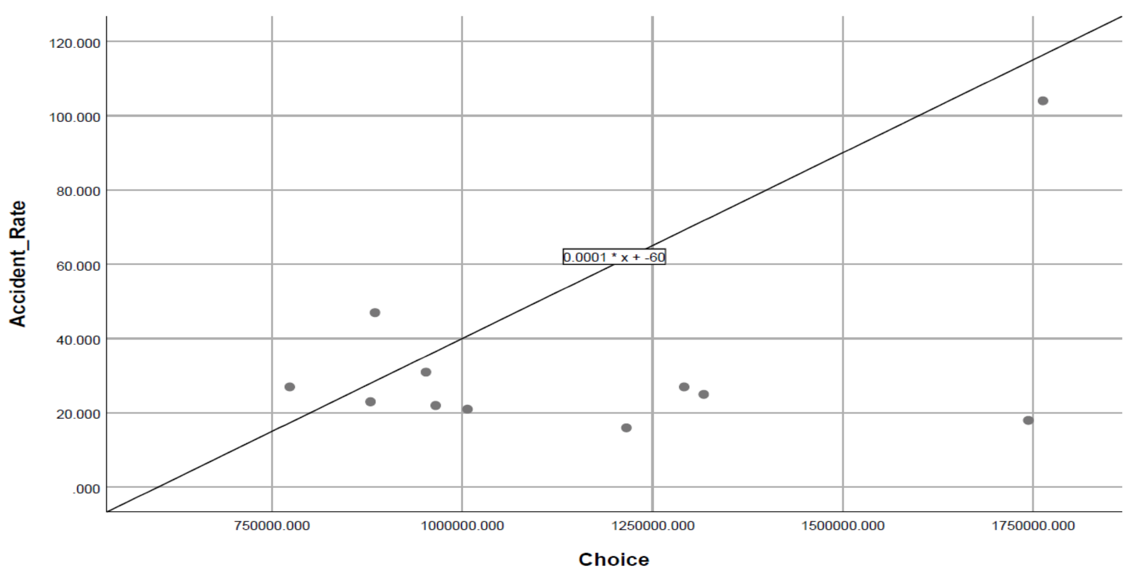


Figure 4.17.1. Correlation between accident rate and choice

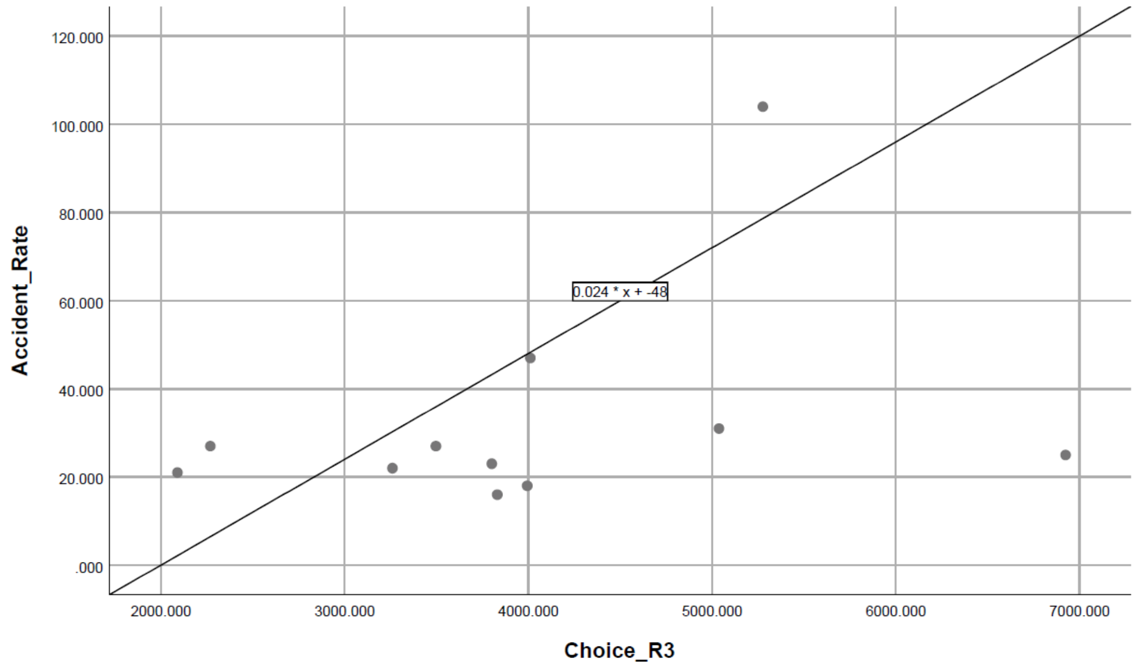


Figure 4.17.2. Correlation between accident rate and choice R3.

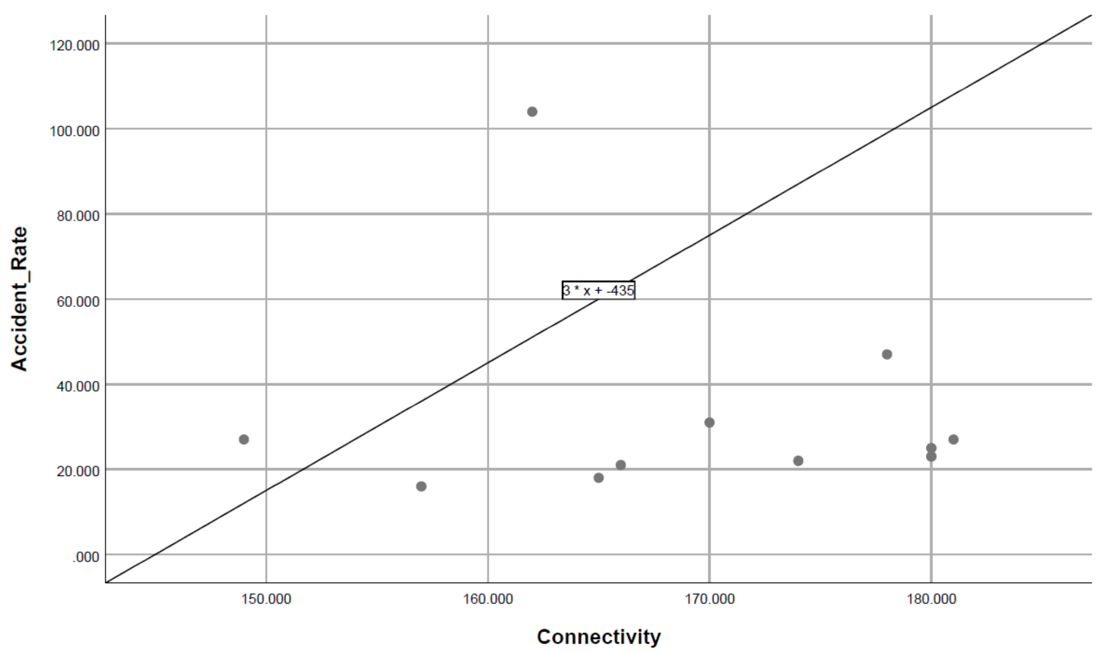


Figure 4.17.3. Correlation between accident rate and connectivity.

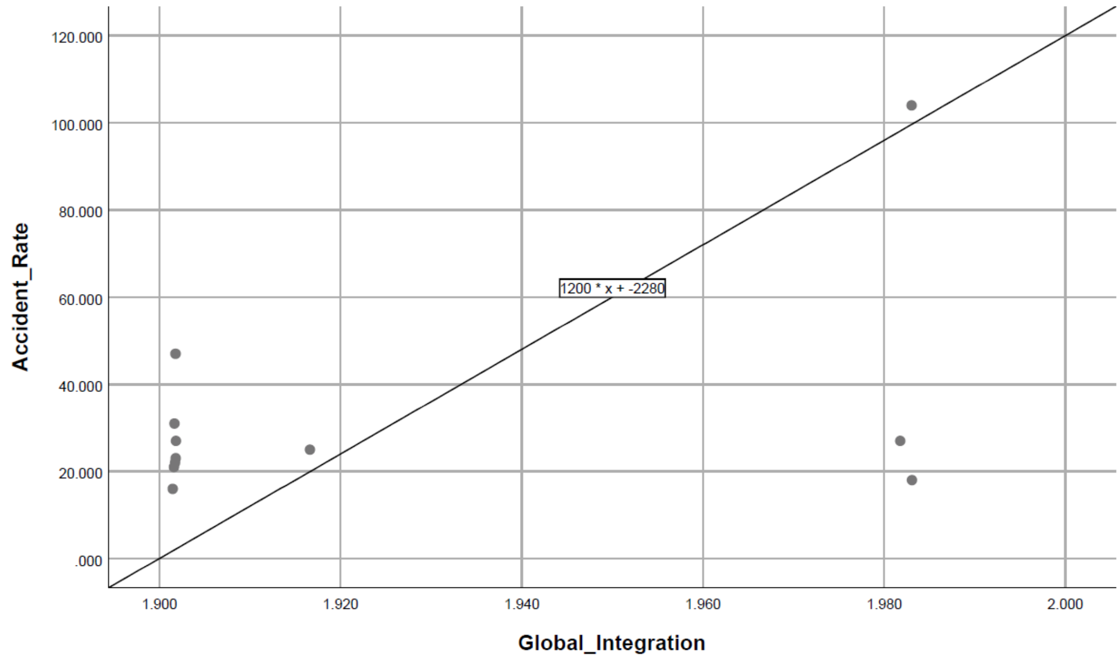


Figure 4.17.4. Correlation between accident rate and global integration.

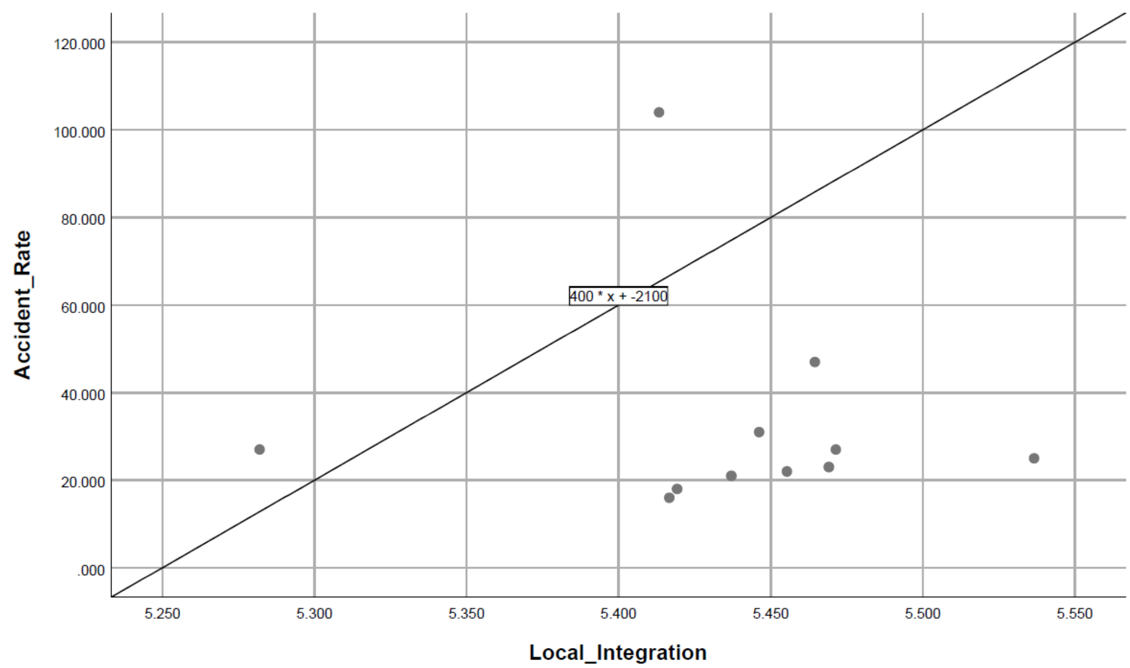


Figure 4.17.5. Correlation between accident rate and integration R3.

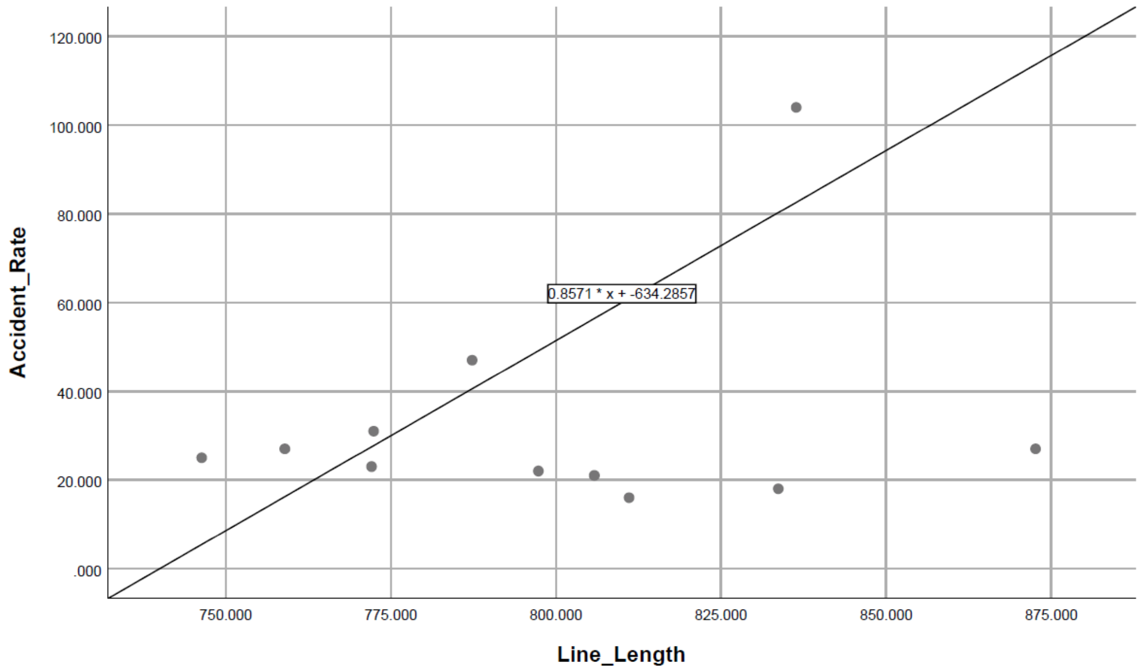


Figure 4.17.6. Correlation between accident rate and line length.

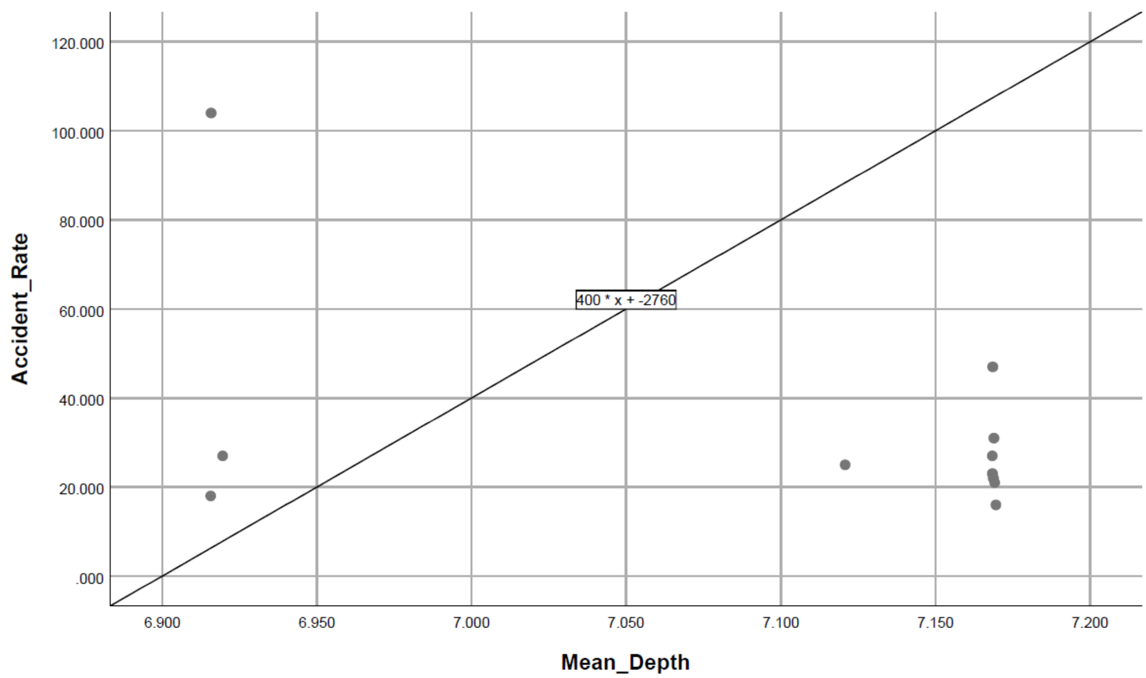


Figure 4.17.7. Correlation between accident rate and mean depth.

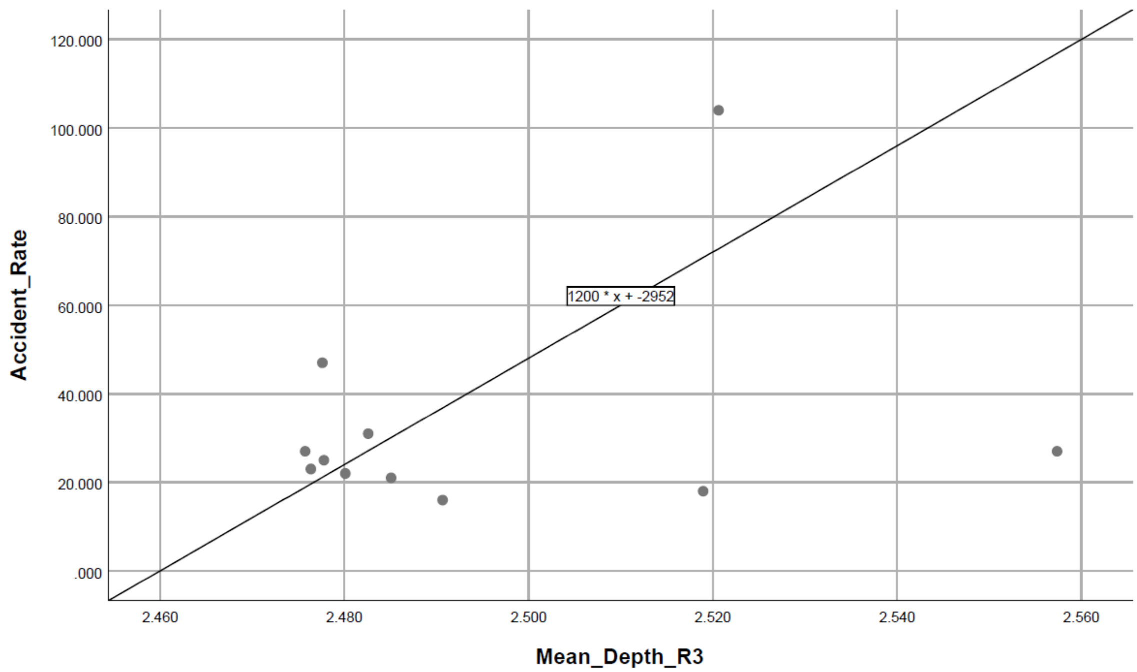


Figure 4.17.8. Correlation between accident rate and mean depth R3.

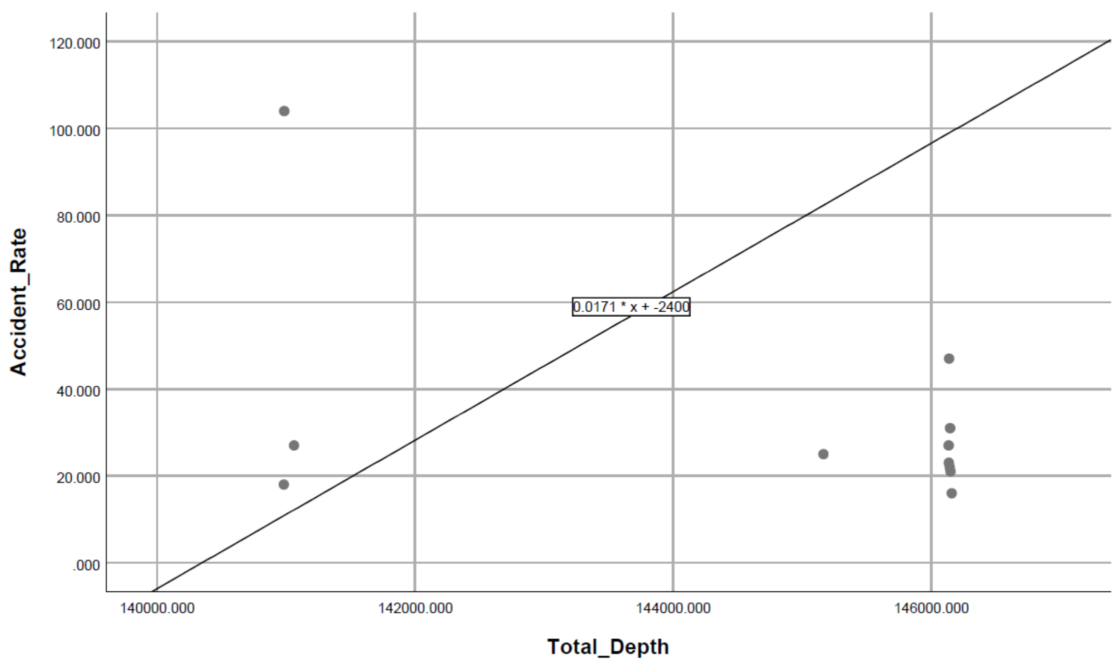


Figure 4.17.9. Correlation between accident rate and total depth.

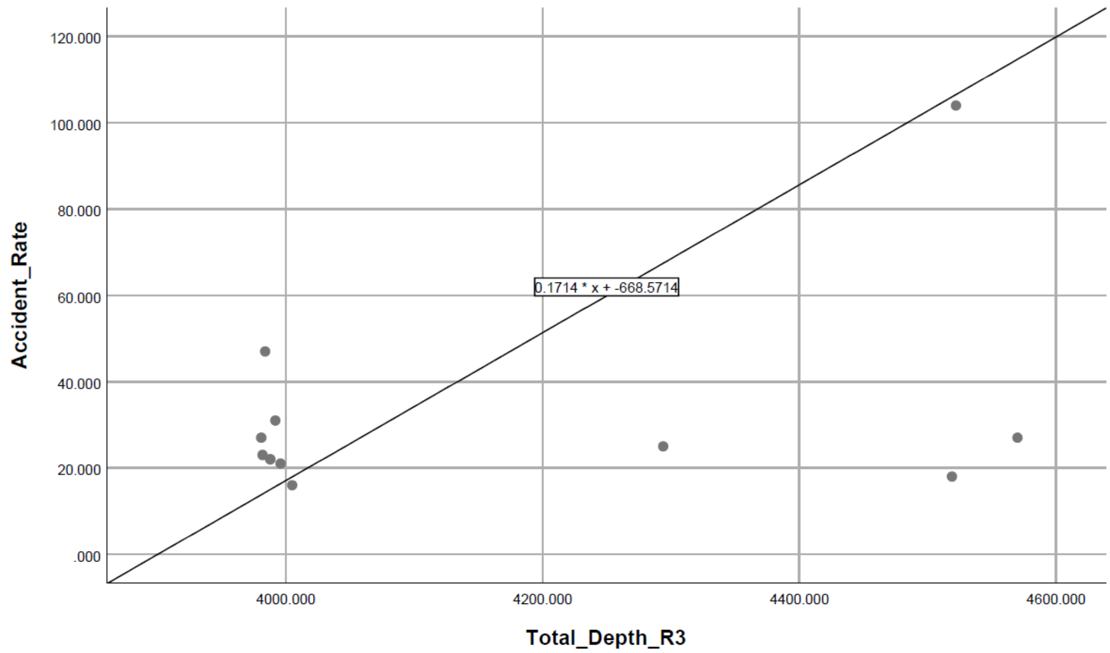


Figure 4.17.10. Correlation between accident rate and total depth R3.

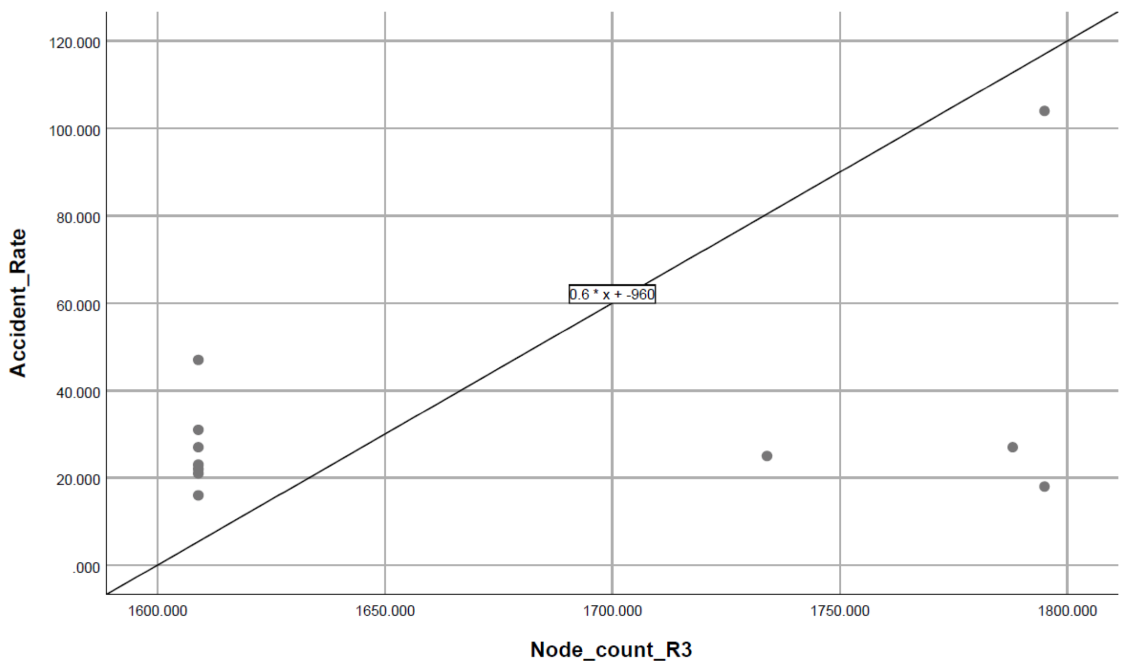


Figure 4.17.11. Correlation between accident rate and node count R3.

4.18. Correlation

One of the objective of this study is to find if there is a correlation between street pattern configuration and accident. The correlation is performed using accident rate as dependent variable and the parameters as independent variables. Pearson correlation coefficient for Dilla in the order of choice, choice R3, connectivity, integration , local integration, line length, mean depth, mean depth R3, total depth, total depth R3 and node count R3 is 0.638, 0.412, -0.412, -0.385, -0.316, -0.293, 0.392, 0.304, 0.392, -0.357, -0.621, -0.293, 0.304, 0.392,-0.357 and -0.621 respectively . This coefficient for Debre Birhan as the sequential order of Dilla is 0.432, 0.335, -0.105, 0.430, -0.084, 0.239, -0.430, 0.253, -0.430, 0.377 and 0.390.

Table 4.1 Association between variables

Model	R	R Square	Adjusted R square	Std. Error of the estimation	Remark
Dilla	0.983[a]	0.966	0.915	8.02	Predictors: (Constant), Total Depth R3, Choice, Node Count R3, Connectivity, Choice R3, Line Length
Debre Birhan	0.894 [a]	0.799	0.330	20.46	Predictors: (Constant), Total Depth R3, Choice R3, Connectivity, Choice, Line Length, Integration, ,Integration R3

Source - SPSS

In the above table under the column of R, it is showed that the over correlation of variables and relational closeness for Dilla city is 0.983 and for Debre Birhan is 0.893.

The R Square value or the coefficient of determination for Dilla city is 0.966. It states that the variation of street pattern configuration parameters explain accident rate 96.6 %. Whereas, the coefficient of determination for Debre Birhan is 0.799 and justify that 79.9 % of street pattern configuration parameters explain accident rate.

The adjusted R Square value for Dilla is 0.915 and for Debre Birhan is 0.325 which brings down the models' explainablity to 91.5 % and 33 % respectively due to predictors that do not improve the fit.

4.19. Multi linear regression

To examine the relationship between a dependent variable and independent variables regression was implemented. It is used to test hypotheses about causal effects and helps to understand how changes in the independent variables affect the dependent variable. Regression can also be used for prediction, estimation, and optimization purposes.

Table 4.2 ANOVA (Analysis of Variance)

Model		**Sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Dilla	Regression	7338.54	6	1223.09	19.03	0.007[b]
	Residual	257.09	4	64.27		
	Total	7595.64	10			
Debre Birhan	Regression	4998.87	7	714.12	1.71	0.357[b]
	Residual	1256.76	3	418.92		
	Total	6255.64	10			

Source – SPSS

a) Predictors for Dilla: (Constant), Total Depth R3, Choice, Node Count R3, Connectivity, Choice R3, Line Length
b) Predictors for Debre Birhan: (Constant), Node count R3, Choice R3, Connectivity, Choice, Line Length, Global Integration, Local Integration
c) Dependent Variable: Accident Rate

The overall regression model for Dilla is statically significant meaning that the variation in accident rate is explainable by the predictors of grid iron street pattern configuration and can be expressed as: $F(6,4)=19.03$, $p<0.05$, $R^2 = 0.966$

In case of Debre Birhan $F(7,3)=1.705$, $p>0.05$, $R^2 = 0.799$ is found to be statically not significant. This means that the predictors do not fully explain accident rate in relation to its mixed street pattern configuration.

Therefore the general multi linear regression formula for Dilla city for predicting future occurrence of road traffic accident is expressed using the formula below.

Y= 6292.35 + 0.001* Choice – 0.002 * Choice R3 - 0.053 * Connectivity – 0.044 * Line length - 0.076 * Node count R3 – 0.223 * Total depth R3.

Eq. 7. Representation of accident rate of Dilla

The regression model of Debre Birhan city is expressed using the formula below.

Y= -27578.162 - 0.001* Choice + 0.031 * Choice R3 – 11.436 * Connectivity + 5972.201* Global Integration + 3343.974 * Local Integration + 2.265 * Line Length – 0.879 * Node count R3.

Eq. 8. Representation of accident rate of Debre Birhan

DISCUSSION

4.20 Road traffic accident in Dilla and Debre Birhan city

The initial reason to perform this study was frequent accident rate taking place in Dilla city streets, The idea of moving freely on the side of the main street of the city, may not be considered as a pleasing thing to do. This is due to sudden bumping with vehicles. Even though many academicians suggested internal factors as a reason, people in the city believe that the reason is the physical aspect of the street.

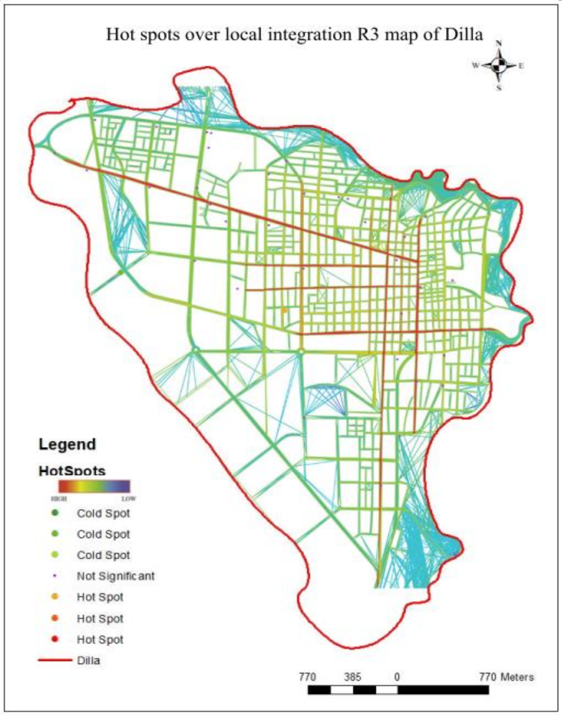
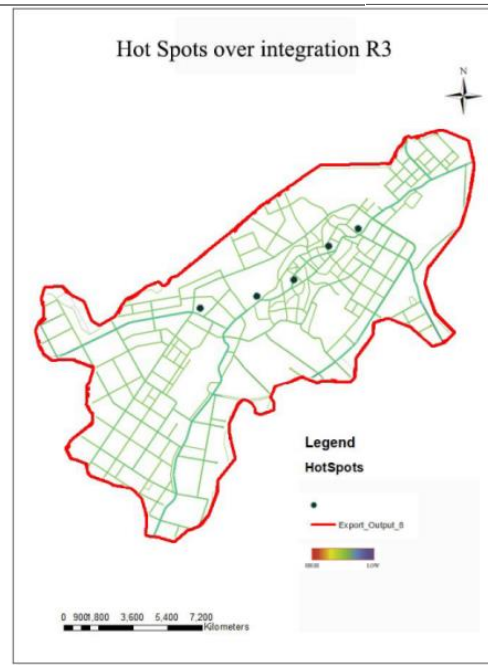
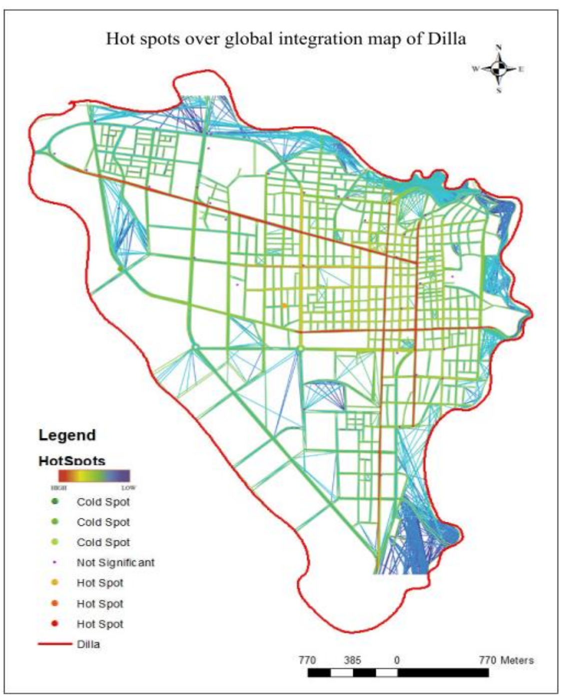
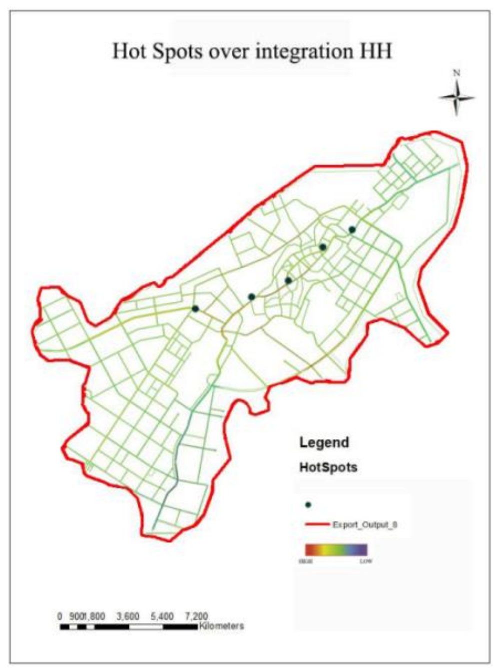
The physical aspect of the road is mostly concerned with its street pattern configuration. Dilla has grid iron street pattern configuration. Academicians like Marks explained the accident rate of different street pattern configuration and concluded that grid iron pattern has greater accident rate per year unlike other types of street pattern configuration.

To make sure that, a city with approximately equal number of population with different street pattern configuration was selected. That city is Debre Birhan city having a mixed type of street pattern configuration.

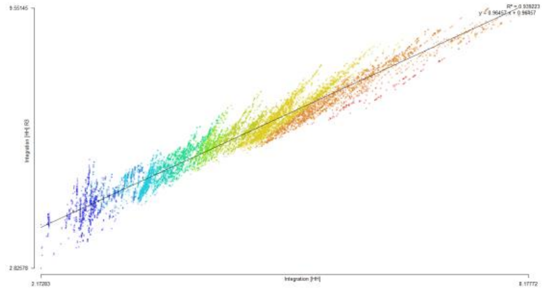
Hot spots were identified after that, the next step is to proceed with analysis of accident indicating parameters and road configuration parameters.

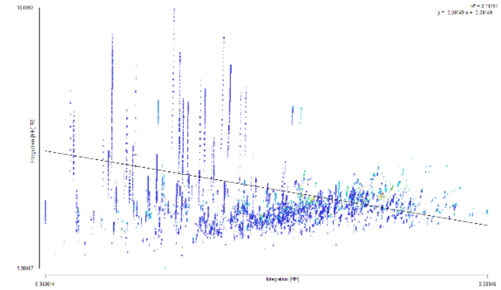
Accident indicating parameters like Accident risk and Accident severity rate are the major once. Accident risk is the number of accidents per 100,000 people. Simply referred as crash rate, is the number of crashes recorded on a specific area for a specific time. Accident severity index: measures the seriousness of an accident. It is therefore defined as the number of persons killed per 100 accidents. Severity index determines the weight of a single crash. This result was correlated with road configuration parameters. From those many road configuration parameters, global integration, local integration, connectivity, total depth, and choice were selected. Also synergy and intelligebility were analyzed. Below Fig. 4.3. Shows the comparison of the two cities namely Dilla and Debre Birhan's street configuration with their respective hot spots.

Table 4.3 Comparison of Dilla and Debre birhan city.

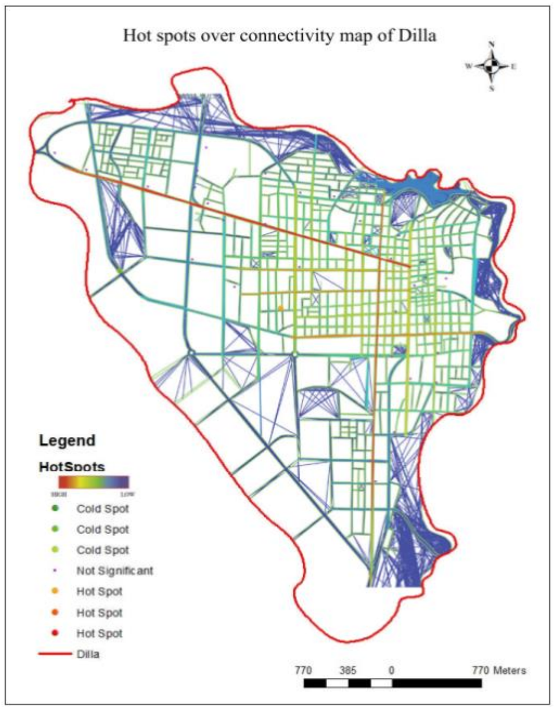
Parameters	Dilla	
Local Integration		
Global Integration		

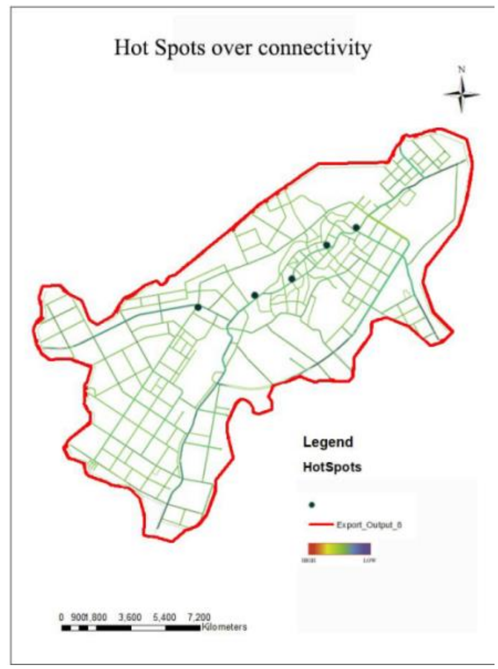
Synergy



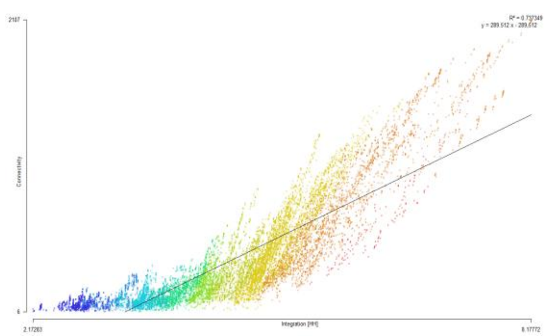


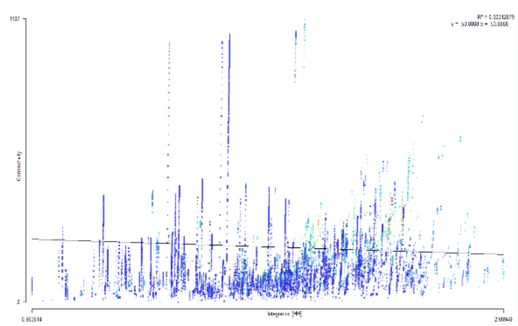
Connectivity





Inteiligeblity





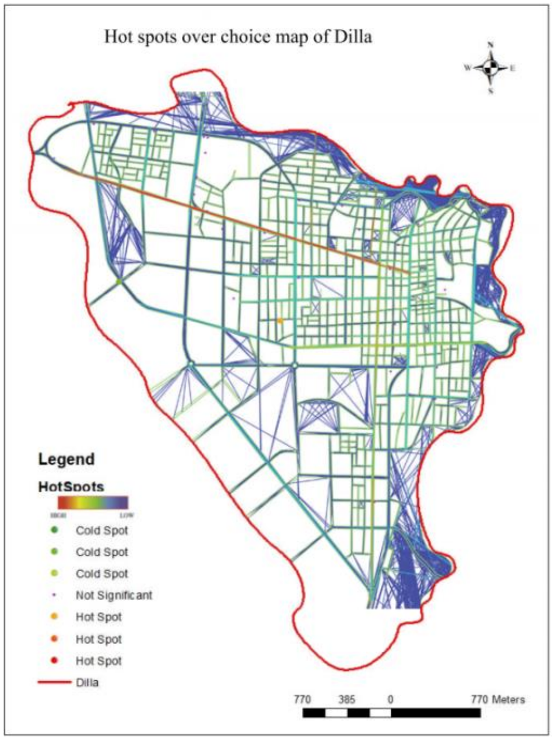
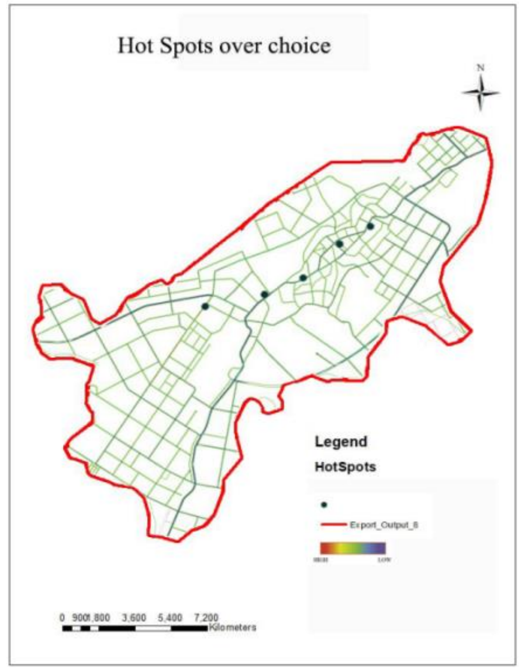
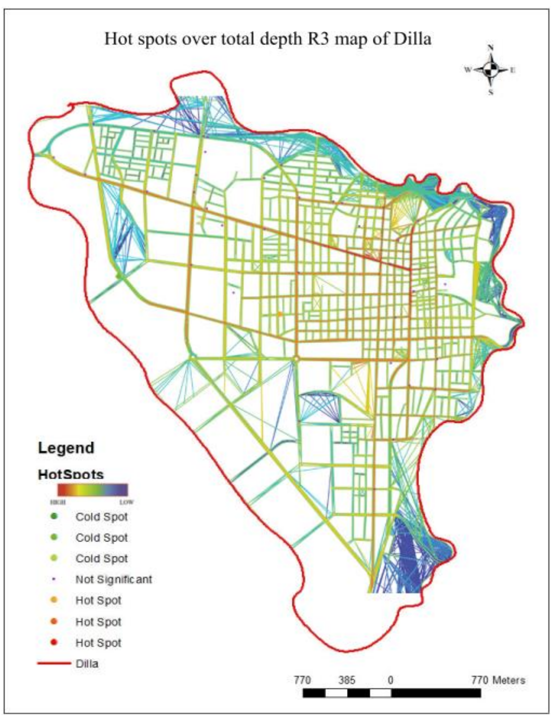
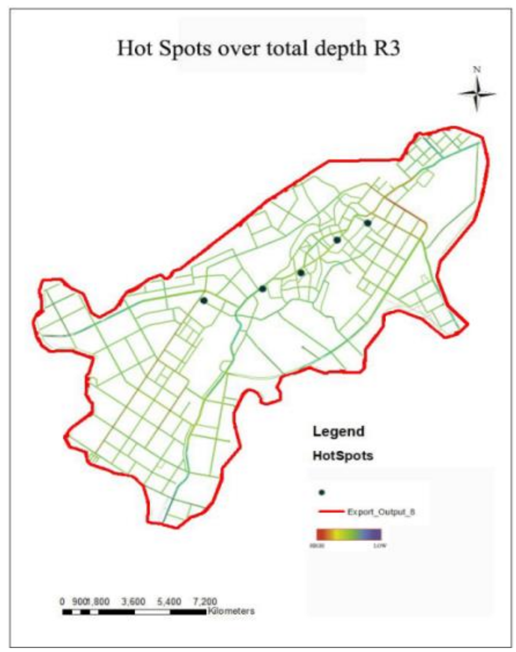
Choice		
Total Depth		

Table 4.3 Parametrical comparing table

The analysis integrated Depthmap-based measures of configuration such as street integration, connectivity and betweenness centrality, with granular geographical mapping of accident locations and intensities.

Even though accidents happen randomly in a certain place and time, certain reasons for the occurrence can be listed. In this research street pattern configuration listed as the most significant factor. To understand the most significant parameter contributing to the hotspots, the result of the analysis of each parameter, the hotspot was over laid on top of each parameter.

Local integration (R3), for the case of Dilla the central part of the city have higher local integration value but for the case of Debre Birhan there is almost no higher and moderately integrated streets in the city. Dilla has 26% of the total street segments have high integration, 72 % of the total street segments are moderately integrated and 2% of the total street segments are segregated and Debre Birhan has 0.5% of the total street segments have high integration, 1% of the total street segments are moderately integrated and 98.5% of the total street segments are segregated. Since R3 is used to show the local value of integration from the perspective of 3 different segments of street with in the city and in the other hand the number of hotspots of Dilla is higher than Debre Birhan, it expresses that the local integration value is highly associated with accident hotspots.

Dilla has 37% of the total street segments have high global integration, 59 % of it are moderately integrated and 4% of it are segregated and Debre Birhan has 86% of the total street segments have high integration, 4% of the total street segments are moderately integrated and 10% of the total street segments are segregated. It has higher value especially in the main roads of the city associated with commercial, recreational, entertainment land use and city exit streets. For Debre Birhan the highest globally integrated street value is located in the central part of the city which is the main street A.A.- Debre Birhan – Debre Sina and A.A.- Debre Birhan – Angolela which is also were the hotspots are located. This as well shows there is strong relation between global integration and accident hotspots.

Synergy which the correlation between local and global integration is used to express its relation with accident hotspots. In Dilla's case when global integration increases the local integration also increases with increasing number of accident hotspots. In Debre Birhan's case the relation between local and global integration is skewed with decreasing value of hotspots. More or less this value appears to be insignificant for the case of Debre Birhan. The Synergy value of R^2 of Dilla is 0.939 and 0.11291 for Debre Birhan. The line equation is Y=0.96457X+0.96457 for Dilla and Y=-3.59149X+-3.59149 for Debre Birhan.

In case of Dilla, the main city exit road has the highest connectivity value and the major city's road like Amsitegna and road around Menahria have the higher value 21% of the total street segments have high connectivity, 32 % of the total street segments are moderately connected and 47% of the total street segments are segregated. For Debre Birhan, the parameter of connectivity appears to be less. Almost all of the roads fall in to the lower category whereas the road located along the newly established villages with grid like structure has moderate value. 86% of the total street segments have high connectivity, 4% of the total street segments are moderately connected and 10% of the total street segments are segregated. For Dilla the hotspot with 95% confidenciallty is located along moderately connected streets but in case of Debre Birhan it is long lowly connected streets. This means that connectivity insignificantly related with hotspots of the cities.

Intelligebility which the correlation between connectivity and global integration is used to express its relation with accident hotspots. In Dilla's case when global integration increases the connectivity also increases with increasing number of accident hotspots. In Debre Birhan's case the relation between connectivity and global integration is crooked with slightly decreasing value of hotspots. This value in case of Debre Birhan, as of its synergy, its significance is near to the ground. The Intelligebility value of R^2 of Dilla is 0.737 and 0.00313 for Debre Birhan. The line equation is Y=289.512X+289.512 for Dilla and Y=-53.8868X+-53.8868 for Debre Birhan.

Most streets of Dilla are less likely to be chosen whereas the vertical and horizontal streets around Meneharial has moderate value and the main exit road of the city has higher tendency to be chosen. 8% of the total street segments have high value, 51 % of the total street segments are moderately placed and 41% of the total street segments are segregated. For Debre Birhan most of the city's street are categorized under lower choice group 4% of the total street segments have high possibility to be chosen, 2% of the total segments have moderate possibility to be chosen and 94% of the total segments are less likely to be chosen.

Finally the equation to determine the accident rate of both cities using street pattern configuraton parameters was derived. This enables to forecast, the accident rate of the cities caused by the street pattern configuration.

4.21. Road traffic accident distribution around hotspots

In Dilla related to its street pattern configuration, the tendency to have numerous numbers of street choice is observed that it leads to scatterness or randomness of road traffic accident hotspot and local integration, global integration, connectivity and total depth also have contribution to the pattern of road traffic accident.

In case of Debre Birhan, even though the parameters like local integration, global integration, connectivity and total depth looks like it has lower value but it has influence on the street pattern configuration and especially since a certain street has relatively higher choice value, the traffic accident hotspots appears to be aligned on that specific street which is the main city road to and from Addis Ababa and other cities like Ankober.

4.22. Road traffic accident distribution in time

Accident occur when there is contact between two things, at least one of which is impelled toward the other at a certain moment. This certain moment increases especially at peak hours. Peak hours in Dilla city as well as Debre Birhan has common peak hours as the other cities in Ethiopia and very early morning since it is a tread- route city. The time also varies depending of the land use character of the area.

4.23. Road traffic accident distribution in Land use

Space in which RTA occur is a result of entities. Land use is one of those entities contributing to the area by its pushing and pulling factors. Since commercial area is subjected to pull people in, it makes the area more active. Whenever the area starts to appear active, the probability of facing RTA will increase. This can be seen in this study in Zone 5. Other pulling land uses like school, churches, mosques, stadium and bus stations also contribute for the activeness of the area in consideration with their scale.

4.24. Road traffic accident in Street structure

At last but not list street configuration of the city has several impacts when applied to residential areas. First, grid pattern requires a larger paved area than necessary, consuming the resource of the city. Then, it needs the installation of a more expensive type of paving that is asphalt for all roads by scattering the traffic equally throughout the area. These reasons are other reasons for increasing number of RTA and also it amplified traffic accident due to the rise in the likely for interactions between vehicular and pedestrian traffic. Last, it creates a tedious and unexciting architectural outcome that may diminish certain community features.

4.25. Road traffic accident severity index and street pattern configuration

Since severity index is a measure of seriousness of the traffic accident per 100 accident most of the records shows that the accident in both cities has high value. In case of Dilla, the average severity index is 54.75 while the minimum is 33.4 per 100 accident and per a year. This means that the more higher the index the more serious the road traffic is. For Debre Birhan, the severity index of 2022/2023 is 24.81.

4.26. Correlation

The correlation of parameters and accident rate in Dilla, appears to be more significant than that of Debre Birhan. The variation of street pattern configuration parameters explain accident rate 96.6 %. Whereas, it is justified that 79.9 % of street pattern configuration parameters explain accident rate of Debre Birhan. The explainablity doped down to 91.5 % and 33 % for Dilla and Debre Birhan respectively due to predictors that do not improve the fit.

4.27. Regression

The overall regression model for Dilla is statically significant meaning that the variation in accident rate is explainable by the predictors of grid iron street pattern configuration and can be expressed as: $F(6,4) = 19.03$, $p < 0.05$, $R^2 = 0.966$ and $F(7,3) = 1.705$, $p > 0.05$, $R^2 = 0.799$ is found to be statically not significant. This means that the predictors do not fully explain accident rate in relation to its mixed street pattern configuration.

4.28. Prediction

The future accident rate of Dilla city occurring due to its street pattern configuration can be predicted using the model below.

Y= 6292.35 + 0.001* Choice – 0.002 * Choice R3 - 0.053 * Connectivity – 0.044 * Line length - 0.076 * Node count R3 – 0.223 * Total depth R3.

The future accident rate of Debre Birhan city occurring due to its street patter configuration can also be predicted using the model below.

Y= -27578.162 - 0.001* Choice + 0.031 * Choice R3 – 11.436 * Connectivity + 5972.201* Global Integration + 3343.974 * Local Integration + 2.265 * Line Length – 0.879 * Node count R3.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This thesis provides an innovative application of space syntax techniques to investigate the influence of differentiated street pattern configurations on the localization of road traffic accidents in two Ethiopian cities - Dilla and Debre Birhan. The spatial network analysis generates several pertinent findings and insights on the nexus between urban morphology and road safety outcomes. The results reveal clear variations in key street network parameters between Dilla's grid layout and Debre Birhan's mixed street layout.

The results also demonstrated that syntactical measures did describe parts of streets that accidents occurrence is more likely to occur. It similarly indicate that a street with little number of connections with neighborhood routes, it more exposed to accidents due to increasing volume of traffic flow at the street level. Land use and time of occurrence has likely played a role of increasing the accident risk and severity index by being a pulling factor towards the occurrence of road traffic accident. Hierarchical concept related to its street structure also influenced the flow of traffic.

In spite of remarkable discovery, this study has a few limitations. First, since these two cities urban forms are unique cases, generalizing the results of this study should be specific. Future studies should consider more case cities for generalization. Second, this study only considered a few quantitative measures of space syntax in investigating the importance of streets. Academicians should consider a variety of quantitative measures of space syntax. Finally, future studies should consider the integration of space syntax measures with other important built environmental factors such as surrounding land use and street layout.

The findings reveal significant contrasts, with Dilla's small block grid layout displaying higher local integration and street network complexity corresponding to the dispersion of accidents citywide. Whereas in Debre Birhan, radial concentric structure focuses accidents along the central arterial with highest global integration but negligible local connectivity.

These results spotlight that while street network designs shape traffic distribution and risks, their effects combine in complex ways with land uses, peak hour densities, and user conduct to produce safety outcomes.

Nonetheless, the study makes an important empirical contribution by demonstrating the value of computational spatial network analysis paired with localized accident data mapping to unravel urban morphological impacts on road safety.

The applied techniques and evidence-base provide directions to inform policy interventions around safer streetscape design, traffic calming and integrated land use planning for enhancing mobility safety, while acknowledging limitations in spatial determinism. structure that closely correspond to divergent accident distribution patterns observable in the two cities.

In particular, Dilla exhibits significantly higher local integration or closeness centrality values concentrated in the downtown streets that also attract most accident hotspots. This indicates that greater connectivity of streets to immediate neighboring segments intensifies local accessibility as well as traffic conflicts and crash risks within Dilla's grid structure. The spatial synergy analysis further underscores this, demonstrating accident hotspots increasing in alignment with higher local integration across Dilla.

In contrast, Debre Birhan shows near-zero local integration throughout its street network, while global integration or closeness centrality is selectively higher on the central arterial road that channels banded clusters of accidents. This spotlights the arterial's connectivity primacy in linking city districts for through-traffic movements that precipitate accidents, over and above the local access provided by minor streets.

Connectivity, measuring street intersection density, manifests a similar divergence, with substantially higher values coinciding with accident hotspots clustered across Dilla's gridded layout. Debre Birhan exhibits sparser connectivity overall, except for points along the central arterial which concentrates traffic and accidents.

Betweenness centrality or choice follows comparable trends, with Dilla displaying greater variability in higher values spread citywide, as against concentration exclusively on the arterial of Debre Birhan. This further crystallizes the arterial's role as the main traffic conduit, creating risks of high-momentum collisions and pedestrian conflicts.

These distinct spatial differentiations evidence that complex local street patterns shaped by higher intersection densities and grid geometries entail a stronger positive correlation with accident likelihoods in Dilla. Whereas Debre Birhan's long radial boulevards funnel accidents onto the most integrated central arterial that links the city.

Additionally, Dilla's mixed land use profile generates greater pedestrian activity and traffic volumes around the downtown grid streets, multiplying the risks from complex intersections. Temporal peaks during rush hours likely worsen these collisions in Dilla. Whereas Debre Birhan's spatial segregation diffuses its land use intensities.

However, while providing substantive quantitative spatial evidence on contrasting network structures associated with observed accident distributions, the research has some inherent limitations.

Firstly, the two cities exemplify specific urban morphologies, hence the findings have limited generalizability. Analyzing more comparative cases is vital to conclusively confirm correlations between street network configurations and road accident outcomes.

Secondly, the study cannot definitively establish causative relationships between urban form and accidents. Road safety arises from complex interactions between street patterns, traffic volumes, user behaviors and other dynamics which either amplify or dampen the effects of morphology. Advanced statistical or econometric analyses controlling for confounding factors as covariates are warranted for robust causal insights.

This research is placed in a scene of Dilla and Debre Birhan., where there are very limited research attempts to figure out the Road Configuration related reasons for the variation accident rate studies. This research provides consideration to expose the relationship between Roads Pattern Configuration and accident rate. Road pattern configuration values which are calculated based on three different configuration parameters shows a significant correlation in case of Debre Birhan. This shows that there is relative higher accident rate concentration around the segment having higher value of these three parameters. Thus, argument (configuration measures are capable to explain the level of vulnerability of accident rate in road segments) put forward in study is well recognized and valid. Segments with relatively insignificant values of those parameters happened to have less concentration on a certain area. Yet, the level of coefficient of correlation is different by configuration parameters and considered scale. Regression models developed in the research are applicable in measuring the level of exposure for accident rate in road segments based on Configuration Parameters. To summarize, measures of road pattern configuration reveal strong relationship with accident rate. Thus, the level of variation in road pattern configuration values is a major cause for road traffic accident. Sudden Visibility Change (Local Integration) is the key factor for accidents. Complexity (Connectivity) is revealed as the other crucial factor. Additionally, any location having this two factors with higher choice will further increase RTA. The models developed in the research are capable of identify the locations which are exposed for RTA in existing networks and the adjustments in road pattern configuration parameters might decrease the exposure. Therefore it can be used as a planning tool to detect the level of vulnerability for RTA in existing roads and to pinpoint the influence from proposed land use plans with new road networks.

5.2 Recommendations

It is highly believed that the priority while considering better Street shall be given to living things. Plants should also be included while designing better street scape.

1. The first important thing to do is, creating awareness towards the theory and the tool of space syntax.
2. Provide pedestrian road on the side while designing
3. Since most of Dilla city's transportation mechanism is motor cycle, bicycle lane should be included as a street element. A raised cycle track on both sides of the corridor promotes the combination of bicycle and transit usage. A center-running 1-way or 2-way cycle track

may be preferable in some cases to reduce the dangers of turning conflicts in combination with transit. (urban street design guide(NACTO))

4. Introducing new traffic lights on the major street .
5. Incorporate green infrastructure, shelters and stations should be built to accommodate the typical number of waiting passengers at the peak hour within.
6. Develop hierarchical street configuration to maintain and control the traffic flow into the main street of Dilla.
7. Intersections and major turning areas should not be connected at 90 degree. Incorporating curve at turning area, allows the vehicles to see the other vehicle from opposite direction. This minimizes the occurrence of road traffic accident.
8. As most of the people in the city uses public transport it is recommended that providing loading unloading area on the side of the street.
9. Provide alternative routes for different types of vehicles. With respect to serving population, covering distance and size of their vehicle.
10. Providing best fitting crossing mechanism or area
11. Providing traffic calming measures such as speed humps, chicanes, curb extensions, raised pedestrian crossings and other elements;
12. Provide station and stop elements like bus pad, sitting area, way finding, bicycle parking and transit shelters.
13. Provide traffic signals
14. Visibility improvement: Poor visibility is a significant cause of accidents on grid structure roads like that of Dilla. Visibility can be improved by trimming trees and bushes which block the sight of drivers and pedestrians
15. Impose traffic laws like seat belt usage, speed restrictions, and drunk driving laws can help decrease accidents on grid structure roads.
16. Educating road users about safe driving practices be able to assist decrease accidents on grid structure roads. Awareness can be organized to educate drivers, pedestrians, and cyclists about the importance of traffic rules and regulations.

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Appendix 1: Publishable manuscript

"The influence of street pattern configuration of Dilla city on road traffic accident in the case of two cities: Dilla and Debre Birhan, Ethiopia"

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June, 2024

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ABSTRACT

The purpose of this study is to determine, locations where road traffic accident is higher, frequent, distributed and concentrated in case of two Ethiopian cities, Dilla and Debre Birhan city. The locations of hotspots are determined from the cities'' traffic police and management office. Locations of hotpots are represented on maps of the cities to understand their frequency, distribution and confidentiality level. In the other hand, these gathered data from traffic police and management office are used to calculated accident risk rate and accident severity index.as a result understanding the character of the hotspot area helps to protect the precious life people.

Keywords: RTA, Dilla city road network, Debre Birhan city road network**,**

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1. INTRODUCTION

Every research is made to enable people get better utilization out of it. Now a days, Road Traffic Accident (RTA) has become the leading killer of young people and is projected to be the 7th leading cause of death by 2030. RTA is defined as an incident on a way or street open to public traffic, resulting in one or more persons being injured or killed and involving at least one moving vehicle.

According to World Health Organization (WHO, 2020) data published in 2020, RTA death in Ethiopia reached 31,564 or 5.60% of the total deaths. The age adjusted death rate is 42.41 per 100,000 of population. This makes Ethiopia to be the 19th in the world RTA.

One of Ethiopian city known for higher motorized activity with higher number of RTA is Dilla city. RTA in Dilla city is the most common type of injury causes that is responsible for higher percentage of death among suffering patients. RTA in Debre Birhan is lower than RTA of Dilla even though, both have resembling population number. This study will mainly focuses on determining RTA rates of the cities and their hot spots.

2. LITRETURE REVIEW

2.1.1 Introduction to RTA

Traffic accident is defined as an accident involving at least one vehicle on a road open to public traffic in which at least one person is injured or killed. (Insee, 2020)

2.1.2 RTA and hotspots

As traffic accident is one of the most attention seeking phenomenon, it requires to understand the character of the accident locations as cold or hotspots. The location which is identified by a high accident occurrence compared with other the other location are known as hotspots or black spots (Dereli & Erdogan, 2017). These locations are identified by many factors such as geometrical design, traffic volume, surrounding or severe weather condition e.t.c.(Xia & Yan, 2008).

2.1.3. Road traffic accident indicating parameters

Accident can be represented in terms of the following terms.

Accident risk: It is the number of accidents per 100,000 people. Simply referred as crash rate, is the number of crashes recorded on a specific area for a specific time.

According to the World Health Organization, The risk of dying as a result of a road traffic injury is highest in the African Region (26.6 per 100,000 population), and lowest in the European Region (9.3 per 100,000) . The average rate was 17.4 per 100,000 people. (WHO, 2015)

Accident severity index: measures the seriousness of an accident. It is therefore defined as the number of persons killed per 100 accidents. Severity index determines the weight of a single crash. So, to accurately identify high or low clustered zones, it is important to incorporate crash severity index in hot spot analysis. The concept of crash severity index is accrediting the higher value to severer crashes based on the expenditures. Many past studies associated crash severity weights in crash hot spot analysis. The crash severity index developed by the Roads and Traffic Authority of New South Wales was utilized in this study. In this system, each crash incident is provided a value of 3.0 for fatal, 1.8 for serious injury, 1.3 for slight injury and 1.0 for property damage. The crash severity index of each zone can be computed by the following equation. (Road Traffic Accidents in New South Wales–1997-Statistical Statement: 1999).

Low-income countries now have the highest annual road traffic fatality rates, at 24.1 per 100,000, while the rate in high-income countries is lowest, at 9.2 per 100,000. (WHO, 2023)

$$SI = 3.0 \times X_1 + 1.8 \times X_2 + 1.3 \times X_3 + 1.0 \times X_4 \qquad \text{Eq. 1}$$

Where X_1 is fatal crashes, X_2 is serious injury crashes, X_3 is slight injury crashes, X_4 is Property-damage-only crashes.

2.1.4. Terms used in hot spots analysis.

i. **Hot Spot Analysis (Getis-Ord Gi)*:**

Hot Spot Analysis identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) using the Getis-Ord Gi* statistic. The analysis creates an output feature class with fields such as z-score, p-value, and a confidence level bin (Gi_Bin) for each feature.

The Gi_Bin field categorizes features based on statistical significance levels:

- +/-3 bins: 99% confidence level
- +/-2 bins: 95% confidence level
- +/-1 bins: 90% confidence level
- Bin 0: Not statistically significant

ii. **Pseudo p-value**: Indicates the statistical significance of the computed index values.

iii. **Z-score**: Represents the statistical significance of the index value. It tells us whether the similarity (or dissimilarity) in attribute values between a feature and its neighbors is greater than expected by chance.

iv. **Moran’s I index** is a measure of spatial autocorrelation. In simple terms, it quantifies how closely values are clustered together in a 2-D space.

v. **Cluster and Outlier Analysis (Anselin Local Moran’s I)** given a set of features (such as points, lines, or polygons) and an analysis field (attribute) identifies spatial clusters of features with high or low values. It also identifies spatial outliers.

3. METHODOLOGY

3.1. Study area description

The study is conducted in two cities Dilla and Debre Birhan. Dilla is the capital of Gedeo zone and located at 356 km away from Addis Ababa, and 90km from Hawassa. The city is located at the co-ordinate approximately 6^0 4’ North Latitude and 38^0 10’ East Longitude. The shape and growth of the town follows the corridor along the Ethio – Kenya main international route. The city includes three district sub cities/ Kifle Ketema/ and covers an area of 21.4 km^2 of land with average elevation of 1,600 meters above sea level. The population number according to the city administration is estimated to be 120,342.

The other city is Debre Birhan which was initially the administrative city of Semen Shewa zone & now it is established as metropolitan city which is directly response to Amhara region. Debre Birhan is located 130 km away from Addis Ababa & has an elevation of 2,840 m, with a geographic coordinate of 9° 41’ North, 39° 32’ East. The city covers about 14.28 km^2 and according to city facts.com, its population by 2030 is estimated to be 127,492.

Figure 3.1 represents the location of Dilla and Debre Birhan city and its placement from the capital city A.A.. For more detailed analysis micro level RTA investigation was made.

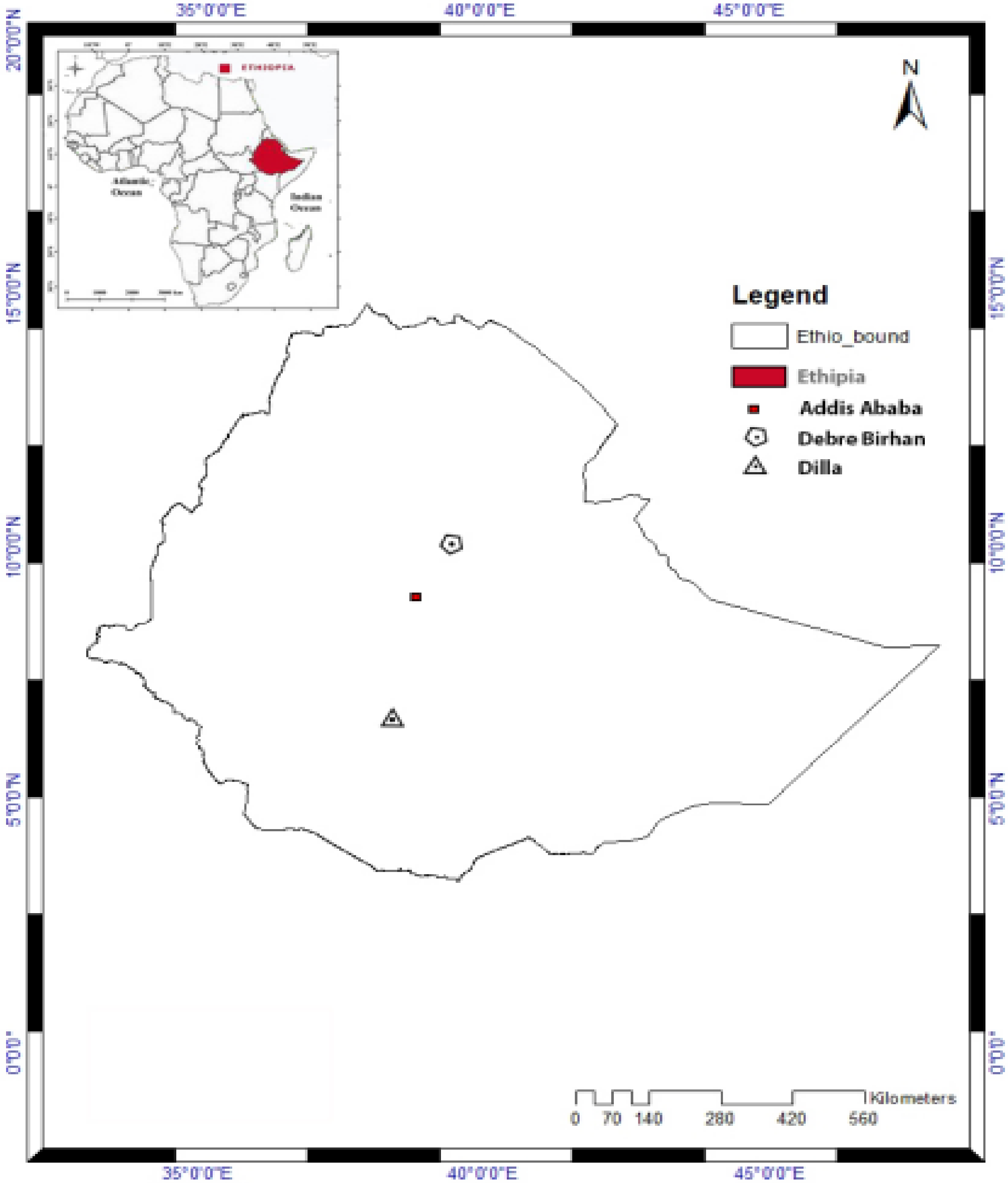


Figure 3.1. Location map of the study areas (Source: illustrated by the author, April, 2023)

3.2. Tool of Data Analysis

To analyze the accident risk rate and hotspot locations simple counting was used. Arc GIS is the other tool that used to point out the most frequent traffic accident areas through graphical representation.

3.3. Method of Data analysis

3.3.1 Accident Rate - Measures how many accidents have occurred in an area over a given period of time. Here table 3.1 and 3.2 below show what is recorded in Dilla Debre Birhans city's accident rate

Table 1 Accident Rate of Dilla city from the year 2022/2023 G.C.

Record	Fatal	Serious	Light	Property	Total
2022/23	6	2	4	98	110

(Source - Road Traffic office of Dilla city, 2022/23)

Table 2 Accident Rate of Debre Birhan city of the year 2022/2023

Record	Fatal	Serious	Light	Property	Total
2022/23	38	27	35	4	104

(Source - Road Traffic office of Debre Birhan city, 2022/23)

3.3.2 Accident Risk - refers to the likelihood or probability of an accident occurring. It is the number of accidents per 100,000 people. Here is what is recorded in Dilla in table 3.3. Each zone comprises percentages out of the city and this give the rate of accident risk for every zone.

Table 3 Accident Risk of Dilla city of the year 2022/2023

Value	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Min	Max	Mean
Accident risk	25.19	23.83	21.18	5.29	30.45	9.26	17.21	5.29	30.45	18.92
Percentage	19%	18%	16%	4%	23%	7%	13%			
Rank	2	3	4	7	1	6	5			

(Source: Organized by the author, April, 2024)

Table 3.4. below shows accident risk of Debre Birhan city. As of Dilla's percentage comparison, zones of Debre Birhan also ranked according to their percentage.

Table 4 Accident Risk of Debre Birhan city of the year 2022/2023

Value	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Min	Max	Mean
Accident rate	31.82	10.60	22.54	11.93	14.58	19.88	21.21	10.60	31.82	18.94
Percentage	24%	8%	17%	9%	11%	15%	16%			
Rank	1	7	2	6	5	4	3			

(Source: Organized by the author, April, 2024)

2.4.3 Accident Severity - refers to the seriousness or criticality of accidents sustained in a street. It provides insight into the impact of accidents on property, vehicle or people and helps assess the gravity of incidents. Table 3.5 show the severity of accident for a fatal accident with multiple rate of 3, for serious accident with multiple rate of 1.8, for light accident with multiple rate of 1.3 and 1 for property damage.

Table 5. Severity Index of Dilla city 2022/23

Record	Fatal	Serious	Light	Property	S.I.
2022/23	6*3	2*1.8	4*1.3	98*1	124.8

(Source: Organized by the author, April, 2024)

The severity index of Debre Birhan is represented in table 3.6 below. Even though the crash recorded in Dilla city is higher than that of Debre Birhan, it does not always mean it has higher severity index

Table 6. Severity Index of Debre Birhan city 2022/23

Record	Fatal	Serious	Light	Property	S.I.
2022/23	38*3	27*1.8	35*1.3	4*1	212.1

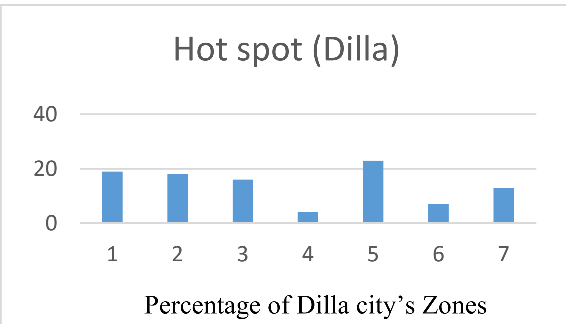
(Source: Organized by the author, April, 2024)

All, accident rate, risk and severity indexes are helpful to determine hotspots of the cities.

4.2. Hot spot Analysis

Based on their frequency and distribution of occurrence of accident over the city, hot spots of the Dilla and Debre Birhan are presented as fig, 4.1 and fig.4.2.

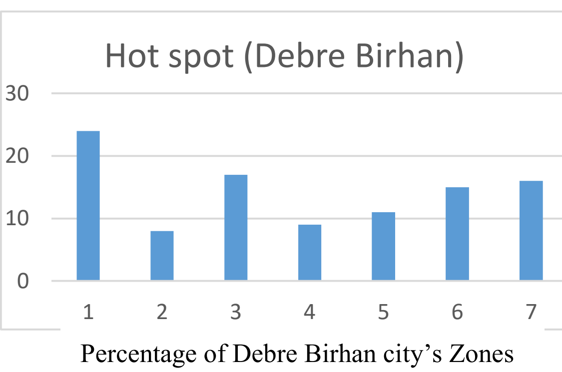
Fig. 4.1 denotes that zone 5 has the highest accident risk with percentage of 23% and then zone 1 with 19%, zone 2 with 18%, zone 3 with 16%, zone 7 with 13%, zone 6 with 7% and zone 4 with the least percentage of 4%.



This figure shows that, the percentages of accident risk rate as hot spots among the seven zones of Dilla city, yielding the percentage for each zone out of 100. The hot spots represents the level of exposer towards accident risk.

Fig 4.1 – Accident risk percentage of each zone's hot spot with respect to Dilla

Fig. 4.2 indicates that zone 1 has the highest accident risk with percentage of 24% and then zone 3 with 17%, zone 7 with 16%, zone 6 with 15%, zone 5 with 11%, zone 4 with 9% and zone 2 with the least percentage of 7%.



This figure shows that, the percentages of accident rate as hot spots among the seven zones of Debre Birhan city, yielding the percentage for each zone out of 100. The hot spots represents the level of exposer towards accident risk.

Fig. 4.2 – Accident risk percentage of each zone's hot spot with respect to Debre Birhan

Next Figure 4.3 shows the street pattern configuration of Dilla city and Fig. 4.4 shows the street pattern configuration of Debre Birhan city.

Figure 4.5 shows zones of Dilla city specifically illustrated for this study only and Figure 4.6 shows zones of Debre Birhan city also illustrated for this study only. The color arrays from the darker to lighter brown color pallet to represent hotspot areas ranging from higher to lower RTA.

Like the above figures, Figure 4.7 shows the weight of accident rate of places with in a specific zone of Dilla that is expressed using resembling color. In Figure 4.8 the most significant hotspot areas of Debre Birhan are expressed using the same sequential order as Figure 4.7. but it differs from it because it is represented using only five main spots due to data saturation.

For the case of Dilla, there are about 38 known hotspots where this seems very much less in case of Debre Birhan. This is not due to insufficient data rather data saturation, at which collecting additional data no longer provides fresh insights related to the research questions. When data saturate, enough information is gathered to confidently understand the patterns and themes within dataset.

Figure 4.9 and 4.10 below shows the hotspots of each city with their level of confidentiality or significance.

Figure 4.11 and 4.12 are also representation of spatial statistics data calculated using Z score and P value. It is based on both feature locations and feature values simultaneously and illustrates the graphical representation of the data as dispersed (outlined), random or cluster pattern.

Figure 4.13 and 4.14 represents cluster/ outlier analysis (Anselin Local Moran's I) that identifies concentration of high values, concentration of low values and spatial outliers

Figure 4.3. Street pattern configuration of Dilla city.

Figure 4.4. Street pattern configuration of Debre Birhan

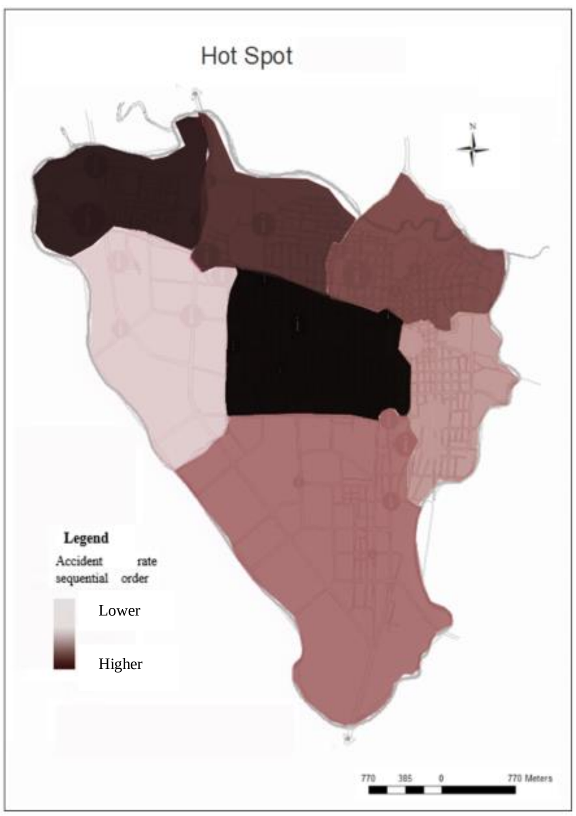


Figure 4.5. Hot Spot of Dilla city with their corresponding zones.

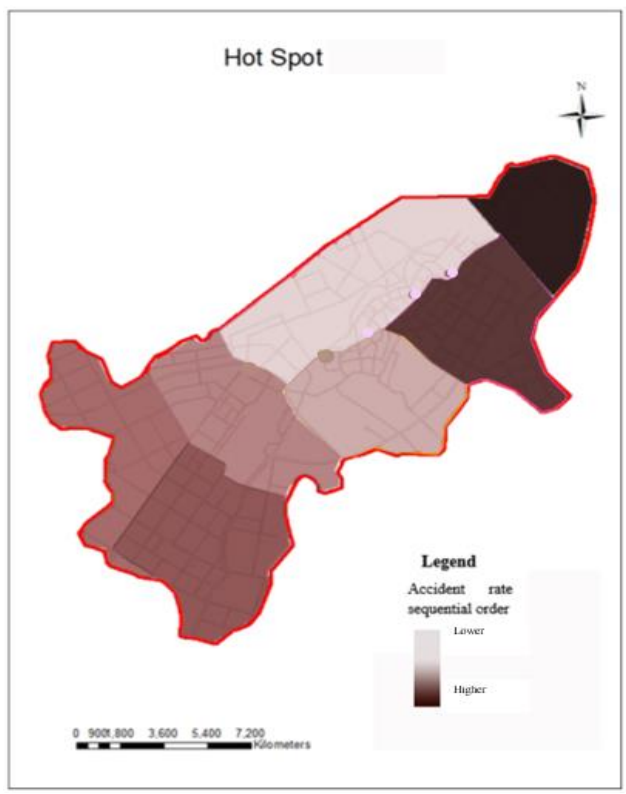
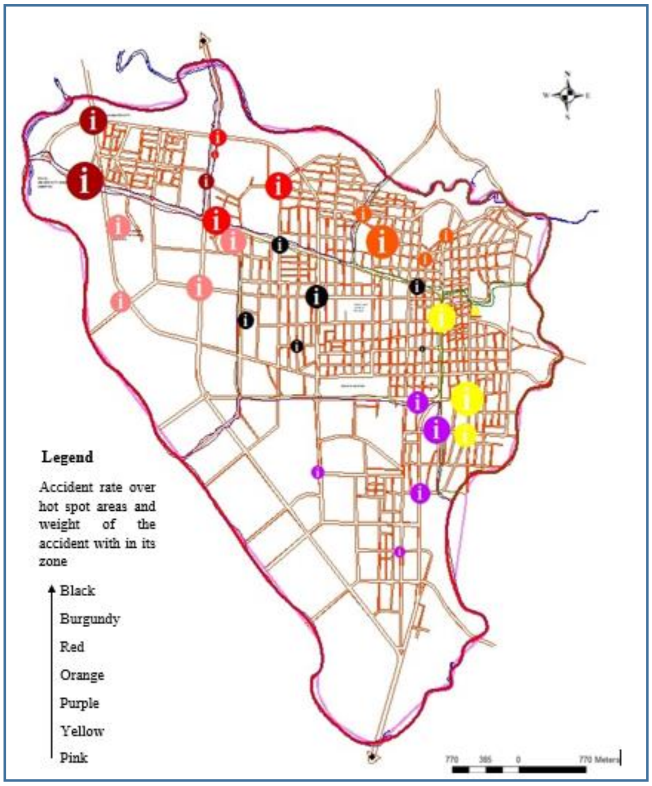


Figure 4.6 Hot Spot of Debre Birhan city with their corresponding zones.



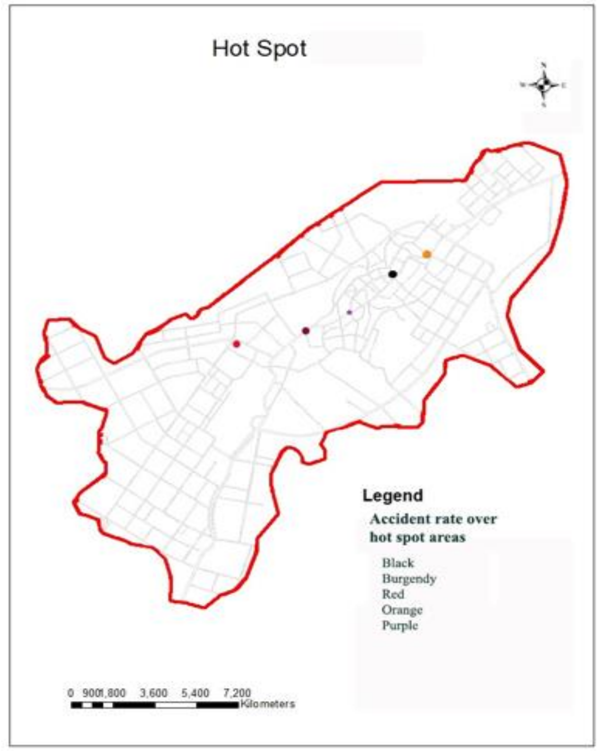
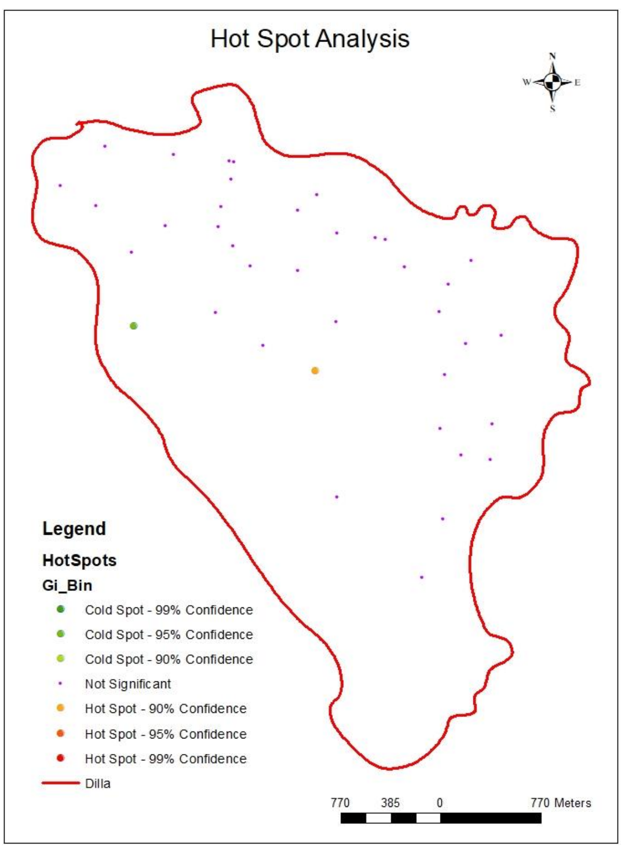


Figure 4.7. Hot Spot of Dilla city.

Figure 4.8. Hot Spot of Debre Birhan city.



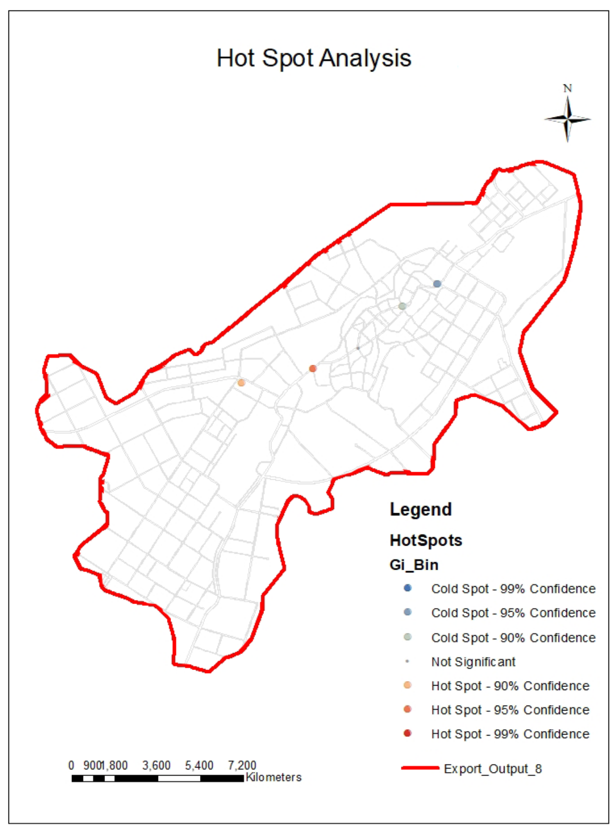


Figure 4.9. Hotspots confidential level of Dilla

Figure 4.10. Hotspots confidential level of Debre

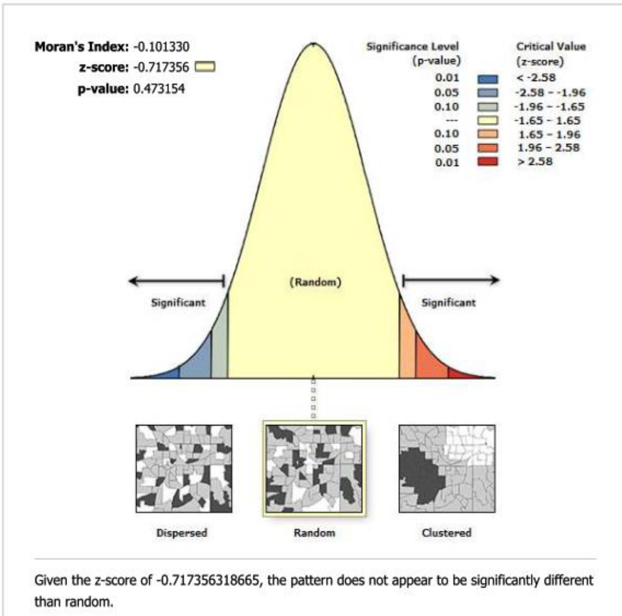


Figure 4.11. Moran's Index, Z-score and P-value of Dilla

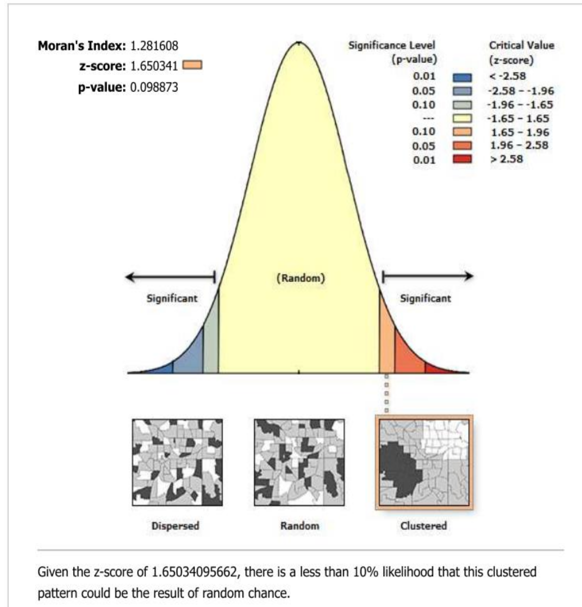
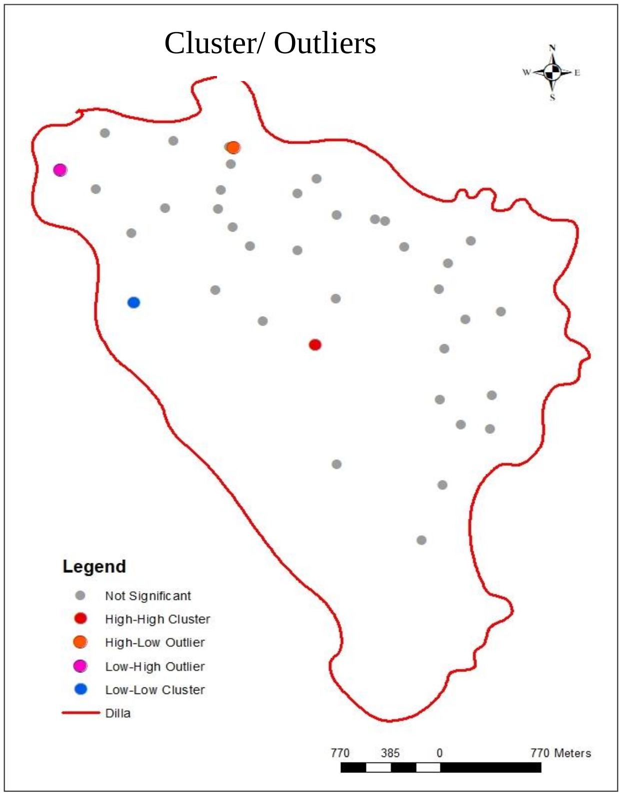


Figure4.12. Moran's Index, Z-score & P-value of Debre Birhan

The z-score has indicated that, where the frequency of road traffic accident is compared to the average road traffic accident's mean value. For Dilla city, the Z Score has negative and close value to the mean and it shows that the value is closely below the mean value. This value with respect to the road pattern configuration, the frequency of the road traffic accident appears to be randomly distributed.

For Debre Birhan city, the Z Score has a positive and value between 1.65 and 1.96, it shows that the value is significantly above the mean value and with respect to the road configuration, the frequency of the road traffic accident appears to be clusterd along a certain road pattern configuration.



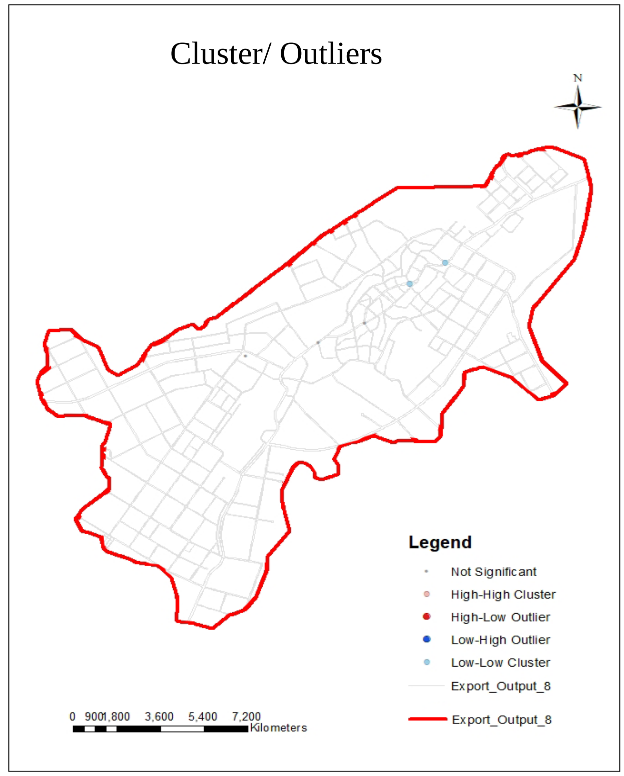


Figure 4.13. Cluster/ outlier analysis of Dilla city city

Figure 4.14. Cluster/ outlier analysis of Debre Birhan

5. CONCLUSION AND RECOMMENDATION

Hot Spot Analysis in this study helps to identify areas of road traffic accident that are cluster together. It goes beyond general observations by assessing statistical significance of these clusters. Hot Spot Analysis helps reveal spatial patterns and informs decision-making in fields like urban planning, public health, and environmental management.

The first important thing to do is, creating awareness on the where and when aspect of the hotspot areas then accident alleviating mechanisms should be applied to minimize further accident occurrence.

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Debre Birhan city administration office - Dilla city road map

Debre Birhan city Traffic management office – annual numbers of traffic accidents

Dilla city administration office - Dilla city road map

Dilla city Traffic management office – annual numbers of traffic accidents

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