ANALYSIS OF URBAN ROAD NETWORK STRUCTURAL PARAMETERS

THE CASE OF ADAMA CITY:

By Kenea Birhanu Benti

A Thesis Submitted to the Department of Architecture,
School Of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirements for the award of Master's Degree in Urban Planning and Design

Office of Graduate Studies
ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

February, 2023

Adama, Ethiopia

ANALYSIS OF URBAN ROAD NETWORK STRUCTURAL PARAMETERS

THE CASE OF ADAMA CITY:

By

Kenea Birhanu

ADVISOR: Samson Kassahun (Prof)

A Thesis Submitted to the Department of Architecture, School Of Civil Engineering and Architecture.

Presented in Partial Fulfillment of the Requirements for the award of a Master's Degree in Urban Planning and Design

Office of Graduate Studies

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

February, 2023

Adama, Ethiopia

Declaration

I declare that the work done in the research entitled "***ANALYSIS OF URBAN ROAD NETWORK STRUCTURAL PARAMETERS, THE CASE OF ADAMA CITY***" is my original work under the supervision and guidance of Samson Kassahun (Prof). This work has not been previously submitted to any higher institution for any diploma, degree or other similar work.

Declared by:

Name: **Kenea Birehanu**

Signature: ______________

Date: __________________

Confirmation

This is to certify that Kenea Birehanu, has carried out his research work on the topic entitled "***ANALYSIS OF URBAN ROAD NETWORK STRUCTURAL PARAMETERS, THE CASE OF ADAMA CITY*". The study fulfills scientific requirements and is accordingly endorsed for submission to the department for the next level of evaluation deemed oral presentation before the award of a Master's degree in Urban Planning and Design.

Samson Kassahun (Prof)

Signature: _______________

Date: ___________________

APPROVAL SHEET

As members of the thesis approval board of examiner we certify that we have read the thesis prepared by Kenea Birehanu with the title, "***ANALYSIS OF URBAN ROAD NETWORK STRUCTURAL PARAMETERS, THE CASE OF ADAMA CITY***" and submitted in partial fulfillment of Master's in Urban Planning and Design complies with regulation of the University and meets the accepted standards as to the originality and quality concerns.

Approved by the Board of Examiners

______________________	______________________	______________________
Internal Examiner	**Signature**	**Date**
______________________	______________________	______________________
External Examiner	**Signature**	**Date**

ACKNOWLEDGMENTS

I wish to extend my deepest gratitude to my advisor Samson Kassahun (Prof) for his professional guidance and advice throughout my study. And Special thanks go to all the staff in the School of Civil Engineering and Architectural Staffs'. Besides this, I would like to thank all government officers who help me by giving different documents relevant to this research and any resources available in a good will without reservation.

Finally, my acknowledgement extends to all my family and friends for their unreserved encouraging support to accomplish this study.

Table of Contents

List of Tables

List of Figures

Abstract

This research modeled the transport system to estimate the land use transport interaction to ultimately determine the level of infrastructure that is required to support the economic activity in the study area. It is well understood that, infrastructure is a profound determinant of nationhood, a measure of a country's success on the world stage. The true goal of an urban road network is to have access and link to destination places. To investigate road transport network and urban land use interaction, the research employed QGIS techniques and Remote Sensing for the cross-sectional efficiency of the system. The objectives of this study have to provide information on urban land use patterns, assess potential travel demand, and identify which network-based indicators can be used to identify inadequate infrastructure. Types of data obtained through methods such as socio-economic data, land use map, current road network, and satellites data. And also this study used QGIS as a tool for analyzing, integrating and displaying information about the road network of Adama city. To demonstrate the use of road network analysis, this project focused on determining the best route between two destinations, the closest facility from a given incident, and a service area for a given facility. For this purpose the database is created using linear referencing tables. Data used by this project included public data and data generated using a Global Positioning System (GPS). Once the analysis is completed, a route representing the (the best route) shortest travel distance, the route representing the closest facility and the polygons representing the service area were developed. The result of this project indicated that road density, higher trip production, and attraction are exhibited in the central areas (characterized by high population and important socioeconomic activities of the city including jobs, service centers, and schools). Residential proximity to the roads within the central areas is 300m, allowing more people to access these roads. However, in the periphery, people have to travel more than 1km to access the existing road infrastructure, indicating the inadequacy of the system. The overall conclusion obtained from the indicators shows that there is less road infrastructure in the peripheral regions of the city and the central area clearly has a capacity limitation.

Key Words: Road Network Evaluation, Road Transport Performance.

CHAPTER ONE
INTRODUCTION

The road network of Adama town is an irregular pattern structure. This pattern of network organization leads to an increased tendency to vulnerability, exposing parts of the town to sharp decreases in accessibility when traffic blockages occur on the main links or at junctions (Risa 2012).Urban safety improvements should be separately identified for practical reasons that they are treated as components of national or urban development projects. Road safety should be managed effectively as part of cities. Dutch (2017) suggested in his comprehensive study that ‘All urban and transport policies have a potential for safety impact and safety should always be considered.

A well-designed built urban environment can help to have feelings of safety. An unsafe the environment can literally imprison people in their own homes. In developing countries like Ethiopia, it seems likely that the slow uptake of urban safety improvements is not so much due to a lack of know-how but more to a lack of commitment, institutional capacity and resources. The problem is compounded by the fact that the urban road network and safety problem requires a multi-sectoral approach involving planners, engineers, police, medical personnel etc. Like many towns in Ethiopia Adama town is also characterized by inaccessible, sub-standard, and not well treated, lacks separated pedestrian walkway and the street furniture road network that inspired the researcher to conduct this study.

There are not many studies undertaken to analyze the transportation problem for Adama transport net work and where the network design itself may be the cause of the problem. Due to population growth the city expanding rapidly but the road network fails to serve the newly developed areas. for this case, what motivated me or the reason why I wanted to choose this topic is that I was able to choose this topic because I saw that due to the lack of road safety and quality of roads in Adama city, I often suffered physical disability and moral damage to the community.

Finally, based on this study, the city municipality needs to fix the problem of the road network, so that they can bring a sustainable solution to the society.

1.1.Background of the Study

The urban road network plays a key role in the urban spatial structure (Weiping, and Chi, 2003). It is the main city's social-economic activities and transportation carrier. Today, more researchers are paying attention to the road network and one of the most important problems is how to assess the accessibility of road networks. The accessibility concept for the first time and defines it as the transport network in various nodes interaction opportunities. Hereafter, accessibility is widely applied in research and road network planning, construction, and evaluation. In transportation geography, road network accessibility evaluation has emerged as an important problem. The true goal of an urban road network is to have access and link to places, facilities, utilities, services etc. (Olowosegun and Okoko, 2012).

Road network is the major and primary function of land use in urban areas and is also the dominant factor for the socio-economic interaction and economic development of the town. Road safety and network patterns vary from country to country (AR Rakhmatulloh 2019). As a result of the increasing urban population and the changing way of life, road transport in most developing countries suffers from many problems like high accident levels, inadequate infrastructures both in capacity and availability, poor quality infrastructure and mismatch between demand and supply. These problems are caused by high urbanization, city growth and lack of proper transport planning and management strategies in the cities of Third world countries.

When we look at the transport planning and decision making strategies of cities of developing countries, most of the times, planning decisions are made based on pure speculation and it is hard to explain how decisions are made that affect the road network plan. Because of this reason cities grow in an uncontrolled manner and change into more and more inefficient transport networks. Many researchers agree that major changes in transport network structure affects patterns of urban development and the location of social and economic activities, households and employment centers. On the other hand, Waddell (2011), in his study suggests that, major changes in land use influence the trip making behavior of people, destination and mode choice (Waddell, 2011). And also, the network structure of an area also affects the accessibility and destination choice of travelers (Huang & Levinson, 2011).

The performance of a road network can be investigated based on the structure of the road network (Xie & Levinson, 2007), the access and mobility it provides (Gtierrez, et. al., 1998 &

Lio and Zue, 2004), measuring the capacity of the network (Chen et al., 1999) and by assessing special mismatch between demand and supply (Grishenko, 2011). Even though, no transport network can serve all travel demands perfectly, the amount by which it fails to do so can be useful to study existing network and identify areas with the inadequacy of infrastructure (Davidson, 1998). Network effectiveness indicators, which compare the real road network to a geographically perfect network, can be used to identify these areas (Davidson, 1998).

Road network pattern is an important problem in the transportation science which has long been recognized as a key component for Network design problem. For the detailed reviews of Net Work design. In fact, the road network pattern problem determines the distribution of the various elements of road network in the space. In reality, the transportation planners generally focus on that which pattern of urban road network is better for a city. This because that the rational plan and layout of road network pattern can not only reduce traffic incidence of the traffic jam and produce spatial agglomeration economy, but also save the investment cost. Therefore, the road network pattern problem has become one of the most active research fields in transportation science in the past decades. According to the view of geography, road network pattern can be investigated from human and urban physical aspects.

As a result the proposed study will mainly be concerned with the urban road network components and their effect on accessibility in Adama town. Hence, the proposed study will mainly be touched on the existing situation of urban road network structural components and their effect on accessibility by different stakeholders and communities towards comfortable use and safe road network in the town and economic contribution. In addition the proposed study will use QGIS technology to access information and evaluate the current performance of the road network

1.2.Statement of the Problem

One of the main reasons that people want to live in urban areas is a better way of life and safety where the main infrastructures and services are provided compared to rural areas. Among the main infrastructures road network has a significant impact on the safety of urban dwellers. Because the flow of traffic throughout a road network is similar to the flow of blood through the human circulatory system and branch system of a tree.The units moving through the system (blood cells, nutrients, etc.) move through progressively smaller network elements as they approach their destination. The same to that road network is used as the human circulatory system of town or city. However, similar to other towns in our country, the road network in Adama town is unable to provide safety to its residents. The road network of Adama town was characterized by problems such as sub-standard, width, not hierarchically arranged, poor surface condition, irregular pattern, improper provision, and topographical problems. These bring inconvenience, poor connectivity and inaccessibility. These all problems have negative impacts on economic growth, development of the town, social interaction of the residents, environmental and peace and security of the town. The residents of Adama town are suffering from poor quality of roads and shortage of paved roads. Households around the earthen and gravel roads are suffering from dust and mud during the dry and rainy seasons respectively. Most of the residents of the town walk on foot to their workplace and back to their home every day. This shows that the residents need improving and quality of road network to make their journey short and get on their business on time. Therefore, to solve the problems of the road network, the researcher has been motivated to identify the existing road network problems, their negative impacts and propose the ways that can maximize the role of the road network to enhance the safety of Adama town.

1.3.Objectives of the Study

1.3.1.General objective

The general objective of the study is to examine the relationship between road network structural parameters and accessibility of the road in Adama town.

1.3.2.Specific Objectives

- To determine existing road network structural patterns of Adama town.
- To examine the relationship between road network structural parameters and accessibility.
- To determine major problems that affects the accessibility of the road network in Adama town.

1.3.3.Research Questions:

The following research questions will be answered in the proposed study:

1) What are the existing road network structural patterns of Adama town?

2) What is the relationship between road network structural parameters and the accessibility of Adama town?
3) What are major the problems that affect the accessibility of the road network in Adama town?

1.4.Significance of the Study

The study has significant importance in strengthening the existing knowledge and understanding of road network structural parameters and accessibility of the road network by examining and empirically testing the relationship between structural parameters and accessibility of the road network for the case of Adama town.

The study also provides some insight or recommendations to Adama town Road\Transportation Authority, to evaluate and improve their road network planning and design practice based on the study findings and it adds input for policy making process in the area of the subject matter. Finally, the proposed study can serve as an additional reference to others researchers who are interested in the area of road Network and their Accessibility.

1.5.Scope of the Study

The study has three important scopes: these are thematic, spatial ,and temporal scopes.

1.5.1. Spatial Scope

This study was particularly limited within the administrative boundary of Adama town.

1.5.2. Thematic Scope

The study was focused on the urban road network connectivity, accessibility, road performance and road network density of the existing road network in Adama town.

1.5.3. Temporal Scope

The study focused on the Road Network Structural Parameters and Accessibility of road network problem of Adama town between 2015-2022.

1.6. Limitation of the Study

The limitation of this study is going to be shortage of time to collect the data. Since the data collection instruments will be in-depth observation, reviewing necessary documents and the government reports document.

1.7.Organization of the Study

The research its intended to be organized into five chapters: 1st Chapter one contain the introductory part dealing with back ground of the study, the statement of the problem, the objectives of the study, the scope of the study, the significance of the study and the definition of basic terms. The 2nd chapter focuses on the theoretical review and empirical review taken from different sources. The 3rd chapter presents the research methodology of the study. The 4th chapter presents data analysis, presentation and interpretation of the study and finally, the 5th chapter presents the summary of major findings, conclusion, recommendations and limitation & suggestion for future research.

1.8.Definition of Basic Terms

Road: A road is a thoroughfare, route, or way on land between two places that have been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse (Risa 2012).

Road Hierarchy- This is a classification of the road according to their function and capacities. While source differ on the exact nomenclature, the basic hierarchy comprises freeways, arterials, collectors and local roads (Silcocks, 2004).

Road network: The **road network** is system of interconnected roads designed to accommodate wheeled road-going vehicles and pedestrian traffic (Rodrigue 2009).

Accessibility: is defined as the possibility of reaching any activity, establishment, or land use in a community by people (or by conveyances of goods or information) who have a reason to get there. It is a measure of the quality and operational effectiveness of a community (Cud, et al 2011).

Urban safety: is a built environment that ensures the safe life of the population on the basis of a combination of factors. Primarily, adverse factors forming urban safety of an area affect human health (World Bank 2010).

CHAPTER TWO
2. REVIEW OF RELATED LITERATURE

2.1. Introduction

The review of related literature contained two parts, this is theoretical and empirical reviews. The theoretical part assesses conceptual definitions, urban road network components, the` function of the road in development, road accessibility, the hierarchy of roads, types of urban road patterns, urban road network safety and management, and urban road network safety(policy, guidelines, and standards). Whereas, the empirical literature review part included the best experiences of urban road network from developed, developing and Ethiopian countries. The researcher had been used books, reports, websites and necessary materials to organize the study.

2.2. Theoretical Literature Review

2.2.1 Conceptual Definitions

Accessibility: is defined as the possibility of reaching any activity, establishment, or land use in a community by people (or by conveyances of goods or information) who have a reason to get there. It is a measure of the quality and operational effectiveness of a community (Cud, et al 2011).

Mobility: is defined as the ability of any person to move between points in a community by walking, private or public means of transportation (Zuidgeest 2011).

Road: A **road** is a thoroughfare, route, or way on land between two places that have been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse (Risa 2012).

Road network: The **road network** is the system of interconnected roads designed to accommodate wheeled road-going vehicles and pedestrian traffic (Rodrigue 2009)

Urban safety: is a built environment that ensures the safe life of the population on the basis of a combination of factors. Primarily, adverse factors forming urban safety of an area affect human health (World Bank 2010).

Road traffic safety: refers to the methods and measures used to prevent road users from being killed or seriously injured. Typical road users include: pedestrians, cyclists, motorists, vehicle Passengers, horse riders, and passengers of on-road public transport (Gitelman 2006).

2.2.2. Components of Urban Road Network

Urban road networking components includes; by-pass, intersections, grading, paving, drainage, lighting, noise control, road side improvement, parking, and pedestrian cross. The road network consists of a system of interconnected paved carriageways which are designed to carry buses, cars, and goods vehicles; the road network generally forms the most basic level of transport infrastructure within urban areas, and will link with all other areas, both within and beyond the boundaries of the urban area(S Cafiso 2005.)

Bypass: One of the principal reasons for the construction of bypass roads in towns is the removal of through-traffic from the center of a town or city to the periphery, for purposes of improving the flow of traffic, shortening travel times, and reducing road accidents. Bypass roads, however, have also environmental and economic consequences. On the one hand, they reduce noise and pollution emissions along the previous route (Evic& Amundsen 2001).

Intersections: Are crossing of one road by other. Most intersections are at the same level, so that vehicles going east and west have to take turns crossing with vehicles going north and south. Sometimes road intersect at angle and it is especially difficult to make a safe crossing. At such places, the traffic engineer may put islands in the paved area to keep traffic is the proper path (Patel 2014).

Grading: The first job in building a new highway is to clear the right of way. There may be trees to cut down and stumps to pull up.Sometimes buildings to be torn down or moved. The right of way then is ready for rough grading. Here other big machines beg into work. Huge earthmovers, which can dig up a roomful of dirt in one scoop, are used. They cut into the hills, carrying the earth along, and drop it into the valley to make a road with gentle graders. This method is known as cut and fill construction. Sometimes, the right kind of earth to be used for the foundation of the road must be halved in, perhaps from some distance away. While the grading is going on, culverts or pipe to carry away rainwater, are put in place under the road or under driveway entrance. It is smoothed and packed down to the required level and shape (Sharpe 2012).

Paving: Begins after grading is completed. The pavement is of definite thickness and is of a stronger material than the earth under heath. The kind of thickness of the pavements depends largely on the weight and amount of traffic expected to use them (Ibid).

Drainage: Full and uninterrupted utilization of pedestrians facilities depends to a the significant extent on overcoming natural constraints, which in this case are too much water. The need for a drainage system is rather obvious and unavoidable, not only to maintain clear paths at all times, but also ensure that no structural damage is done to the infrastructure through gradual erosion or sudden washout.

Lighting: Good lighting helps to cut accidents for both vehicles and pedestrians.On most roads and highways, near all light lame from the lights of the trucks and cars. But on busy streets and at dangerous locations over head lights are used. Reflectors for the lamps are designed specifically to shine most of the light down on the road way without glaring into the eyes of drivers(B Han · 2020).

Noise control: The increased use of highways causes loud traffic noise, creating the problem for people who live near highways, for this reason, engineers have designed noise barriers made of concrete, wood, metal, plastic and other material that block the sound in some areas, vegetation, or mounds of earth provide protection from traffic noise (CH Hansen 2019).

Road side improvement: Roadsides are often planted with special grasses or vines to keep the earth from washing into the ditches in addition,many roadsides are beautified with trees and bushes such planting and landscaping help break the monotony of travel and make the countryside move attractive all states have laws that prohibit putting billboards and other commercial signs close travelers can stop to picnic or where tourists can admire a scenic view world. Sidewalks are normally placed within the public right of way on either or both sides of the lateral vehicular channel, within the marginal reserved strips, which will usually be at least two meters wide (F La Torre · 2012).

Parking: Parking affects mode choice, the vitality of communities' commercial business centers and transit system as well as the efficiency of traffic circulation in down town areas. Parking has a direct economic impact as well. On, micro-scale parking costs may result in tax benefits for employers and entrepreneurs. At a macro scale parking generates revenue for both public and private institutions (J Hill 2019).

Pedestrian crossing: Pedestrian crossing is very important for pedestrian safety as they guide pedestrians in the proper paths. They have marked off all intersections where there is the substantial conflict between vehicles and pedestrians movement. In addition, they may also, provide at non-intersection locations; where it is concentrated, pedestrian movement. The location of the pedestrian crossing should be selected properly to ensure adequate visibility, sufficient space on the foot obstructions (AM Mulyadi · 2018).

2.2.3. The Function of Road Network in Urban Development

The road networks have an essential role to build a foundation for improving our daily life and economic activities. Road network allows easier access to jobs, health care and education as well as used for the mobility of goods and services to markets. The road network development in un urban area, for example, can help people to reduce time in moving from one place to another, increasing the safety of the residents, and helping the government provide public service efficiently (International Transport Forum 2015).

2.2.3.1. Social Function of Road Network

The road network facilitates the movement of people allowing for social interaction. A high-quality road network is essential not only for connecting key urban centers but for improving connectivity of more isolated local communities for whom many public transport options are limited or not available. Roads connect remote communities with the areas where employment options are more concentrated and services and facilities more readily available (Rodrique, et al 2013).

2.2.3.2. Economic Function of Road Network

By connecting geographic locations, road networks facilitate the transport and movement of people, goods, and services, creating welfare. Road networks played a crucial role in the economic development of the 20th century, enabling relatively fast individual transportation for the masses from the second part of the 20th century (Rodrique, et al 2013).And although the development of air transportation and telecommunication networks started to compete with road networks during the later part of the 20th century, in most EU countries road transport still plays a crucial role in the national and local transportation networks.

Investments in road networks reduce the travel time between two locations increase the robustness of the transportation network and hence reduce the travel costs. These kinds of effects are referred to as the so-called direct effects of road networks. The economic impact of road networks extend in most cases beyond these direct effects due to the further rounds of economic activity as a result of the efficient transportation of goods, skills and persons, the so-called indirect economic effects. The investments in road networks, however, do not just lead to positive effects. Apart from the necessary investments in terms of time and money, road networks fill up land and have negative social and environmental impacts such as congestion, traffic accidents, light and noise pollution, and (of course) air pollution. In order to assess if an investment in a road the network has a positive effect on society, or to compare different alternatives of transport infrastructure, economic tools can be used to value the positive and negative direction, indirect and external effects of these alternatives. The difficulty with this kind of economic appraisal is first of all that it is not easy to measure the valuation of travel time, and secondly that new road infrastructure will generate road use that would not have been made without the investments, the so-called induced demand. A third problem is that especially external effects such as quality of life, the value of unique nature, the value of no air pollution, is very difficult to be expressed in monetary terms (M Aldagheiri 2009).

In economic terms, checkpoints help to apprehend persons in violation of laws and remove contraband (such as smuggling goods). The benefits of checkpoints can be quantified in terms of the number of apprehensions per patrol agent. Some detailed studies suggest that checkpoints have a positive benefit-cost ratio. Take for example a study on the community control checkpoint program estimated benefits from the National Highway Traffic Safety Administration. This report states that for every $1 spent on the sobriety checkpoint program the community saves more than $6, including $1.30 of insurer costs. Nevertheless, screening of persons also generates indirect costs that are generally hard to measure. Think of effects such as delays (for both private persons as commercial transportation companies), inconvenience for travelers, and the quality of life for local residents. On top of that, checkpoints may possibly also raise concerns about the overall safety of the region, influencing economic activities such as tourism and local business customer ship (Sharpe 2012).

2.2.3.3. Mobility

The function of a road network is to facilitate movement from one area to another. As such, it has an important role to play in the urban environment to facilitate mobility. It furthermore determines the accessibility of an urban area together with public transport options. The capacity of a network is determined by its roads. The capacity of a the road is the maximum number of vehicles that can pass a certain road section per hour. The capacity of a road is determined e.g. by its width, the number of lanes, and speed limit. If the traffic demand is larger than the road capacity, congestion will occur. When congestion is present, the road network can no longer fulfill its task. Therefore, one tries to prevent or reduce congestion with traffic management measures.

Developing a good road network has many positive effects, such as stimulating the development of certain areas (commercial activities, urban development, creating jobs etc.). For security, good accessibility by the road network is also important, for example for good accessibility in case of incidents (see also incident management). However, the road network may also facilitate criminals to reach their target. This could be controlled with access control (Zuidgeest 2011).

2.2.3.4. Safety of Road Users

Safety of road users is typically focused on road safety (prevention of accidents through speed control, seatbelt enforcement, etc). Proper planning is critical in ensuring road safety: In the case of national roads, where the speed limit can exceed 50-60 km per hour, the proliferation of roadside development should be avoided. The intensification of or the development of new accesses to national routes can generate additional turning movements which in turn can introduce additional safety risks to road users. The lay-out of the road should help to improve traffic safety, for example by providing separate bicycle lanes and physically separated driving directions for motorways and larger urban roads (Dutch 2017).

2.2.3.5. Security Issues

The presence or absence of routes from one place to another can influence the mobility of the public, but also of criminals. This can have a direct effect on the perceived the attractiveness of a location to criminals. Security issues are influenced by the pervasiveness of the road network because an easy escape adds to the attractiveness of targets, are:

Burglary, Robbery, Raid and Vehicle theft. The layout of the road network and its associated potential to ram a car through a window front is essential to the attractiveness of objects for ram-raiding. Disturbance of important traffic nodes can attract a lot of public attention. This can make these nodes (like important or prominent bridges or tunnels) attractive objects for the destruction of property by fanatics(Dr Geetha Menon 2012).

2.2.4. Road Accessibility

Access refers to the opportunity to use or the right to or the ability to reach some destiny. Accessibility is measured as the percentage of the population having access to all whether roads. The benefits of having access to a road network are measured in terms of reduction in monetary costs or time needed by beneficiaries to access output markets or key public social services like health and education (SVC Somenahalli 2016). The accepted theory, according to Ethiopian Road Authority (2008) study, is the accessibility has three elements: are the location of the individual; the location of the supply, service, or facility to which the individual needs access, and the link to bring the two together. The study used three approaches namely; the random model approach, the graph theory approach, and the square grid approach to cover the network of the area..

One of the goals of the transport system is to increase mobility and access to facilities. Even though the definition of accessibility varies depending on its application (Zawartereen 2011), based on the context, it can be generally defined as the ease with which certain destinations can be reached from a particular origin using a specific mode of transport can be measured by the mobility the transport system provides and density of opportunities that can be accessed within a certain time or distance. It depends on the spatial distribution of activities, the origins of demand, and the transport system connecting the origins and destinations.

The other important function of the road network is to provide linkage and open access to major centers, by giving connectivity to all economic centers, to sub-city headquarters and national and international entry points like airports and freight hubs. By providing good connectivity of the road network will contribute to the economic growth, increase accessibility and people mobility. One of the important factors affecting the performance of the transport network is the availability of adequate transport infrastructure. Transport infrastructures include road length, road width, public transport hubs and even road furniture and these factors affect the accessibility of the transport system. Especially road length per area and road length per unit population indicate the accessibility of the road network(Ibid).

2.2.5. Hierarchy of Roads

2.2.5.1. Free ways/Express ways

They are designed to carry traffic in fast and unobstructed lanes, sometimes adjoined with service lanes or streets. At the top of the hierarchy are limited-access roads Freeways or Expressways, including most toll roads. These roads provide largely uninterrupted travel, often using partial or full access control, and are designed for high speeds. Some freeways have collector/distributor lanes (also known as local lanes) which further reduce the number of access ramps that directly interface with the freeway; rather, the freeway periodically interfaces with these parallel roadways, which themselves have multiple on and off-ramps(Eric Avila 2014).

2.2.5.2. Arterials

An arterial road or arterial thorough fare is a high-capacity urban road. The primary function of an arterial road is to deliver traffic from collector roads to freeways or expressways, and between urban centres at the highest level of service possible. As such, many arteries are limited-access roads, or feature restrictions on private access. Because of their relatively high accessibility, many major roads face large amounts of land use and urban development, making them significant urban places. Though the design of arterial roads varies from country to country, city to city, and even within cities, they share a number of common design characteristics. For example, in many cities, arteries are arranged in concentric circles (commonly referred to as ring roads) or in a grid. Many jurisdictions also classify arterial roads as either principal (major) or minor.In traffic engineering hierarchy, an arterial road delivers traffic between collector roads and freeways. For new arterial roads, intersections are often reduced to increase traffic flow. In California, arterial roads are usually spaced every half mile, and have intersecting collector(s) and streets. Some arterial roads, characterized by a small fraction of intersections and driveways compared to most arterial roads, are also considered to be expressways in some countries and some states of the United States (C Mc Andrews 2017).

2.2.5.3. Collectors

A collector road is a non-arterial road that collects and distributes traffic in an area as well as serving abutting property. Collector roads generally provide a link between either arterial roads or distributor roads and local roads. These roads usually provide for the movement of traffic, have one lane in each direction, allow parking and provide direct access to residential properties. Collector roads are the responsibility of local government(Ibid).

2.2.5.4. Local

Local roads are largely the neighborhood street system. These roads are relatively free of through traffic and mostly handle local traffic. The challenge in these areas is to provide a high level of safety and adequate access to neighborhood services and facilities. Local Street means a street that provides access to each parcel. At the bottom of the hierarchies are local streets and roads. These roads have the lowest speed limit, and carry low volumes of traffic.(Ibid).

2.2.6. Types of Urban Road Pattern

2.2.6.1. Rectangular/Block/Grid Pattern

The rectangular/ block/ grid pattern is a plan where the streets and roads are in the form of grids or blocks running perpendicularly into each other thus forming a grid or block. The North Naziabad area of Karachi in Pakistan is a factual example of this type of the pattern where the streets and roads run at an angle of ninety degrees into each other. Usually in this type of pattern the streets and roads are far away from each other and it takes a long time to reach the center of the area or city. This type of pattern is normally considered weak from the road safety point of view as the vehicles meet at opposite directions at intersections. Usually, the main road is wide which passes through the center of the area and other roads connecting to it are narrow. This pattern is sufficiently easier to construct and maintain(Risa 2012).

2.2.6.2. Radial Pattern

A Radial Pattern arranges the specified features spaced along the circumference of a circle. The spacing can be set so you only arrange features along an arc instead of the whole circle. Spacing and angles are set with dimensions settings(Ibid).

2.2.6.3. Hexagonal Pattern

A hexagonal pattern is a network of roads that forms a hexagonal shape, similar to a circular road pattern. At every corner of the hexagon, three roads meet the built-up area. Boundary by the sides of hexagon is further divided into plots of suitable sizes(Ibid).

2.2.6.4. Linear Pattern

Linear pattern concrete footpath provides a distinctive feature for Moreland's Small Shopping Strips. Concrete provides a cost-effective and easy to maintain surface while the saw cutting is used to create simple pattern. The sandblasted pattern can be applied differently in the same linear manner (Ibid).

2.2.7. Urban Road Network Safety

Good urban road networks have the following requirements/parameters: urban roads should be durable, cheap and have good impervious surface finishing; they should have good alignment adequate visibility, easy gradient, smooth, large radius curves, and adequate width; they should remain in dry condition, be well-drained, and must be founded on ground unyielding soil; they should have shady avenues, parking places, and proper camber, footpath, and traffic signs; and they should possess well-designed junctions, traffic congestion points should be minimum(Dutch 2017).

2.2.8. Grid Model

This model is named Hippodamian Plan proposed by Hippodamus of Miletus. The grid plan, grid street plan, or gridiron plan is a type of city plan in which streets run at right angles to each other, forming a grid. The infrastructure cost for regular grid patterns is generally higher than for patterns with discontinuous streets. According to Hippodamus Costs for streets depend largely on four variables: street width, street length, block width and pavement width. Two inherent characteristics of the grid plan, frequent intersections and orthogonal geometry, facilitate pedestrian movement. The geometry helps with orientation and way finding and its frequent intersections with the choice and directness of the route to desired destinations. As Example, Piraeus s a port city in the region of Attica, Greece in Southern Europe was planned by this model EU Commission (2010).

2.2.9. Urban Road Safety Management

Urban safety management is a structured method to crash prevention and causality reduction on urban roads, which takes account of other policies that influence road safety and involves all the agencies which can have an influence on road safety. It recognizes that it is important to help people feel safer as well as reduce death, injury, and damage caused by crashes. There are a number of stages to the process, which include the development of objectives, setting aims for the scheme design, and implementation and monitoring. It involves the cooperation of a number of agencies, and public consultation is a vital part of the whole process. The basic methodology is to identify the current road hierarchy and assess its performance in terms of the various activities that the different types of road have to support. This includes consideration of the needs of different road user groups and the frontage properties, crashes and numbers of pedestrians and vehicles, including traffic speeds. Each part of the road network is then examined to determine if it is adequate. Where this is not the case, specific improvements need to be introduced, or its role in the hierarchy needs to be changed. This requires the consideration of the redistribution of traffic and road space for all users. The process has to be based on defined areas to which the process can be applied, and the definition of a functional road hierarchy is a vital requirement (Dutch 2017).

2.2.10. Road Safety Policy, Guidelines, and Standards

2.2.10. 1. Road Safety Policy

The promotion of road safety should be a priority for every road authority. Attention is generally focused on situations where a relatively large number of accidents and/or fatal accidents occur. Measures designed to tackle those accident concentrations should be based on a thorough, objective analysis of the problems (determination of the origins). While accident analysis and investigations are very important, this is a reactive approach to an existing situation. With sustainable road design the approach of road safety is proactive: Prevention is better than Cure! A pro-active attitude by the road authority is essential to avoid situations that can result in accidents (MUDC 2012).

2.2.10. 2. Guiding Principles

According Ministry of Urban Development and Construction (2012), the guiding principles of the street design standards are:

Pedestrian and mass transport oriented*:* Walking is the dominant mode of transport in urban centers in Ethiopia. It is also economical and ecologically better. Therefore it is necessary to support and facilitate this mode of transport through Pedestrian Oriented Developments. On the other hand as the population increases, urban centers expand and increase in size, demand for transport and motorization increase. It is more efficient and environmentally beneficial to address transport demand through public transport rather than private cars and taxis. Furthermore, larger urban centers including Addis Ababa, Regio-polis and first-grade urban centers require Transit- Oriented developments.

Walk able and attractive urban spaces: Streets are urban spaces where people walk, talk, sit, trade, recreate, socialize and do other activities. To be used as urban spaces, streets shall primarily be designed for people and have to be walk able and attractive. For these streets shall have dedicated sufficient space for people to walk comfortably and safely; have mixed land use and dense developments. Creating attractive street spaces requires regulating the design of the context to have enclosure, unity and uniformity.

Mixed activity and local economic development: Mixed activity streets support the flourishing of adjoining economic activities and services and also establishment of new business enterprises thereby create jobs, and wealth. They also help to exploit the economic Street Design Standards for Urban Ethiopia stated by Ministry of Urban Development and Housing (2017) potential of streets by bringing different land uses, to where people live and providing street vending, shop fronts and outdoor spaces.

Safe and comfortable: Streets shall be safe from traffic accidents and be comfortable to be usable. Streets shall have dedicated spaces and provisions for each user, traffic signs and signals. They shall also have trees for providing shades and beauty; seats to rest and enjoy the street life and have refreshments; good enclosure, and aesthetics. They shall also have provisions for people of different physical conditions and age.

Smart, sustainable, and resilient streets*:* Street shall be elegant, organized and neat. They shall accommodate the growing and varying demands of users and urban centers. The planning and design of streets shall result in well connected, legible, cost efficient and effective streets. Streets shall accommodate current as well as future demands of urban population without incurring costs that could be avoided.

2.2.10. 3. Road Network Standards

The road hierarchy is simply a division of the road network into identifiable road classifications or types which reflect the functionality of the roads making up the network. Each classification has a number of criteria to differentiate it from other classifications. The criteria are based on the purpose and function of the roads making up the particular classification. The Road Hierarchy attempts to reflect the preferred movement of vehicles throughout the network and gives guidance to road managers, road users and land developers as to Council's intended road network objectives stated by Ministry of Urban Development and Construction (MUDC 2012),.

The layout and design of streets depends on the variety of travel needed high ways or express ways carry through traffic at high-speed arterial streets carry traffic within and across the urban area and local streets provide low-speed travel but access to many local destinations. Long delays and frequent accidents are common outcomes of inadequate road planning, which results in an insufficient number of roads to meet travel needs. Here to minimize the problems traffic control may help, but it is not a substitute for adequate provision of transportation supply (Ibid).

For easy movement of people and goods, it is necessary to have different type of road hierarchy standards within an urban area regarding the main groups of urban road net work are classified in the following. Design and construction of roads (local, collector, sub-arterial and principal arterial, boulevards, avenues, and high-speed streets) should be based on the typical cross-section standards proposed in this document. Utility lines construction should also refer to these cross-section standards as stated in Revised Standards for Structure Plan Preparation and Implementation (MUDC 2012). According to Revised Standards for Structure Plan Preparation and Implementation (MUDC 2012), the road width standards are stated as in the following table.

Table 2.1 Road Width Standards

No	Streets	Righit-off-way width(m)			Remark
		Core areas	Intermediate zone	Expansion areas	
1	Principal arterial-	25,30	25,30	30,40,50,6	In existing built up areas,

	PAS			0,100,120	where widening is difficult,25m streets are also categorized as principal arterials ones.
2	Sub-arterial-SAS	20,25	20,25,30	20 and 25	In some cases, existing streets of 30m width with less important connections are categorized as sub-arterial streets.
3	Collector arterial-CS	>11 and <20	>11 and <20	>11 and <20	Within the built-up area where widening is difficult, streets with width less than 12m having important function in collecting traffic are also categorized as collector ones.
4	Local streets-LS	4-10	8-10	10-12	Special design and traffic management considerations should be taken into account to use existing streets in the built-up city areas. widening of streets targeting at optimum size should be considered in redevelopment projects.

Source: (MUDC 2012)

Minimum access roads

In core areas should be a minimum of 4 m for a single plot and 6 m for shared access (if more than one plots use). Special design and traffic management considerations should be taken into account to use existing streets in the built-up city areas efficiently. In intermediate zones should be 8 m and 10 m in expansion areas.

Streets Spacing Standards

According to Revised Standards for Structure Plan Preparation and Implementation (MUDC 2012), the street spacing standards are stated as in the following table.

Table 2.2 Street Spacing Standards

No	Streets	Standard Spacing
1	Principal Arterial Streets (PAS)	Maximum of 1.5
2	Sub-Arterial street (SAS)	0.8 km-1.5 Km
3	Collector Street (CS)	300-800 meters
4	Local Street (LS)	150-300 meters

Source:(MUDC2012)

Road classifications and naming

Classification of roads could be named as according to the type of construction jurisdiction an important function, etc. Names like earth, gravel roads, asphalt roads and concrete roads indicate the type of constructions; names like local roads, district roads, state highways, national highways indicate their jurisdiction; names like rectangular roads, ring roads, and diagonal roads, radial and circular roads indicate their geometric shape; and names like a venue, promenade (a pleasure drive, with the waterfront at least on one side), boulevards and parks indicate their dominant functions (MUDC 2012).

Urban roads are classified as per their importance such as; (arterial roads, secondary or sub arterial roads local roads and other roads including; By-pass, outer and inner ring roads, expressways, and freeways). In other words, there is are also a different system of streets and roads such as: rectangular or grid-iron steel system, rectangular combined with the diagonal street system, concentric and radial street system, rectangular combined with the radial street system, organic street system, irregular medieval street system and combination of the rectangular and irregular street system *(*Ibid).

Design Standards for Road Cross Section and Elements

Design standards for road cross-section and elements are: road width determined by local development plans shall prevail over those specified in the table above for areas to be covered by such plans; the minimum corner curvature for roads entering a junction or round about squares should be 7 -15 m depending on the required design speed and angles of the junction; the radius of the roundabout island should not be less than 8 m and for greater carriage ways it should be greater than one-third of outer carriage way boundary; the minimum horizontal alignment curvature of a road for a design speed of 60 km/h r is 150 m (allowable urban speed) and for the urban high speed (80-100 km/h) minimum radius is 230 km; the maximum recommendable vertical grade for asphalted arterial street is 12%***; t***he standard (requirement) of vertical open space for motor ways is 4.7 m and for the rest 4.5 m; and the minimum average road density in the city should be 20%(Ibid).

2.2.10. 4. Mass Transport

Pedestrian ways

Pedestrian ways are stated as in the following: pedestrian ways should be provided on both sides of the arterial street; for the collector and local streets provision, location and size of pedestrian ways should be decided by local development plans, detail plans, and other studies as applicable; pedestrian ways should be raised 15-20 cm above the carriage way; minimum drainage slope of such streets should be 2.5%; the capacity of footways should be 30 to 50 persons per minute per meter width after deducing approximately 0.9 m dead width in shopping areas and 0.45m else were; the gradient of continuous ramps should not be steeper than 10%; a minimum height of 2.3 m should be provided for pedestrian ways; pedestrian ways of the following widths should be provided for the following areas; and pedestrian ways width standards(MUDC 2012).

Table 2.3 Pedestrian Ways Width Standards

No	Street types	Average width of pedestrian ways (m)
1	Urban motorway	No pedestrian ways
2	Sub-arterials	2.5-4 both sides 5-8
3	Principal arterial	Should not be less than 3.5m and maximum 5.

		both sides total 7.00 - 10.00m
4	Collector streets	Should not be less than 2.00m
5	Local	Should be decided based on local conditions.

Source: (MUDC 2012)

The average width of pedestrian ways along sides of arterial streets in: industrial areas - 1.8 m; shopping frontages - 3.7 - 4.5 m; business and commercial areas- 3-5 m and areas along all-purpose roads - 2.7 m.

Cycle tracks

There should be track segregation if large numbers of cyclists are using a street. The following standards should be considered as a basis in detailed studies and implementation. These are: minimum width of pavement = 2m (2 lanes); vertical clearance= 2.25 m minimum; gradients of 5% and 3.5% may be allowed for short lengths of 20m and 50 m respectively; and tracks should be clear of obstructions such as hedges, ditches, tree roots, curbs etc. by at least 0.5 m(Ibid).

2.2.10. 5. Parking and Stopping Places Provision Standards

Parking and stopping places are stated as in the following: **o**ff - street of carriage way stopping points should be provided along major traffic lines at distance of 400 - 500m and at end points of buses trips(Ibid).

Types of on - street parking and standards

Parallel parking 2.5 x 5.9 m per car P No. L/5.9

30_0 angle parking 5 x 2.5 m P No. = L-1.25/5

45_0 angle parking 5 x 2.5 m P No = L-1.77/3.54

60_0 angle parking 5 x 2.5 m = P No = L-2.16/2.89X90°angle parking 5 x 2.5 m = P No = L/2.5

L= Length of Kerb

P No = Number of parking spaces (MUDC 2012).

2.2.10. 6. Building Type and Parking Requirement Standards

Table 2.4 Building Type and Parking Requirements Standards

Building type	**Parking requirement**
Flats in rental apartments and condominium housing	1 parking/flat
Offices	1 parking/every 40 m2 floor space
Supermarkets, Department stores, trade fares etc.	1 parking/every 60 m2 floor space
Primary and secondary schools	1 parking/2 class rooms
Universities	1 parking/every 5 employees
Hospitals	1 parking/every 40 m2 floor space
Museums and libraries	1 parking/every 40 m2 floor space
Hotels and motels	1 parking/every 5 beds
Theatres and Cinemas	1 parking/every 10 sitting spaces
Stadium	1 parking/every 10 spectator
Restaurants, bars, coffee houses, pastries etc.	1 parking/every 10 sitting spaces

Source: (MUDC 2012)

2.2.10. 7. Standard Widths for Bus and Taxi Bays

The length of the recess should be about 15 m for single bus with an additional length of 15 m for every additional bus; the length of the recess for mini-bus taxi should be 7 m; the taper on either side should be about 8:1m; and separate bay with passage provision should have widths of 6.0 to 6.5 m for mini-buses and buses respectively (MUDC 2012).

2.3.Empirical Literature Review

2.3.1.Developed Countries

2.3.2.. Singapore

The Road Safety Engineering Unit of Land Transport Authority is responsible to ensure good and sound road engineering practices, enhance road safety, and work with other agencies involved in road safety. This unit recently carried out a black spot program to identify crash prone areas in the transport network. Since the program was launched in 2005, it has identified and treated over 100 crash prone locations. Other initiatives of this unit include 'Enhanced School Zone' to improve traffic safety around schools, installation of crash cushions at high-risk locations to reduce injury severity, and erecting concrete bollards at selected bus stops to protect waiting commuters from runaway vehicles (Haque et al. 2008).

While Land Transport Authority looks into road safety through various engineering solutions, the Traffic Police is responsible for enforcing traffic laws and regulations on roads and promoting road safety by influencing behavior and skills of road users. Singapore has included world class traffic legislations, regulating and monitoring systems into the transport network, and the Traffic Police are highly efficient and have noncorruptible violation enforcement on the roads. Besides enforcements, various education and safety campaigns have also been organized by the Traffic Police. Every year, the Singapore Traffic Police in collaboration with other agencies develop a myriad of public education outreach programmes primarily targeted at vulnerable road users. Some of these include the ride safe programme, the road courtesy campaign, the anti-drink drive campaign and other educational programmes to encourage the proper use child seats (Ibid).

Trade associations, non-government organizations, and various private companies also play a vital role in organizing safety campaign and awareness programmes. For example, the Automobile Association of Singapore is a key supporter of Traffic Police's road safety outreach programmes for many years and also disseminates useful motoring information and road safety advises to its members and public through their regular newsletters and magazines. Similarly, the Singapore Motorcycle Trade Association, the National Safety Council of Singapore, and various private companies such as Shell Eastern Petroleum Pte Ltd and 3M Technologies Pte Ltd also arrange and support various activities including road safety conferences to promote road safety of various road users (Haque and Chin 2010).

There are also road safety research undertaken by the National University of Singapore (NUS) and the Nanyang Technological University. In particular, National University of Singapore under the Safety Studies Initiative develops targeted counter measures to combat safety problems of different road users (Haque et al. 2009; Haque and Chin 2010). SSI also works with various agencies and organizations to facilitate public education, training programs and activities to promote road safety.

To create road safety awareness and encourage good habits an early development stage, Ministry of Education has included road safety education in its curriculum for primary school students. The curriculum includes pedestrian safety, cyclist safety, causes of traffic crashes, use of traffic lights, and safety on public transport. In addition to the formal classes, all primary five students are given practical classes by arranging traffic games at Road Safety Park. Furthermore road safety talks are also conducted by schools at assembly talks and exhibitions. Ministry of Education works in partnership with traffic and neighborhood police in promoting road safety education at schools as well as controlling traffic during school events.

Achievement

A scientific estimate put the total cost of road traffic crashes in Singapore at about S$610.3 million for the year 2003 which was about 0.3% of the annual GDP. They increase the road safety standards of Singapore bring a change in mind-set of all road users must be made so that individuals understand the social responsibility toward safety and begin to act safely on roads. To achieve a higher level of safety awareness, authorities did more conscientious for promoting and enforcing road safety. Moreover there are greater coordination and dialogue among different road safety stakeholders.

2.3.3. Japan

Run by Japan, East Asia is the most rapidly industrialized region of Asia. China, Hong Kong, Republic of Korea, Singapore, and Taiwan are named the “five little dragons of Asia”. Their quick-economic advance is mostly attributed to the well-developed infrastructure base, particularly in urban areas. Their economic development has also contributed to an increased need for more infrastructures. Infrastructure demands are also apparent in other rapidly urbanizing cities in Asia (Perera &Sugandi, 2009).

The Republic of Poland (country in central Europe), the city's urban planning unit decided to initiate a participatory process to rehabilitate and revitalize the districts. The operation involved an extensive outreach effort, requiring consultation with every home. Regularly scheduled public meetings were declared, and gradually, residents became aware of the role they could play in molding the future of their region. And so, the city council took a fresh scheme to stimulate local investment in infrastructure and construction based on partnership between the metropolis and the occupiers. The human action for the reinforcement of local investment committed the municipality to cover, 70 percent of the cost of road infrastructure (road bed and sidewalks). The cost sharing formula can be modulated to bring into consideration issues of fairness and cost burden. (Ibid). Eventually, a partnership between the municipality and the residents was sent through the local initiatives program to assure its persistence as a citywide development (Eziyi, 2009).

2.4.Developing Countries

2.4.1. Cairo (Egypt)

Road system

An extensive road network connects Cairo with other Egyptian cities and villages. There is a ring road that surrounds the outskirts of the city, with exits that reach to almost every Cairo district. There are flyovers and bridges such as the Sixth of October Bridge, designed to allow fast and efficient means of transport from one side of the city to the other; in practice, however, Cairo traffic is known to be overwhelming and overcrowded, with traffic jams frequently increasing travel time far beyond the theoretical speed.

Bus system

There is a public bus system that offers several lines of service at different prices. There is the standard full-sized bus service run by the Cairo Transport Authority (1 LE) and minibuses run by companies subcontracted by the government (2 LE). Since the devaluation of the Egyptian pound, the bus prices have risen slowly. Cairo Transport Authority buses now cost 2-2.5 LE and the smaller privately run buses cost 3LE. Some of the latter (e.g. the 381 from Imbaba to the Airport) have air-conditioning and wi-fi and cost 5LE. Recently most of the CTA buses do not have working air-conditioning (Cairo Bus Routes 2015).

Other transport services includes the traditional Cairo Taxi and Micro-buses, both are privately run by individuals. The Micro-buses are the cheapest form of transport in Cairo, yet not very reliable. The traditional Cairo Taxi is also run by individuals and usually operates on older models of cars that are being replaced by the effective Cairo Cab for a more modern look in the city.

Cairo Achievement in road network problems

Cairo Road is the main thoroughfare of Lusaka, Zambia and the principal business, retail and services centre of the city. It was a section of the Great North Road and was so named because it is a link in Cecil Rhodes' then dream of a Cape to Cairo Road through British colonies in Africa. Cairo Road is 1.8 km long, running north-south between the Great East Road and Independence Avenue, and is a wide dual carriageway with an avenue of trees down the centre. It runs parallel to the main railway line which is one block to the east. As the main north-south road it became very congested. This has been partially alleviated by the expansion of Lumumba Road to the west as a by-pass, taking much through traffic. All Heavy Goods vehicles are required to use Lumumba Road.

Two routes in the Trans-African Highway network originate in Cairo. Egypt also has multiple highway links with Asia through the Arab Mashreq International Road Network. Egypt has a developing motorway network, connecting Cairo with Alexandria and other cities. Though most of the transport in the country is still done on the national highways, motorways are becoming increasingly an option in road transport within the country. The existing motorways in the country are:Cairo - Alexandria Desert Road: It runs between Cairo and Alexandria, with an extension of 215 km, it is the main motorway in Egypt: International Coastal Road: It runs from Alexandria to Port Said, along the Northern Nile Delta. It has a length of 280 km. Also, amongst other cities, it connects Damietta and Baltim; Geish Road: It runs between Helwan and Asyut, along the Nile River, also connecting BeniSuef and Minya. Its length is 306 km; Ring Road: It serves as an inner ring-road for Cairo. It has a length of 103 km; Regional Ring Road: It serves as an outer ring road for Cairo, also connecting its suburbs like Helwan and 10th of Ramadan City. Its length is 130 km; Plus, Egypt has developed an extensive system of 4-lane highways that can be classified as freeways, because they serve as normal roads and do not discriminate the traffic on it, thus rendering them slower than motorways stated by Maritime Transport Sector of .Egypt Government (2018).

2.4.2. Ghana

In West Africa, is a comparatively small rural area bordered in the north and northwest by Burkina Faso, in the east by Togo and in the west of Ivory Coast. Nearly one million urban dwellers in Ghana's three main cities reside in an expanse extending 3,000 hectares. Communities are inaccessible by vehicles due to the poor state of primary, secondary and tertiary access roads. To up-grade basic infrastructures in these countries would involve an investment of some USD 75 million at today's price. The Investment required would equate to about US$ 80 per-capita of the current population (World Bank, 2010).

2.4.3.Ethiopia

Road

Road in Ethiopia is overseen by the Ethiopia Road Authority. Over the last years, the Ethiopian federal authorities have significantly increased funding for rail and road construction to build an infrastructure, that allows better economic development.

Road projects now represent around a quarter of the annual infrastructure budget of the Ethiopian federal government. Additionally, through the Road Sector Development Program, the government has earmarked $4 billion to construct, repair and upgrade roads over the next decade Government of Ethiopia. The vision is "Construct reliable, standardized and quality roads in the cities or towns. Besides to expand the road transport coverage of the cities or towns strives to attain in 2020 the road network to 20% for the community to get interchangeable traffic flow." And its mission is "Building asphalt roads, gravel, access roads, coble stone pavement roads, drainages, bridges and concrete roads and making that for residents of the cities or towns remarkably enhance the regular activities, there of using hi-tech and low cost being constructed by contractors and own force at improving level on time available for public service (ERA 2014).

The power and duties of Road Sector Development Program are: Initiate policies and laws with regard to road network, construction, protection and use of roads; determine design standards for road and implement same; prepare long term, medium and short term plans and programs with respect to the construction of roads and other related activities and implement same upon approval; carry out or cause the carrying out of feasibility study and implement; prepare design for the construction of roads or cause its preparation through qualified consultants; construct roads on its own or have them construct through contractors; and determine the criteria for selection of consultants and contractors for roads to be constructed by other bodies (Ibid).

2.5. Lesson Learned From Developed, Developing and Practices of Ethiopia

2.5.1. From Developed Countries

They modernize the main roads to fulfill the needs of the community of the city. In addition to maintenance, they expanded of the road network and widening the existing roads increasingly. They are able to handle increased traffic and also allow for corresponding increase in the average movement speed on their roads through defined rules and regulations. Pollutants from poor road network and from resultant poor fuel efficiencies include hydrocarbons, Nitrogen dioxide, sulfur dioxide, methane, carbon monoxide and carbon dioxide all which cause health problem due to climate change and environmental damage because of congestion. To overcome these problems the government improved the road network of the city and improving the public transport including railways and rapid transit systems. They proposed and implementing mass transit systems (Haque and Chin 2010).

The Minister in charge of the central government department administering, describing wasteful poor road construction and funds being diverted to corrupt officials. Improving skilled technicians on construction sites and fulfills skilled manpower. Rules against machinery and contractors are also claimed to be in force, requiring unskilled labor to maximize employment, resulting in roads that are destroyed must be rebuilt annually. They build modern highways and improve its road network have made a significant difference to trucking logistics (Ibid).

The Road Safety Engineering Unit of Land Transport Authority is responsible to ensure good and sound road engineering practices, enhance road safety, and work with other agencies involved in road safety. Other initiatives of this unit include 'Enhanced School

Zone' to improve traffic safety around schools, installation of crash cushions at high-risk locations to reduce injury severity, and erecting concrete bollards at selected bus stops to protect waiting commuters from runaway vehicles. The Traffic Police is responsible for enforcing traffic laws and regulations on roads and promoting road safety by influencing behavior and skills of road users. Besides enforcements, various education and safety campaigns have also been organized by the Traffic Police (Ibid).

Trade associations, non-government organizations, and various private companies also play a vital role in organizing safety campaign and awareness programs. They arrange and support various activities including road safety conferences to promote road safety of various road users. There is also road safety research undertaken by the National University of Singapore. They develop targeted counter measures to combat safety problems of different road users. NUS works with various agencies and organizations to facilitate public education, training programs and activities to promote road safety. Ministry of Education (MOE) has included road safety education in its curriculum for primary school students. The curriculum includes pedestrian safety, cyclist safety, causes of traffic crashes, use of traffic lights, and safety on public transport safety talks are also conducted by schools at assembly talks and exhibitions. MOE works in partnership with traffic and neighborhood police in promoting road safety education at schools as well as controlling traffic during school events (Haque and Chin 2010).

2.5.2. From Developing Countries

The lessons learned from the above best practices and experiences are giving priorities to implement the road infrastructure fund effective to its specific objective is advantageous to have adequate transport facilities and hence it provides to integrate traffic mobility in the entire vehicle movement. The well managed financial allocation is the basis for the provision of road infrastructure development activity and well trained technicians and professionals are better human power development to provide road quality Maritime Transport Sector of .Egypt Government (2018).

Generally the review gives us a lesson how to use the land and budget properly in the provision of road infrastructure for good mobility of people, good and services to bring the quality of life of the town residents. And also it helps how to reduce the problem seen in our town like congestion, air pollution, accidents, socio-economic crises, land degradation, by providing the good road quality on which the public transport use efficiently and effectively for the residents.

2.5.3. From Ethiopia Frame Work and Practice

Increased funding for rail and road construction to build an infrastructure that allows better economic development. Allocating the necessary budget for construction, upgrading and maintenance of road network. The federal governments have planned to improve the provision of road infrastructure. The government has earmarked $4 billion to construct, repair and upgrade roads over the next decade government of Ethiopia (2014). The vision is “construct reliable, standardized and quality roads in the cities or towns. Besides to expand the road transport coverage of the cities or towns strives to attain in 2020 the road network to 20% for the community to get interchangeable traffic flow.” The mission is “building asphalt roads, gravel, access roads, coble stone pavement roads, drainages, bridges and concrete roads and making that for residents of the cities or towns remarkably enhance the regular activities, there of using hi-tech and low cost being constructed by contractors and own force at improving level on time available for public service. Initiate policies and laws with regard to road network, construction, protection and use of roads and determine design standards for road and implement same. Prepare long term, medium and short term plans and programs with respect to the construction of roads and other related activities and implement same upon approval.

Conclusion

In general, the researcher believes that the review of related literatures stated above can be a starting point for this study. The trend of road safety programs in developed countries,best practices concerning road safety programs in developing countries and policy issues about road safety enhancements in our country are all their contribution to have better know how about urban road safety problems, their consequences and alternation solution to be taken. The study area of the researcher, Adama Town can also share common features of road network and its accessibility of other urban centers in developing countries in general and in our country in particular. So the review of related literature above can showed the direction of the study and better alternative solutions to be taken for the urban road network structural parameters.

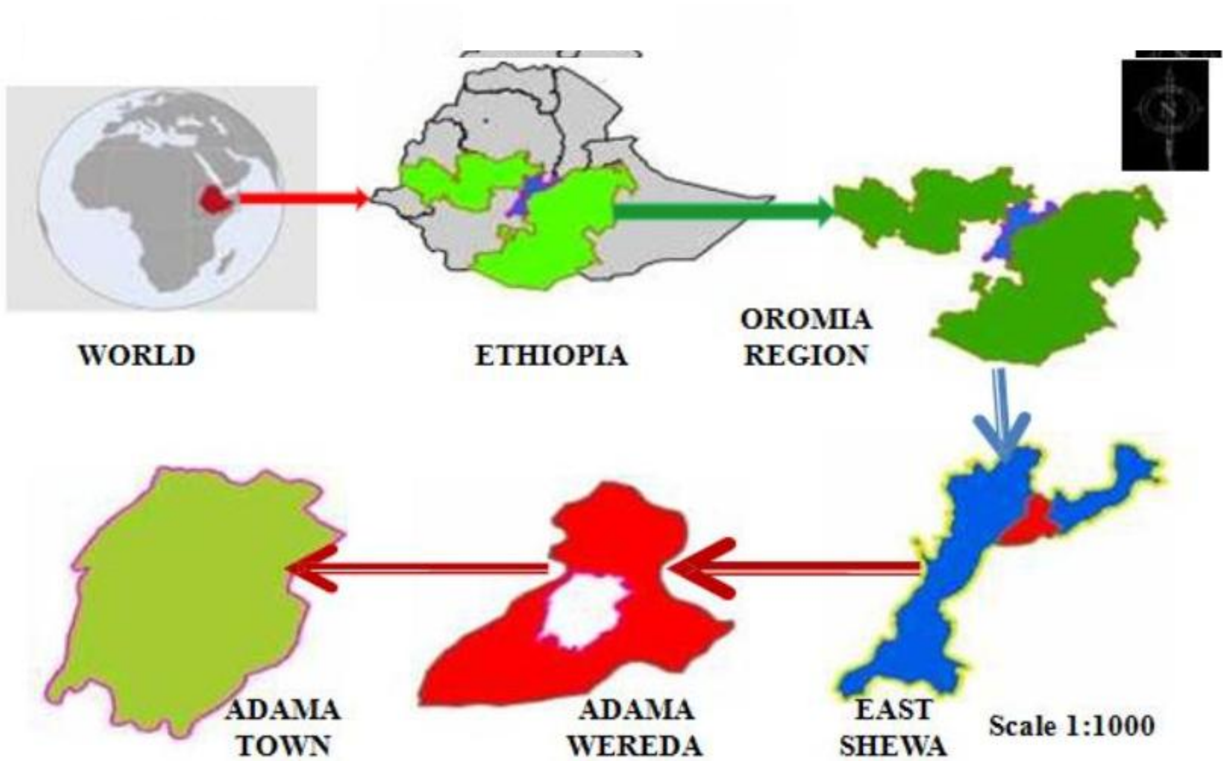
CHAPTER THREE
DESCRIPTION OF STUDY AREA

3.1.Description of Study Area

3.1.1.Geographical Location

Adama city is located in central Ethiopia and Oromia regional state. Adama city is a special zone of Oromia and is surrounded by the east Shewa zone. It is located at 8.54°N 39.27°E at an elevation of 1712 meters, 99 km southeast of Finfine. The city sits between the base of an escarpment to the west, and the Great Rift Valley to the east.

Figure 3.1: Location of Study Area



Source: *From Adama city structural plan*

3.1.2.Formation/Establishment

It was in 1916 that the city of Adama was established with the introduction of the Finfinne/Addis Ababa-Djibouti railway line. The name of the city was derived from "Adaamii" (in Afan Oromo) which refers to 'a generic milky small plant with thick fleshy stems bearing spines called cactus/euphorbia tree'. According to the local people, there were plenty of "Adaamii" trees in the vicinity.

Recently, the city celebrated its hundredth anniversary demonstrating continuous progress and significant developmental achievements in the last a couple of decades since the democratic and developmental government of Ethiopia designed a new urban policy to enhance the transformation from a lower-income society to middle-income society.

3.1.3. Demography

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia this city has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 census, of whom 108,872 are men and 111,340 women. With an area of 29.86 square kilometers, Adama has a population density of 7,374.82; all are urban inhabitants. A total of 60,174 households were counted in this city, which results in an average of 3.66 persons to a household, and 59,431 housing units (CSA 2007).

3.1.4.Road Network, Transportation & Utilities

This is a category of land use that accounts for about 12.16% of the general existing land use of the city. Its details are summarized in the land use plan of the city document (2018) in which the road network is dominant over the other details by accommodating 96% of this particular land use.

3.1.4.1.Transportation

Based on the inputs from physical as well as the transport sector studies the following transportation components were proposed.

- ✓ In addition to the old and the Migra bus station two bus stations were proposed. The first One is on the Finfinnee outlet within the proposed Malkaa Adama sub-center, and the second one is on the Harar outlet.
- ✓ One minibus station was proposed along the way to Wonji road.
- ✓ Three freight terminals were proposed; the first one is by the side of the Alway fuel station to the right of the way to Harare, the other is near Bekalcha/ Tikur Abay transport and the third one is near the new industrial park.
- ✓ One parking service was proposed within the central business districts.
- ✓ The existing rail way line and its stations were reserved

3.1.4.2.Road Network

Concerning the road proposal of the structure plan of the city two alternative mechanisms have been adopted. The first one is widening the existing roads that are not to the standards while the second option is proposing additional roads based on the requirements. To do so some factors were taken in to consideration including Traffic considerations, Land use features, Physical and topographic features, Social and environmental features factors. Hierarchically, the proposed road network contains Express way, Principal Arterial Streets, Sub Arterial Streets, and Collector Streets. Their width as well as the coverage area in each category is presented in table 3.2 below.

Accordingly, some of the upgraded existing roads include;

- ✓ The width of the high way from Finfinne to Harar that passes through the city is upgraded to 50m,
- ✓ The width of the main road form Darartu square to Assela widened to 40m up to the express way and to 50 after that.
- ✓ The width of the main road from Darartu square to Bole is widened to 30m.
- ✓ The road that radiate from Gada No 2 is widened to 25m, etc., for further details

Besides widening/ upgrading the width of the existing roads new proposals for roads were undertaken within the planning boundary from collector streets to the principal streets based on their requirements.

3.1.4.3.Road Network Pattern

Adama city mainly has three types of patterns distributed throughout the city. Those areas

1. Grid pattern or rectangular and
2. Organic pattern
3. The radial pattern of roads

The grid or rectangular exist in the area of the city and new developing area; the organic pattern occurs in the unplanned area.

3.1.4.4.Street Hierarchy

Depending on the purpose and the width the street has a different hierarchy. Those are: -

- **Express way:** It provides for expeditious movement of large volumes of thorough traffic between areas and across the city not intending to provide land access
- **Arterial Street:** It provides for the through traffic movement b/n areas and across the city and diverts access to the abutting property subject to necessary control of entrance exit and curbs.
- **Collector Street:** It provides traffic movement between major arterial and local street systems and direct access to the abutting property.
- **Local Street:** It provides direct access to the abutting property.

The potential of the City's street

- Accessible in a built-up area and the implementing ring road increase accessibility and aesthetic view of the city
- Walk way separated from the main carriageway
- On-street greenery
- Cycle way starting one principal arterial (ring road)

Main problem

- Below standard
- Absence of street furniture and sign
- The width of the main road from Finfinne through the city is not proportional to the ring road radiating from it.
- Dead end
- Not hierarchy
- Organic road in the unplanned area need readjustment to increase the accessibility

3.1.4.5. Roundabout

At the intersections where it is required, roundabouts were proposed and the Darartu square which is below the standard is brought to the standard by the proposal. Accordingly, four new roundabouts were proposed and the details of some of the cross sections of each proposed road by hierarchy are presented in detail below.

According to the street standard that has been prepared by the Ministry of Urban Development and Housing of Ethiopia, the cross-section of each road depends on the local condition of the land use function. For example, a road of 20m road may have different types of cross sections which depends on the land uses it can serve. The cross-section that serves the residential quarter is different from that can serve commercial or industrial land uses. Therefore, it is vital to refer to the standard while implementing the proposed road network.

CHAPTER FOUR
METHODOLOGY

4.1.Introduction

This chapter discussed research methodology and presented the bases and processes within which this study was conducted. It clearly presented research design, research approaches, research methods, sources of data, and Data Preparation.

4.2. Research Design

The research design of this study was concerned with the logical sequence or procedure that followed in the collection of data and analysis. Data collection was designed to commence from one case to the other. This was deliberately done to familiarize with the respondents, with town municipality, transport office and police office experts and officials and drivers of the town. Thus, in this study, a descriptive method was used to describe the extent of the **problems** in terms of hierarchy, surface treatment, accessibility etc. This was because the intention of the study was to describe urban road networks and its accessibility on the town safety. To achieve the intended objective, the researcher used both primary and secondary sources of data and primary data.

4.3. Research Approach

For this study both qualitative and quantitative research approaches will be employed to ensure the reliability and validity of this research. The quantitative approach dominantly used to describe the characteristics of the population of this study. The exploratory and descriptive types of research were used. Regarding the time dimension of the study, given time and resource constraints the efforts have made to use a cross-sectional type of research design by observing the existing situations of road network and its accessibility in a time.

4.4. Research Method

In this study, in primary data collection method, the researcher was used direct observations. Finally secondary data collection method the researcher was used published and unpublished documents from different governmental offices.

4.5. Data Sources

Both primary and secondary sources were explored to collect the required data. The type and the availability of data are evaluated before the commencement of the field work.

4.6. Primary Data: -

The primary data was collected by visiting relevant offices like Adama City municipal office, land administration offices and different offices under Adama city Administration. Interviews with Adama City municipal authority, Adama City land administration, and experts were conducted for capturing their experience on the current practice of road network design.

4.7. Secondary Data: -

The secondary data was collected from the city administration, Adama City land administration and Transport Office, as well as from published and unpublished materials. Moreover, different books, journals and reports were also referred.

4.8. Data Preparation

After gathering all the necessary data, the next step was preparing the data for analysis. The major tasks were converting data format, defining projection and coordinating transformation.

Most maps were collected in AutoCAD and for analysis in QGIS tools. The method used is to export the data in QGIS. This is done by unifying data, changing data formats, building geo-database, updating the demographic data, joining with the map and adding missing attributes. Before exporting these files to QGIS, the data was cleaned and defined in AutoCAD.

CHAPTER FIVE
DATA PRESENTATION ANALYSIS AND DISCUSSION

5.1. Introduction

This section presents the results obtained in various stages of the study road network structural analysis and modeling the accessibility.

5.2.Road Network Performance

The current performance of major road networks that are providing transportation service for Adama city is evaluated based on road density, accessibility, connectivity, and road performance. The outputs are mapped and interpreted.

5.2.1.Road Density/Availability

Road density or road availability can be measured as the ratio of the total road network in an area to the land area or to the total population in that area. Given a similar network topology, in a different area, higher road density (road per area) implies a higher availability of alternative routes (Jenelius, 2009). Also, this implies higher directedness and connectivity levels within the network. The road density per area investigates the network structure only considering the supply side whereas the road density per unit of population measures the availability of network distance per person. The dimensions are normally in [km/km^2] depending on the scale of the network.

The formula for road network density is given as:

Road Density = Total Road Length in km/Total Area in km2

= 1043.57km/133.66km2

= 7.84km/km2

The above result shows, the road density of Adam City is increasingly significant and from the total area of 133.66km2, the road network cover 7.84km/km2. Although, the length of the major asphalt road network in Adama city is seen increasing over the past 3 years. So, this result means, the ratio of the area covered with the road in the city is increasing which in other words enhances mobility and availability in the study area. The road density trend in Adama city shows an increasing value and the total areal share of the road also shows an increasing value.

Figure 5.1(A) shows the road density in the study area.

The road density per area shows a higher value in the central area, but this is not true for the road density per population because of higher population density in the CBD; rather the north-east and some areas in the west have proportionally higher road density per area value.

Figure 5.1.Road density, Road length per area (road length km/km2)

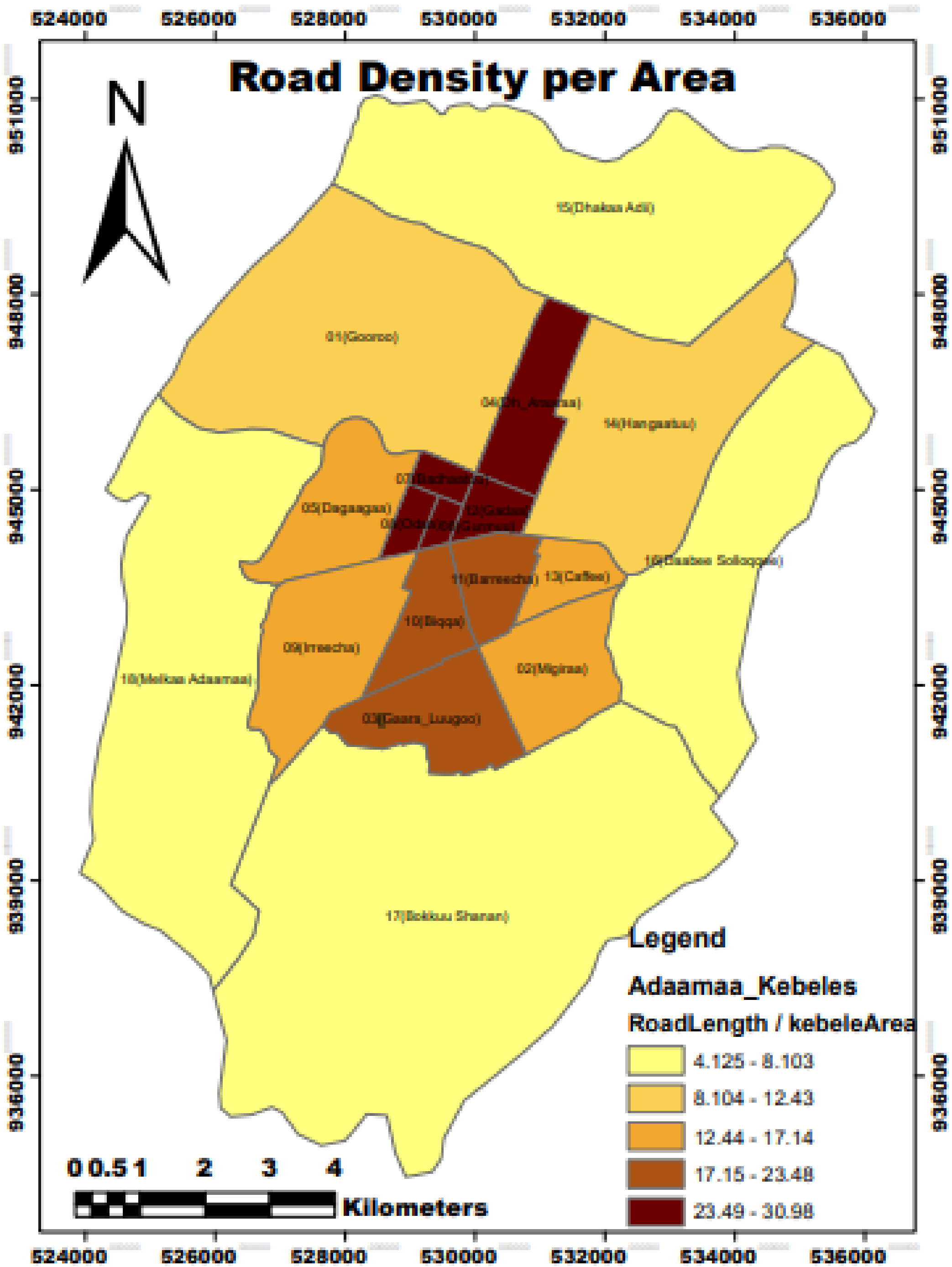
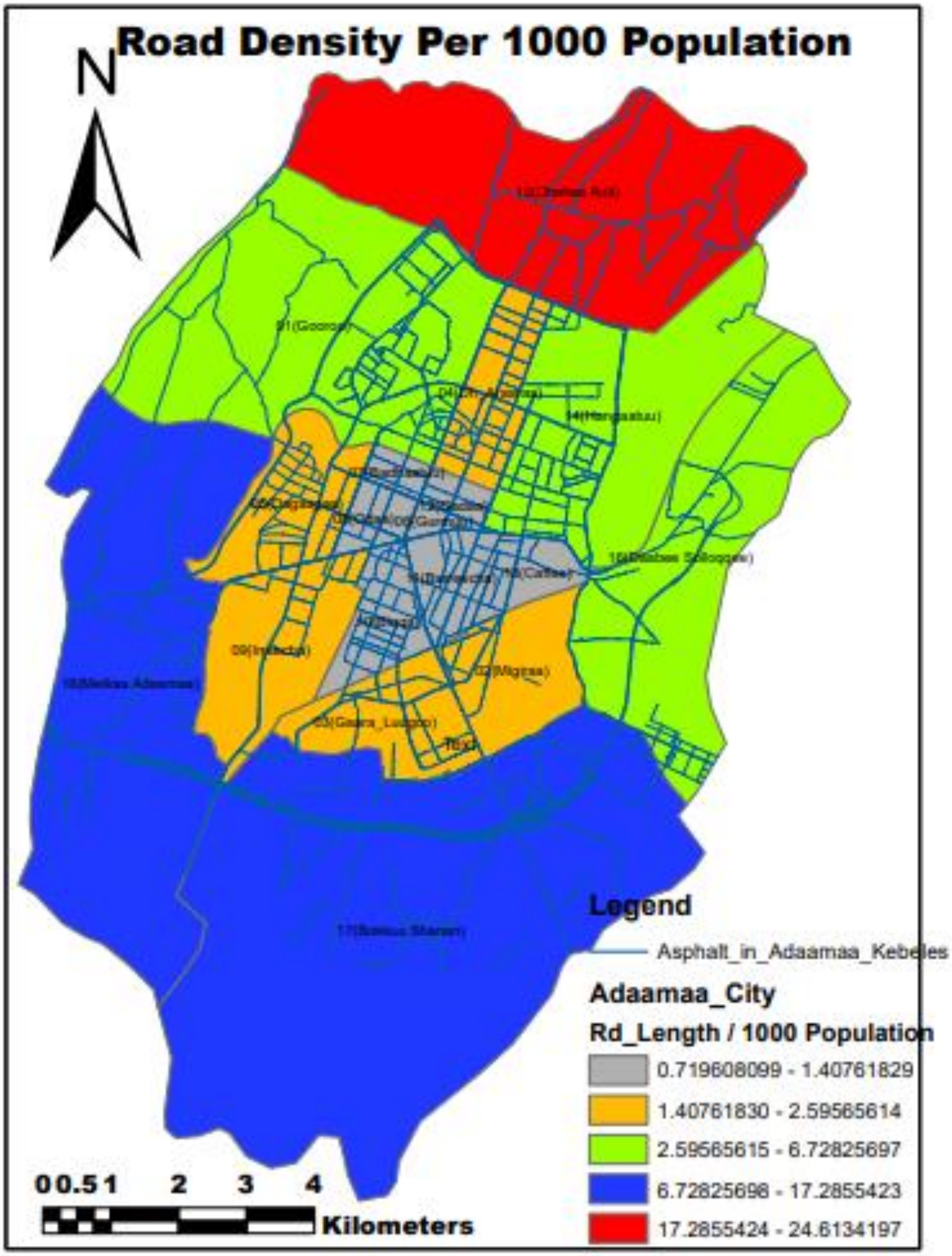


Figure 5.2. Road length per 1000person (road length km / total population)



The road density per unit of the population shows the availability of road distance per person. Based on the result, there are areas and populations suffering from road networks; especially, areas that are situated at the center and north east and west part of the study area.

Hence, road infrastructure exists in more quantities in areas where there is high population density, though vice versa could be true. There is an area that has more infrastructure and higher population density. This implies there is high road density per population in this Kebeles, locally known as Dhaka_Adii(15), Malkaa_Adaamaa (18) and Bokkuu_Shanan(17). There are also areas that have lower value of road per population. These areas have relatively higher population densities. There is a low value of road per population in kebele 06(Gurmu) 07(Badhatu)10(Biqa) 11(Barecha) 12(Gada)and 13(Cafe).

From this it can be concluded that, because they are having larger areas 01(Goro) ,14(Hangatu) and 16(Dabe Solloqe) have lower road transportation infrastructure availability with respect to road density per area and per population.

On other hand, Dhaka_Adii (15), Malkaa_Adaamaa (18) andBokkuu_Shanan(17)have relatively higher road infrastructure with respect to the road per population. Most of the areas that are found in the center of the city have a low infrastructure.

5.3. Linear Referencing

Dynamic segmentation is the process of computing the map location (shape) of events stored in an event table. Dynamic segmentation is what allows multiple sets of attributes to be associated with any portion of a linear feature.

The result of the dynamic segmentation process is a dynamic feature class known as a route event source. A route event source can serve as the data source of a feature layer in the GIS Map. Many organizations collect data about linear features, such as highways, city streets, railroads, rivers, and pipelines as well as water and sewer networks. In most geographic information systems (GIS), these features are modeled in two dimensions using x and y coordinates. Although these systems work well for maintaining features with static characteristics, many organizations have realized that their linear features often have characteristics that are more dynamic in nature. To handle this, these organizations have developed one-dimensional linear referencing systems to model their data. How these organizations store and utilize their linear referencing data varies not only between the organizations themselves but also between the departments within the organizations. This variance necessitates flexible tools to create, display, query, analyze, and distribute linear referencing data.

The need to visually represent features on a map whose coordinates are not geographic but are recorded as a relative distance along another linear feature led to the development of dynamic segmentation. Dynamic segmentation is the process of displaying linearly referenced features on a map. When data is linearly referenced, multiple sets of attributes can be associated with any portion of an existing linear feature independently of where it begins or ends.

These attributes can be displayed, queried, edited, and analyzed without affecting the underlying linear feature's geometry. That is, location is given in terms of a known linear feature and position, or measure, along it. For example, route K-10, Meter 500, uniquely identifies a position in geographic space without having to express it in x,y terms.

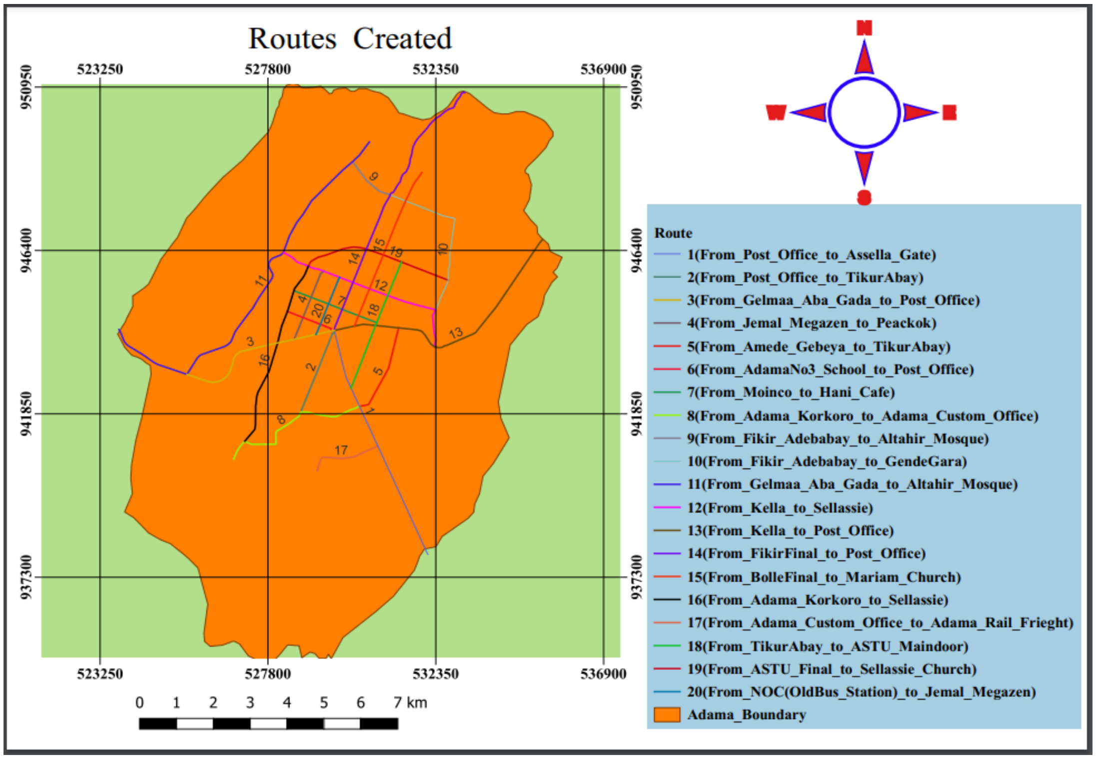
5.4. Creating A Route and Defining the Direction

After creating the database using SQL server the next step is to create a route for each separate road which is a pre-requisite for making a route event layer (dynamic segmentation).In this case we have twenty different routes, most of which radiate from a given point (POST_OFFICE) each of which has a route identifier ROAD ID (RID) which is a unique identifier for that given road (route) that speeds up the dynamic segmentation process.

Route

RID	Route_Name	R_Type
1	From_Adama_Custom_Office_to_Adama_Rail_Frieght_Station	Asphalt
2	From_Moinco_to_Hani_Cafe	Asphalt
3	From_ASTU_Final_to_Sellassie_Church	Asphalt
4	From_Jemal_Megazen_to_Peackok	Asphalt
5	From_Amede_Gebeya_to_TikurAbay	Asphalt
6	From_AdamaNo3_School_to_Post_Office	Asphalt
7	From_Post_Office_to_TikurAbay	Asphalt
8	From_Adama_Korkoro_to_Adama_Custom_Office	Asphalt
9	From_Fikir_Adebabay_to_Altahir_Mosque	Asphalt
10	From_Fikir_Adebabay_to_GendeGara	Asphalt
11	From_Gelmaa_Aba_Gada_to_Altahir_Mosque	Asphalt
12	From_Kella_to_Sellassie	Asphalt
13	From_Kella_to_Post_Office	Asphalt
14	From_FikirFinal_to_Post_Office	Asphalt
15	From_BolleFinal_to_Mariam_Church	Asphalt
16	From_Adama_Korkoro_to_Sellassie	Asphalt
17	From_Post_Office_to_Assella_Gate	Asphalt
18	From_TikurAbay_to_ASTU_Maindoor	Asphalt
19	From_Gelmaa_Aba_Gada_to_Post_Office	Asphalt
20	From_NOC(OldBus_Station)_to_Jemal_Megazen	Asphalt
(New)		

Figure 5.3. Route creation of the study area



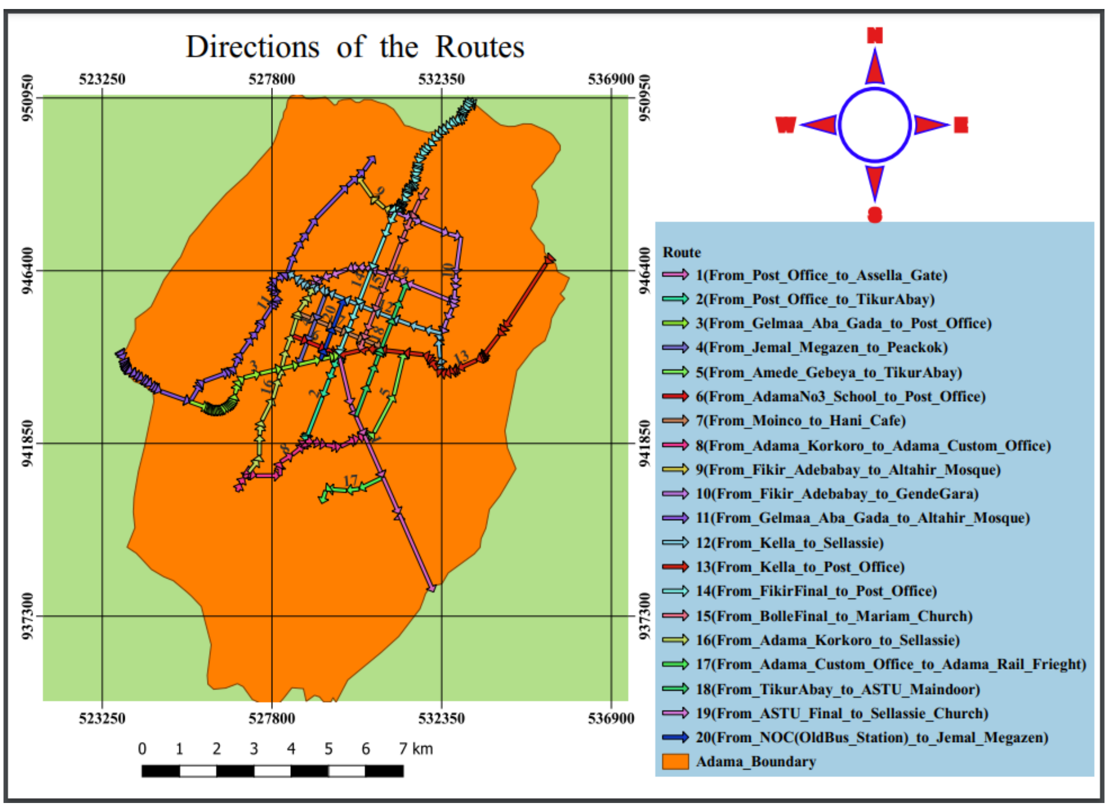


Fig 5.4. Direction of the routes of the study area

5.4.1. Creating “Make Route Event Layer” (Dynamic Segmentation)

Once creating a route for the entire roads one can say that it is ready for making a route event layer.In order to speed up and facilitate the linear referencing process as well as finding the best route ,closest facility and finding service area primarily creating a route is essential.

5.4.2.Dynamic Segmentation by Road Width

The need to visually represent features on a map whose coordinates are not geographic but are recorded as a relative distance along another linear feature led to the development of dynamic segmentation.

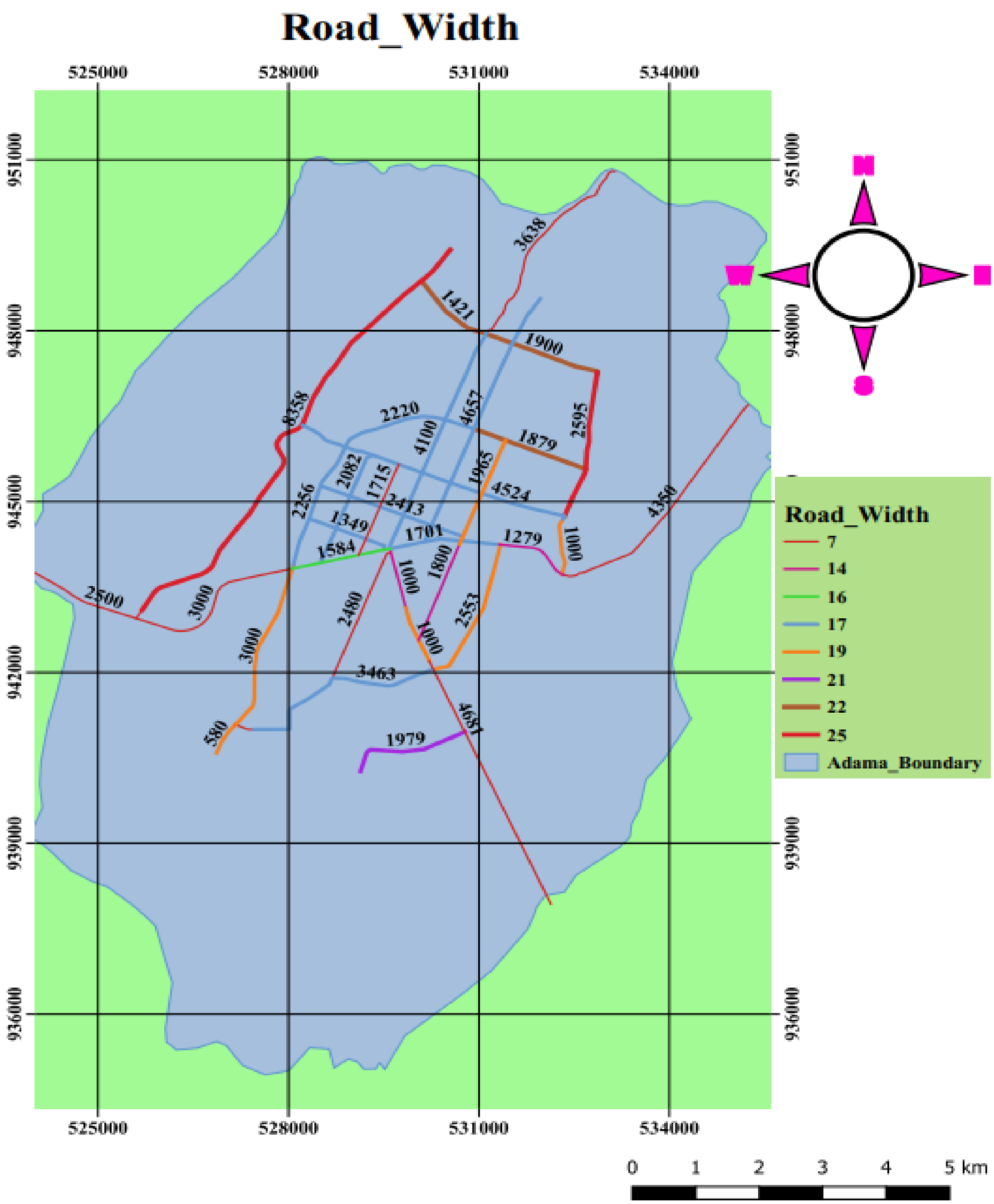


Fig 5.5. Dynamic segmentation taking road width as criteria

The figure illustrates that the roads are segmented through a defined criterion (road width) keeping the above steps consecutively. In the case of Adama city the road has eight different sizes of width (7, 14, 16, 17, 19, 21, 22 and 25) meters.

For each of the roads, a given road width is assigned according to their width size. Moreover, they are defined by different colors to distinguish various types of sizes of road width. Thus, the segmented road along with the change point of the road width is seen clearly.

Other than the above, the linearly referenced entities like that a traffic sign, major locations, pot holes and traffic lights. The Figure below describes that in which route, road name, and in which place the traffic lights are distributed across the sub-city and it also shows weather these traffic lights are functional or not along with the road width of the route.

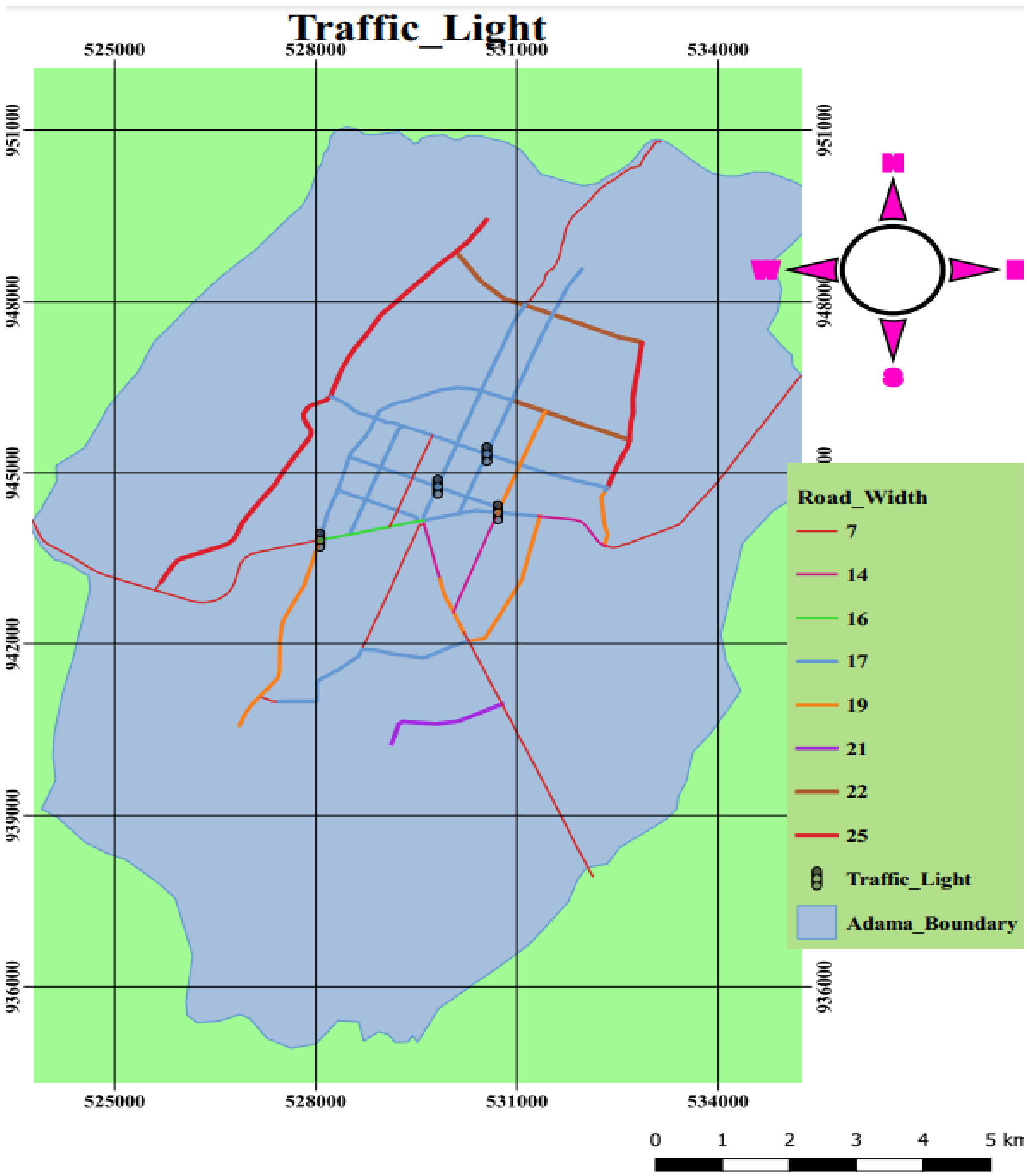


Fig 5.6: Map of the traffic light on a dynamically segmented road.

Thus, generally in the study area there are four different areas that have traffic lights with different light numbers and functionality. The first one is found on the Mebrat Haile (RID=7), when one goes from Moinco to Hani Cafe at 1409 meters. The second one is found on the ROUTE ID 15, from Bolle_Final_to_Mariam_Church at 3548 meter, the third one is found on the ROUTE ID3 from Galma_Aba_Gada_to_Post_Office at 3004 meters. The fourth one is found on the ROUTE ID13 from Kella_to_Post_Office at meter 6196.

The figure below shows the distribution of traffic sign throughout the city, the type of traffic sign, and which type of sign is found in which area. The traffic sign found in the study area is generally categorized in to four types; namely no parking (NP), end of no parking (ENP), NO TURN and a sign of STUDENT and for each of the signs a symbol is assigned.

It also describes weather these signs stand at their target place or not. For instance, On the road from Kella to Selassie around the Gendegara taxi terminal (Genet resident) there are more than two kindergartens and final point on the Route at Selassie church there is a school called Gore School but there is no student sign around these areas on the reverse unnecessary signs existed like for Garisigns. Duplications also existed on the road from Moinco to Hani Café around Adama city Administration Office No Parking sign three times existed except the one at the beginning the rest are meaningless.

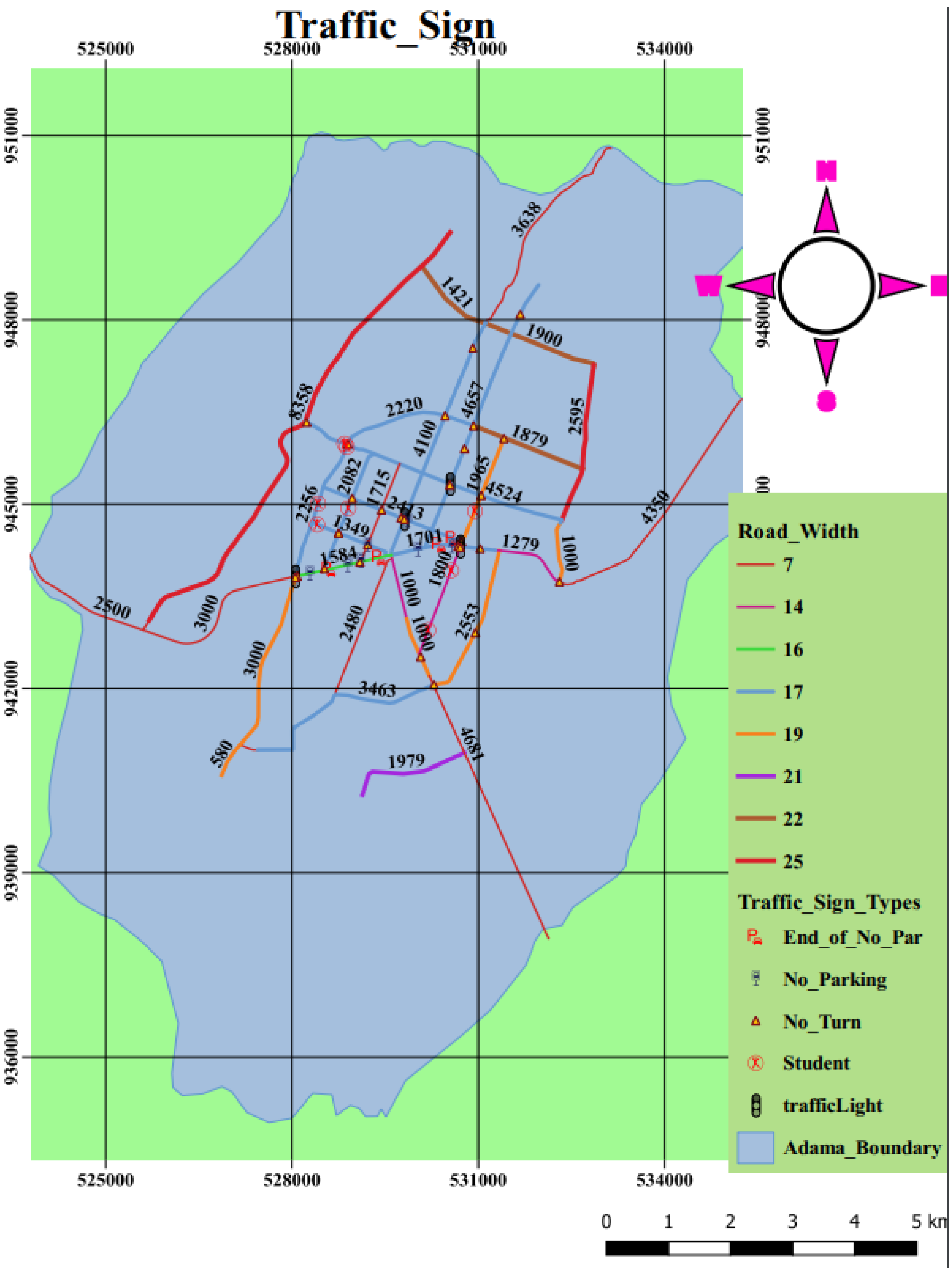


Fig 5.7. Map of traffic sign on the dynamically segmented road

The other entity that give due attention in this study is corridor information (illustrated on the map below). Corridor information in this case includes known institutions, religious places, different organizations, higher institutions, shops and others that give a reference for the other entities as the intention of this study is linear referencing. They are many in number and type, thus they are given a unique symbol to distinguish easily. The big reason behind the inclusion of these entities is to refer to and identify the other entities in an easy manner for further use along with the other entities like that of change point of road width and change point of lane number. Linear referencing and Dynamic segmentation is the process of displaying linearly referenced features on a map. Furthermore which known place is found in which road name, at what distance from the given reference a given known place is found at identified in a good manner.

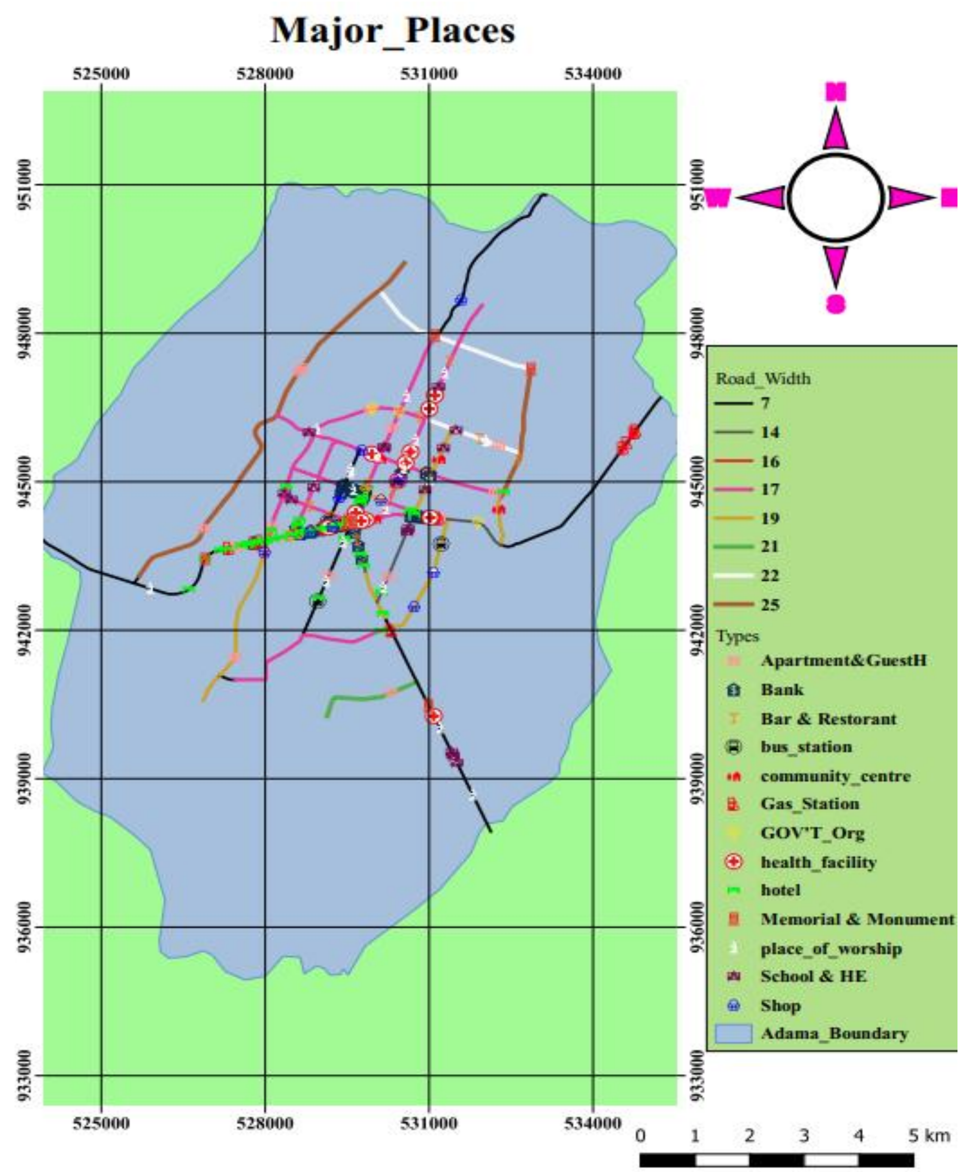
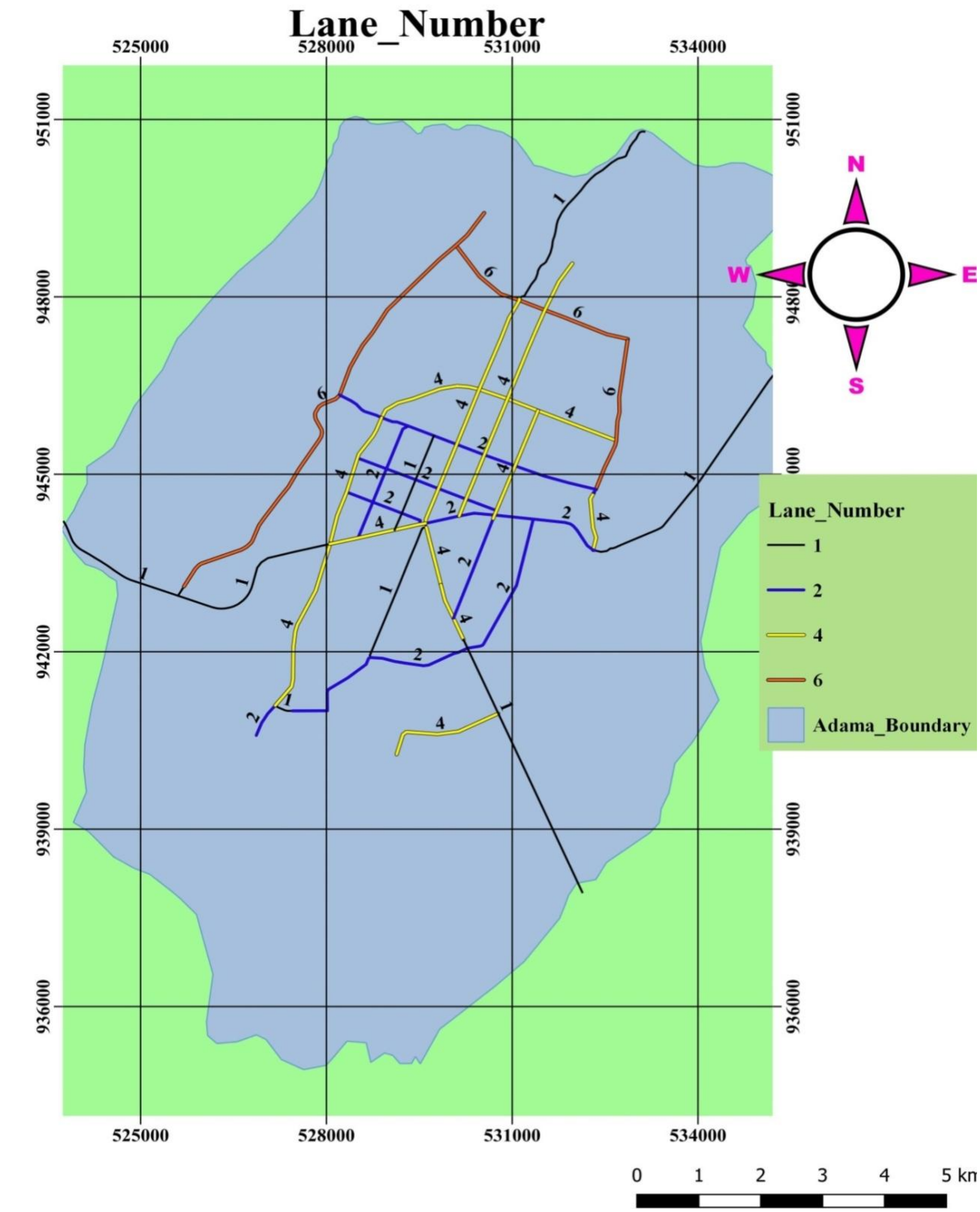


Fig 5.8. Known places of the study area

The other criterion used for dynamic segmentation of the road other than road width is that of lane number of the road (the number of cars passing through the given road at a time or the number of lines on the given road that a car passes through).



The numbers of lanes of the road is different in the study area. Even in a given route the lane number changes from place to place or as the distance increases from the start point. The number of lanes of the road in the study area varies (ranges) from lane number one to six. There are four types of lane numbers in the study area; a road with one lane, a road with two lanes, a road with four lanes and a road with six lanes.

RID	Route_Name	Dist_Start	Dist_End	width_in_m	Lanes
1	From_Adama_Custom_Office_to_Adama_Rail_Frieght	0	1979.38	21	4
2	From_Moinco_to_Hani_Cafe	0	1409.26	17	2
3	From_ASTU_Final_to_Sellassie_Church	0	1879	22	4
3	From_ASTU_Final_to_Sellassie_Church	1879	4117.42	17	4
4	From_Jemal_Megazen_to_Peackok	0	2082.27	17	2
5	From_Amede_Gebeya_to_TikurAbay	0	2553.14	19	2
6	From_AdamaNo3_School_to_Post_Office	0	1349.01	17	2
7	From_Post_Office_to_TikurAbay	0	2480.14	7	1
8	From_Adama_Korkoro_to_Adama_Custom_Office	0	580	19	2
8	From_Adama_Korkoro_to_Adama_Custom_Office	580	890	7	1
8	From_Adama_Korkoro_to_Adama_Custom_Office	890	4352.84	17	2
9	From_Fikir_Adebabay_to_Altahir_Mosque	0	1421.39	22	4
10	From_Fikir_Adebabay_to_GendeGara	0	1900	22	4
10	From_Fikir_Adebabay_to_GendeGara	1900	4494.88	25	4
11	From_Gelmaa_Aba_Gada_to_Altahir_Mosque	0	2500	7	1
11	From_Gelmaa_Aba_Gada_to_Altahir_Mosque	2500	10858.14	25	4
12	From_Kella_to_Sellassie	0	1000	19	4
12	From_Kella_to_Sellassie	1000	5523.65	17	2
13	From_Kella_to_Post_Office	0	6196	7	1
13	From_Kella_to_Post_Office	6196	6763	14	2
13	From_Kella_to_Post_Office	6763	7329.51	17	2
14	From_FikirFinal_to_Post_Office	0	3638	7	1
14	From_FikirFinal_to_Post_Office	3638	7738.01	17	4
15	From_BolleFinal_to_Mariam_Church	0	3548.40	17	4
16	From_Adama_Korkoro_to_Sellassie	0	3000	19	4
16	From_Adama_Korkoro_to_Sellassie	3000	5255.69	17	4
17	From_Post_Office_to_Assella_Gate	0	1000	14	4
17	From_Post_Office_to_Assella_Gate	1000	2000	19	4
17	From_Post_Office_to_Assella_Gate	2000	6681.37	7	1
18	From_TikurAbay_to_ASTU_Maindoor	0	1800	14	2
18	From_TikurAbay_to_ASTU_Maindoor	1800	3765.04	19	4
19	From_Gelmaa_Aba_Gada_to_Post_Office	0	3004	7	1
19	From_Gelmaa_Aba_Gada_to_Post_Office	3004	4583.95	16	4
20	From_NOC(OldBus_Station)_to_Jemal_Megazen	0	1714.76	7	1

Table 5.2 Lane table from the LRS tools

Thus, as it is a linear referencing and Dynamic segmentation is the process of displaying linearly referenced features on a map, the point at which the lane number changes is shown in the table as well as on the map.

After putting all the entities of the road in a linearly referenced and dynamically segmented way and once the database is created it is easy for the road authority working crew to manage the road and its entities in an integrated way. Any worker in the authority can query and observe what happens on the road. So it is supposed to save time, and resources and above all it enhances the work efficiency of the authority.

5.5.Network Analysis

Using the network analyst one can perform all types of network analyses that as finding best the route analysis, finding the closest facility, finding service area, and cost matrix analysis.

5.5.1Finding the "Best" Route

Whether finding a simple route between two locations or one that visits several locations, people usually try to take the best route. But the best route can mean different things in different situations. Creating the best route can mean finding the quickest, shortest, or most scenic route, depending on the impedance chosen.

If the impedance is time, then the best route is the quickest route. If the impedance is distance, then the best route is the shortest route. Hence, the best route can be defined as the route that has the lowest impedance, or least cost, where the impedance is chosen by the user. Any cost attribute can be used as the impedance when determining the best route.

Accumulated attributes play no role when computing the solution. For example, if you choose a time cost attribute as the impedance attribute and also want to accumulate a distance cost attribute, only the time cost attribute is used to optimize the solution. The well-equipped network analyst gives the best out of many routes depending on the impedances that a given person wants. For this case the best route is created from fikir final road which is found in Kebele 15 (Dhaka Addii) to Bokku Michael (Kebele 17 or Bokku Shanan), and the impedance taken for the analysis is that of distance in minutes. This means, by the existing road network, in order to travel from the fikir final Taxi terminal to Bokku Michael Area using the shortest path one has to follow the figure below (***see also the detailed route part direction description in appendix*** one). Thus we can say that this is the best route from fikir's final Taxi terminal to bokku Michael.

The second one is from Adama korkoro factory Area via Bole road final (figure below). Here the impedance is distance. Thus out of many routes from Adama korkoro leads to Bolle the figure (the best route) the one seen below is selected. Thus it is the best route out of many routes for these two different locations.

(*see also appendix 2 for detailed route part direction*).

Figure 5.9. Best route

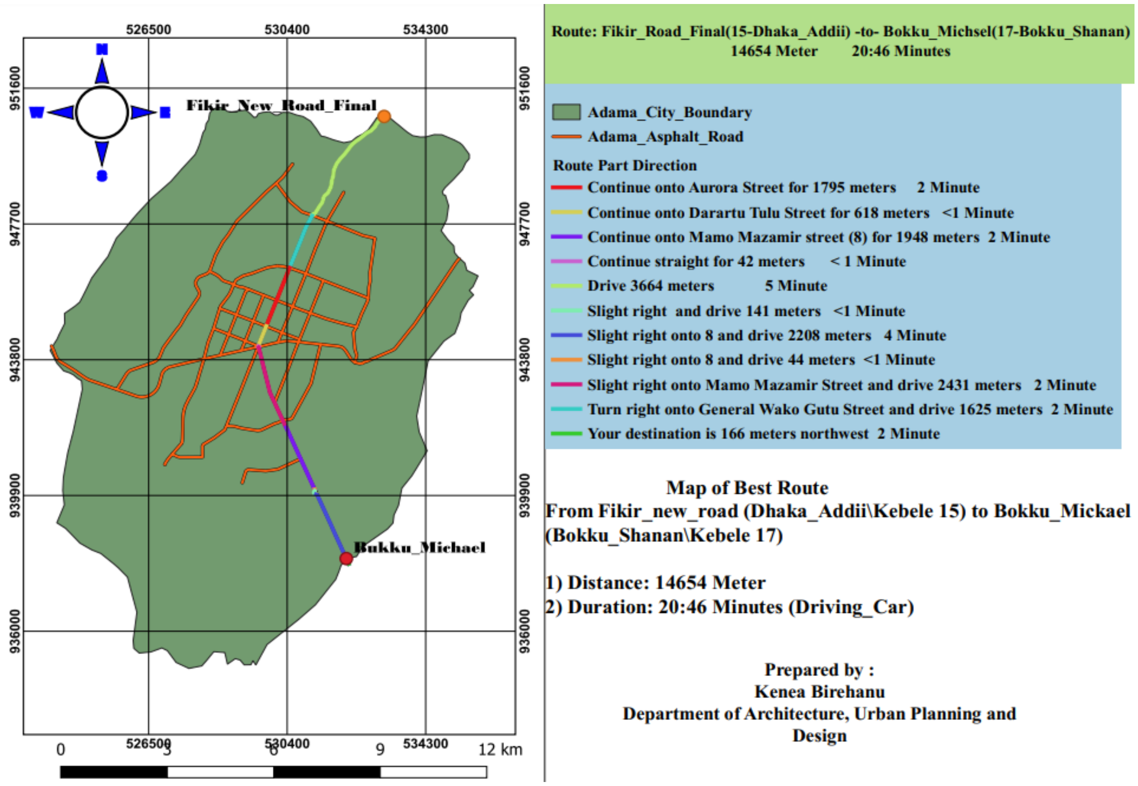
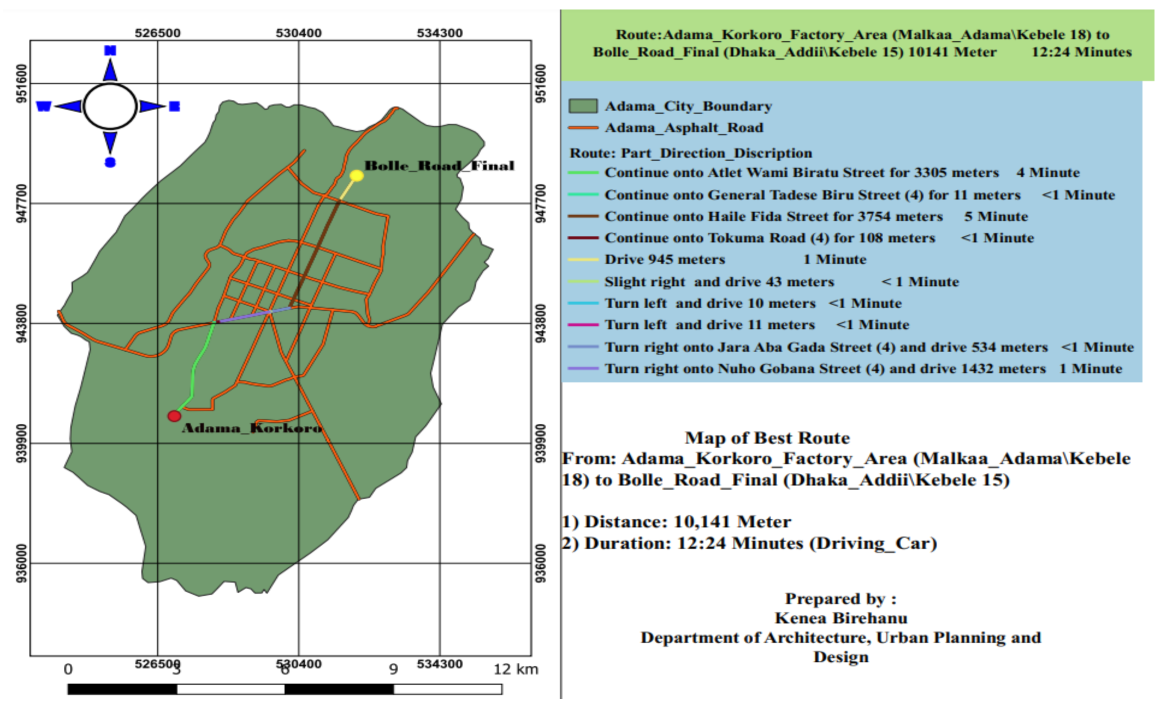


Figure 5.10. Best route of Adama korkoro



5.5.2.Finding Service Areas

With Network Analyst, one can find service areas around any location on a network. A network service area is a region that encompasses all accessible streets. Those streets are lie within specified impedance. For instance, the 10-minute service area for a facility includes all the streets that can be reached within 10 minutes from that facility.

In GIS environment, service areas created by Network Analyst toolbox which can help to evaluate accessibility of road network. Accessibility refers to how easy it is to go to a site. Accessibility can be measured in terms of travel time, distance, or any other impedance on the network. Evaluating accessibility helps answer basic questions.

It can help to identify what is near an existing business to help you make other marketing decisions. One simple way to evaluate accessibility is by a buffer distance around a point. Service networks computed by GIS Network Analysts can be analyzed by identifying the accessible streets within a specified distance of a site via the road network. Once aservice area is created, you can use service networks to see what is alongside the accessible streets, for example, find competing businesses within a 5-minute drive or it can be used, for example, to show how many hospitals are within 5-, 10-, and 15- minute drive times of schools.

Concentric service areas show how accessibility varies with impedance. Once built, you can use service areas to identify the kind of services that a given incident area like that of market places, bus stations, government organizations, hospitals, school or anything else within the neighborhood.

Based on figure 5.9a, the distance of all service areas from the major road networks is computed, taking distance as the impedance. Based on the result, service areas having lower value are more accessible and needs lesser travel time. Accordingly, the figure below shows the closest facilities along the major road network taking three isochrones breaks 100, 300 and 500-meter distance from the network.

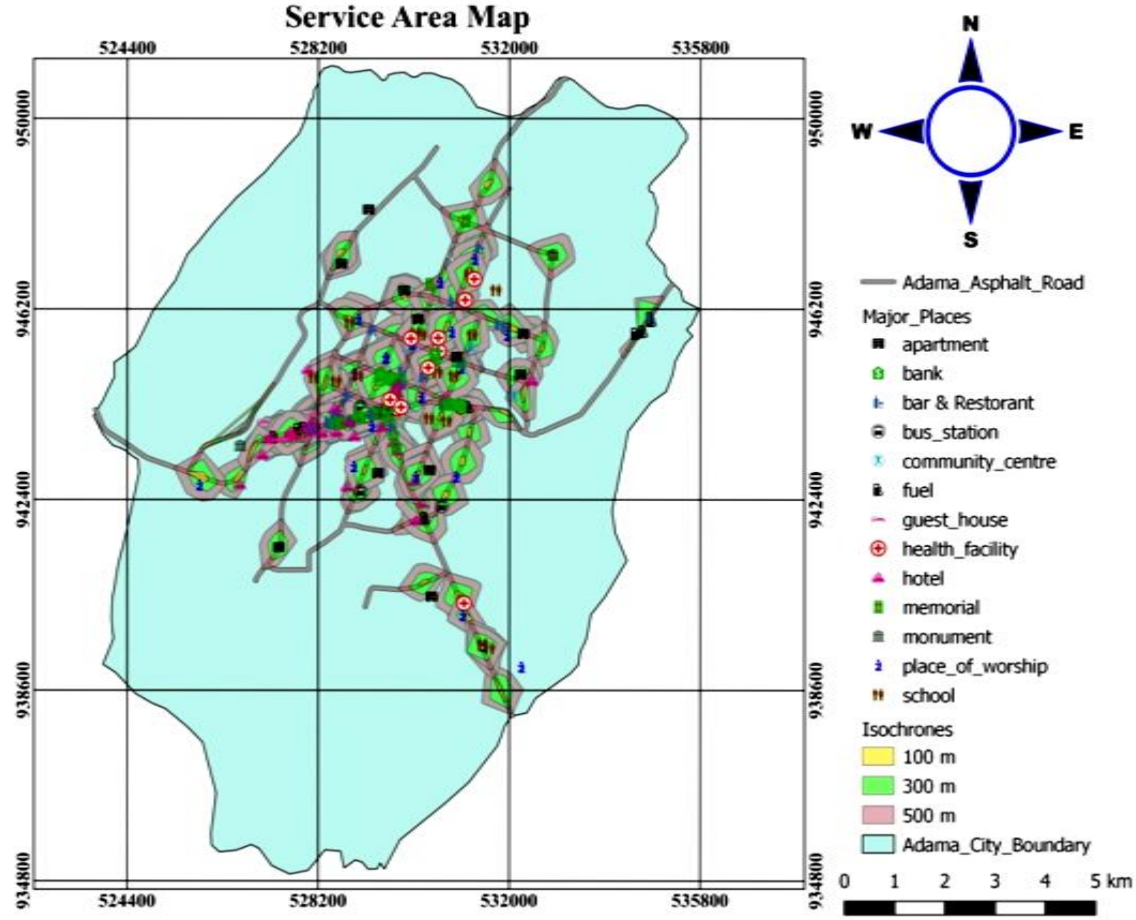


Figure 5.11. Map of Service area

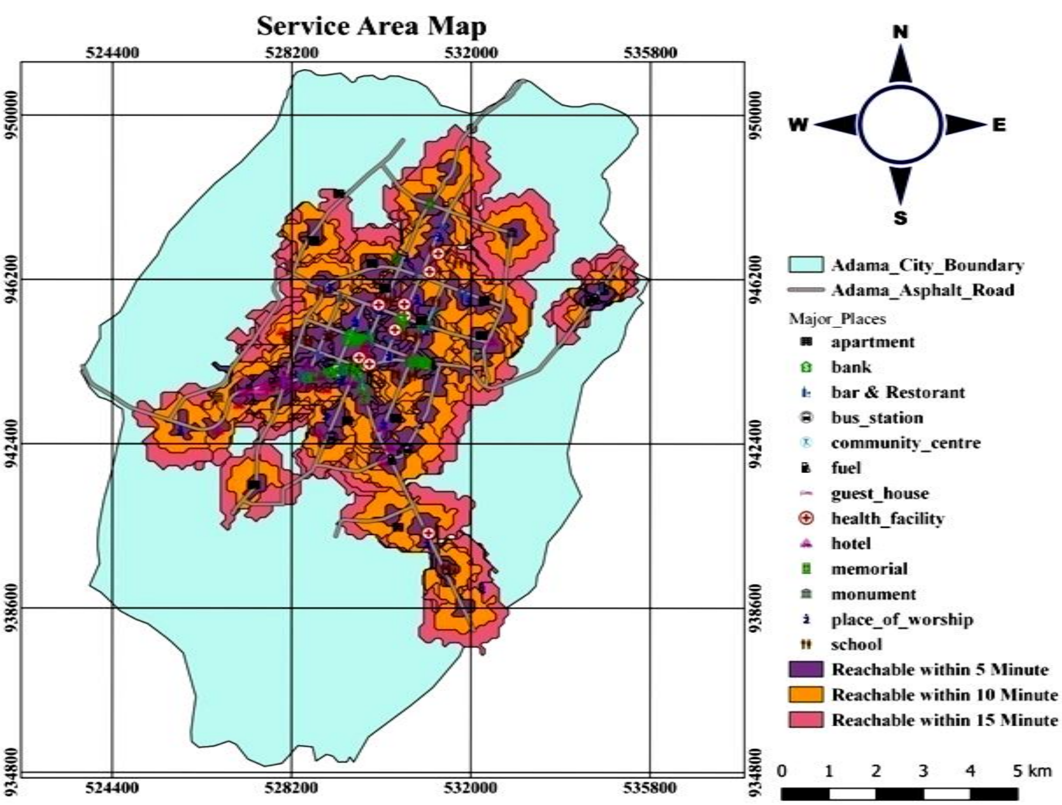


Figure 5.12. Map of Service area

Figure 5.12. illustrates the analysis that is done using the impedance travel time by foot for a given facility. In this case, the analysis is done using the impedance travel time by walking for specific facilities namely service areas using three different default breaks; five minutes, ten minutes, and fifteen minutes impedances. Thus, it (the polygon) illustrates that major roads serves that much of the area within a five-minute travel time by foot, which is designated by a brown polygon, which means a person in the major road network, can have such a kind of services within five-minute travel time by foot. The other one is that ten minutes' travel time by foot, which means these facilities, can serve areas within this polygon, or a person at the areas (facilities) can get service within the polygon designated by yellow within ten minutes. The last one is within fifteen minutes of travel time by foot, which means these facilities can service within the polygon designated by red within fifteen minutes of travel time by foot.

On the other hand, service area analysis is done using the impedance distance for Hospitals that are found within the city. Using three different default breaks; 100 meter, 300 meter, and 500 meters. Thus, the polygons shown in Figures 5.10a and 5.10b illustrate the distance of available asphalt road within the service area of Hospitals.

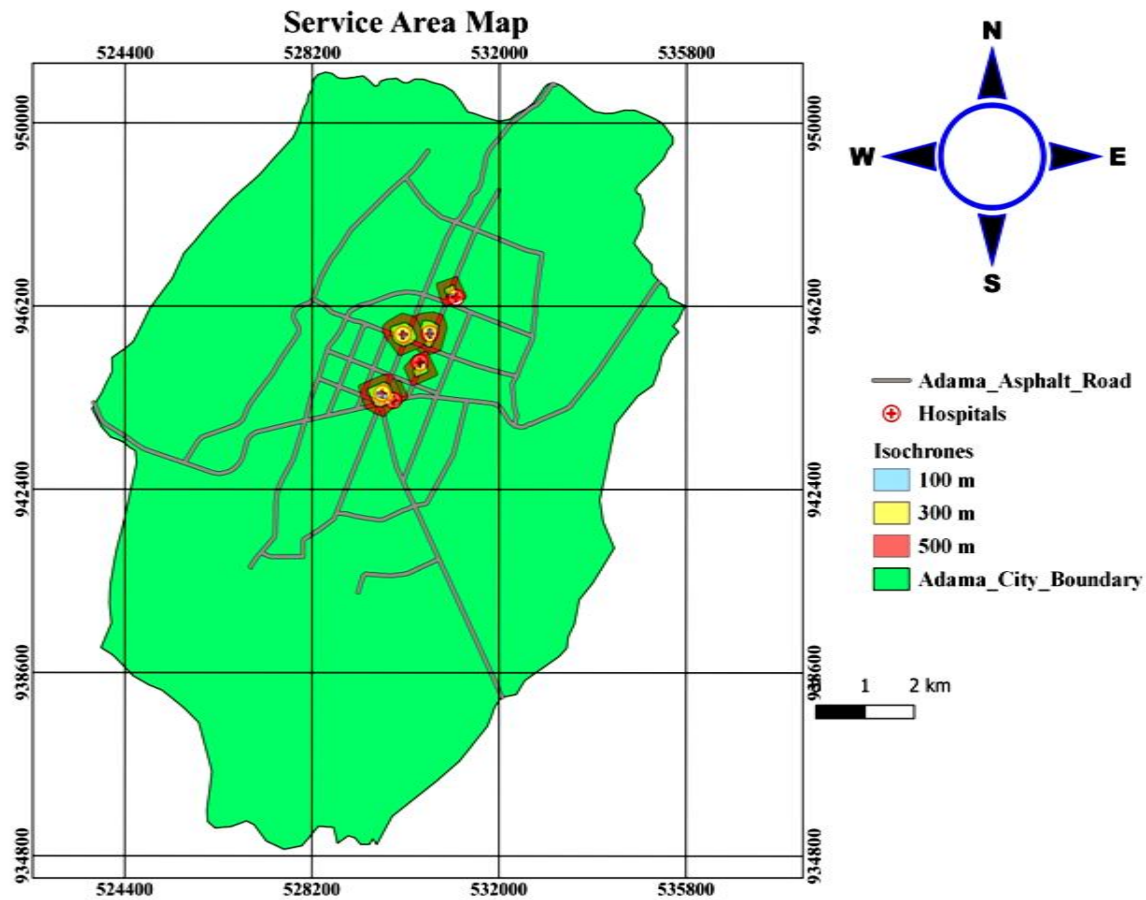


Figure 5.13.: Service area coverage for a facility of hospitals in Adama city

In the below Fig 5.12, the analysis is done using the impedance travel time by walking for specific facilities namely hospitals using three different default breaks; 15 minutes, 25 minutes, 35 minutes and 60 minutes impedances. Thus, it (the polygon) illustrates that facilities (hospital) serve that much the area within a 15-minute travel time by walking, which is designated by the blue polygon or a person at the hospital, can have such a kind of services within 15 minutes' travel time by walking. The other one is that 25 minutes' travel time by walk, which means these facilities, can serve areas within 25 minutes travel time shown in this polygon, or a person in these areas (facilities) can get service within the polygon designated by green within 25 minutes and within 35 minutes for the polygon designated by yellow. The last one is within 60 minutes' travel time by walking (impedance), which means these facilities can service within the polygon designated by red within 60 minutes' travel time by walking.

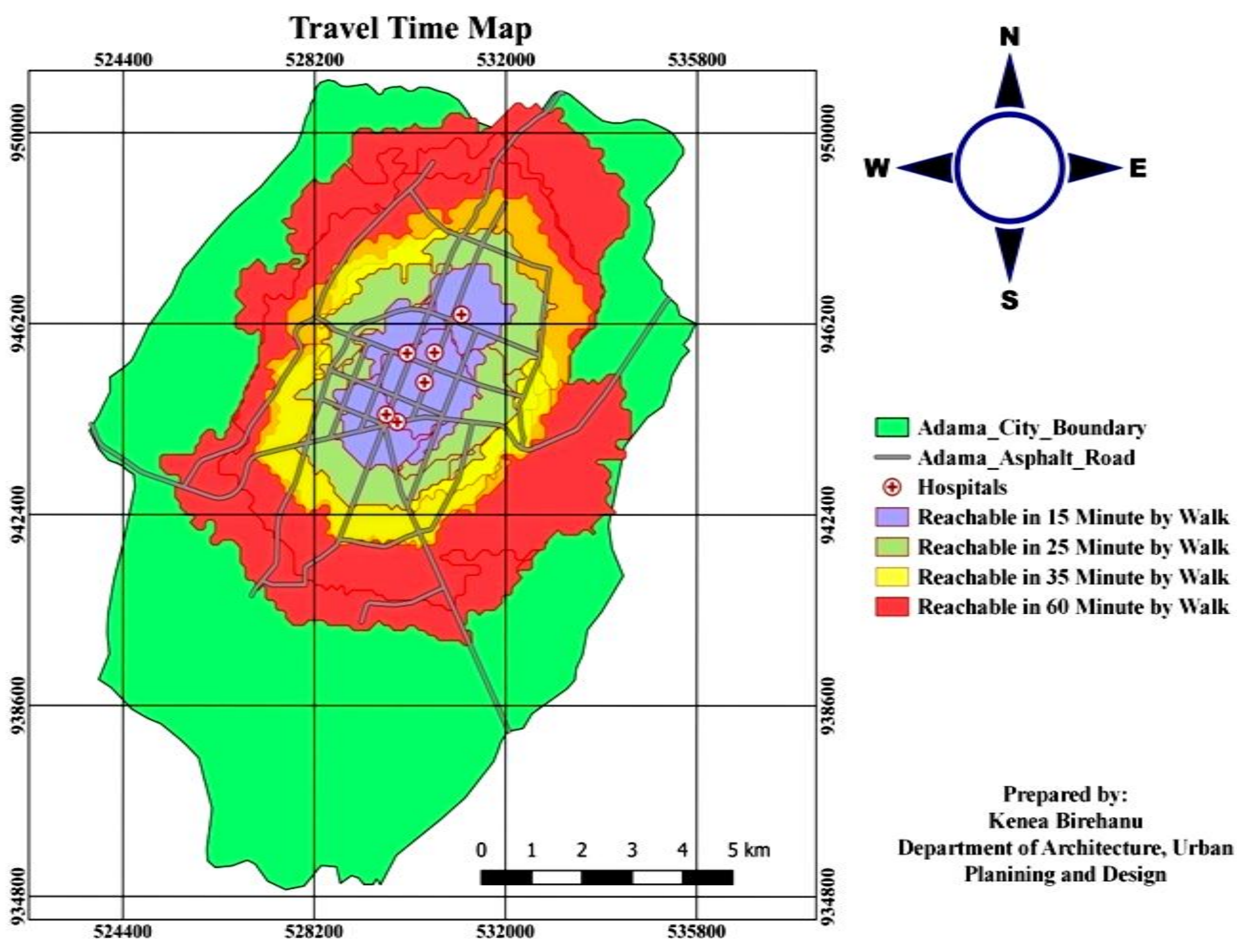


Figure 5.14: Service area coverage for a facility of hospitals in Adama city

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

In this study, GIS-based network analysis was implemented and applied to the Adama city road network. It focuses on the analysis of road network performance, finding the optimal route between two locations on the road network and specific distance, the closest facility from a given incident; this also is based on distance as impedance and a service area for a given facility which is based on travel time as impedance.

Generally for the purposes of this project, distance is taken as the impedance in order to find the best route and the closest facility and travel time is taken as the impedance in order to find the service area. A Geographical Information System (GIS), which is a network analyst, determined the best route, the closest facility and the service area. Data used by this project included public data and data generated using a Global Positioning System (GPS). Once the analysis was completed, a route representing (the best route) the shortest travel distance, the route representing the closest facility and the polygons representing the service area were developed. Moreover maintaining existing roads and building new ones are challenges for any growing municipality. Without coordinated digital tools for planning, scheduling, and performing work. Status reporting was activity based and did not address asset-based accounting or inventory. In this context, the inherent capabilities of the technology offered in a GIS were looked upon as one having a great potential to successfully cater to the specified requirements.

A project for utilizing it to develop a Road Information and Management System was conceptualized with the objective of creating a region (Adama city) wide, up-to-date database of roads that would induce efficiency and accuracy in monitoring, management, planning and subsequent development of the road network (road transport network). The application which was developed has shown that multiple linear referencing can be accomplished using GIS capabilities. The application is practical to implement and may be used to support additional analysis capabilities which rely on multiple location referencing. We have different tables that explain the status of the road, the facilities for the traffic system and related information. These tables relate to each other systematically using relational database.

A coalition of maps to a uniform scale base was accomplished while registering it to a common projection system in a GIS. The updated spatial data layers, which included road network, administrative boundaries and GPS readings (Points) as well as collected information from the field by observation was put into a GIS (geo database) for further processing that included meter-wise dynamic segmentation.

Commonly segments of road in the network are identified solely by a descriptive name. Additionally, locations along road segments are determined not by absolute location but by a relative method of addressing or local names. Street names and addresses have become integrally related attributes for virtually all road networks. Additionally, under the present study, the roads of Adama city are segmented and linearly referenced using linear referencing. All these are done by creating a geo database.

Finally, the quality checking of the spatial data is done to ensure accuracy. Discrepancies were removed by proper editing (topology). By querying different road entities as per the duty (interest) what will be done by the road authority it is possible to have a good result.

From this point forward the Adama City Road Authority can make use of this integrated database for the maintenance of the roads of Adama city, for the standing of traffic signposts, guideposts, traffic lights and other entities related to the road. Therefore, it eases the works of transport and road authorities. Thus the whole transport and road information should be put in this way to ease, facilitate and simplify access to data and change of information (if any) for everybody who has no knowledge of GIS for ease of use. Doing so is supposed to save time,and resources and above all enhances the work efficiency of the road authority crew.

On the other hand this study assessed the road network performance of Adama city. An effective evaluation of transportation network efficiency/performance is essential to the establishment of sustainable development in any transportation system. Based on a definition of transportation network efficiency, a quantitative efficiency evaluation method for the road transportation network is proposed, which could reflect the effects of the existing road network structure of Adama city.

One of the objectives of measuring road network performance was to identify the existing road network efficiency and provide information on the prevailing road network structure and the demand for travel in the area. In this particular project, the researcher evaluated the existing road network structure to estimate its efficiency and ultimately determine the level of infrastructure that is required to support economic and social activity in the study area. Furthermore, the road network performance was calculated using some road network performance indicators.

Based on the result of this study, it is observed that higher road transport infrastructure is exhibited in some areas of the city. These areas are having common characteristic except population number. They are commonly characterized by important socio-economic activities of the entire city including Bus stations, shopping, employment centers and higher educational institutions.

The road density, expressed by the length per area is found to be high in the central area of the city. As well as, the road length per unit of person in the west, north and southern areas is observed low. Proximity to the road network within the central area is not more than 100m, which allows more people to access those road networks found in the area.

However, in the outskirts, people have to travel more than 1km to access the existing road infrastructure, indicating the inadequacy of the system. This result indicates the inadequacy of the road network in those areas. This study focused on calculating the service area for a specific facility using travel time as an impedance to demonstrate the application of network analysis. The overall conclusion obtained from the indicators shows that there is less road infrastructure in the peripheral regions of the city and the central area had a capacity limitation. In general, the public transport demand in Adama city was not balanced concerning several vehicles, which served the existing travel demand of the city.

6.2. Recommendations

Based on the result of the study, the current road network of Adama city is evaluated and identified inadequate road network which needs further development and improvement. The indicators used in this research consider distance as impedance and travel time. Population density is considered while computing corridor and zonal (city) statistics to identify inadequate road networks. This opens an opportunity for further studies.

Based on the result of this study, the following issues are recommended:

- The master plan development of Adama city (2018) shows, the peripheral areas are reserved for further extension of industrial and residential land use, but in these areas, the road network is not well developed, which created obstacles to the mobility of people.

Even though road network development was planned in these areas, it is not implemented due to unknown reasons. Therefore, actions have to be taken by the city road authority, to upgrade and construct a new road network that has lower road density areas such as northern, southern and western parts of the city, because the population and socio-economic activities in the study area are changing dynamically.

- More attention is given to diverting the traffic flow from the central areas to the peripheral areas by constructing new links or upgrading the existing roads. This eases the traffic load in the central areas but since the peripheral areas have long distances, the network is not efficient with respect to cost (considering distance as cost).
- Despite the availability of a road network in the central areas, the performance is poor. Thus to improve the performance of the road network in order to meet the mobility demand, the existing roads should have been upgraded and maintained to hold large capacity.
- Accessibility can be improved not only by increasing vehicle flow and personal mobility, but also by increasing land use clustering and mix, improving walk ability. So for better road transport accessibility in the study area, increasing the land use of the road network is essential.
- This study's results can be used as base information for the urban planner, land administration and management office, and environmental protection office, to investigate the impacts of land-use land-cover change and urban expansion to transport natural resources, and land resources management in the future.
- Furthermore, based on the leaner referencing model of this research by including and merging other entities that are not taken into consideration in this project, it is possible to produce a better result. Therefore, if this is done at the city level, organizations like that the Adama city road authority at large and other institutions that need such a kind of integrated information are more beneficiary from the result. The decision-making process of these institutions facilitates and they will have up-to date and well-organized information.

Reference

Abate, A. D. (2007). Analyzing public transport performance using efficiency Measures and spatial analysis: the case of Addis Ababa, ITC, and Enscheda

AUSTROADS (2002), Integrated asset management guidelines for road networks, Austroads Incorporated, Sydney, Australia.

Baradaran and Ramjerdi, (2001), "Performance of Accessibility Measures in Europe", Beuro of Transportation Statistics, journal of transportation and Statistics.

Cafiso, S., La Cava, G., and Montella, A. (2007), Safety lndex for Evaluation of Two-Lane Rural Highways, Transportation Research Record: Journal of the Transportation Research Board, 136-145.

Cardoso, J., Stefan, C., Sørensen, M., and Elvik, R. (2007), Road Safety Inspections: best practice and implementation plan, Deliverable D2 of the RIPCoRD-ISEREST project, European Commission, Brussels,

Demsar U., Spatenkova O. & Virrantus K. (2008) Identifying Critical Locations in a Spatial Network with Graph Theory, Transactions in GIS, Volume 12, Issue 1, pp 61–82.

Derrible S. & Kennedy C. (2009) Network Analysis of World Subway Systems Using Updated Graph Theory, Transportation Research Record: Journal of the Transportation Research Board, No. 2112, Washington, D.C, pp. 17–25. DOI: 10.3141/2112-03.

Durdin, P. and Janssen, K. (2012), "SafetyNET – Breathing Life into Road Safety Analysis", Australasian Road Safety Research, Policing and Education Conference, 4-6 October 2012, Wellington, New Zealand.

El-adaway, I. H., Abotaleb, I. S. & Vechan, E. (2017) Social Network Analysis Approach for Improved Transportation Planning, Journal of Infrastructure Systems, Volume 23, Issue 2, ASCE, ISSN 1076-0342

Elvik, R. (2010), Assessment and applicability of road safety management evaluation tools: Current practice and state-of-the-art in Europe, Institute of Transport Economics (TØI), Oslo.

Erath, A. Lochl, M. & Axhausen, K. W. (2009) Graph-Theoretical Analysis of the Swiss Road and Railway Networks Over Time, The Evolution of Transportation Network Infrastructure, Volume 9, pp 379-400, DOI 10.1007/s11067-008-9074-7.

European Commission (2008), Directive 2008/96/EC of the European Parliament and of the Council of 19 November 2008 on Road Infrastructure Safety Management, Brussels.

European Transport Safety Council, ETSC (2001), Transport safety performance indicators, Brussels, ISBN: 90-76024-11-1.

EuroRAP (2014), EuroRAP Risk Mapping, http://www.eurorap.org/protocols/risk-mapping

Ganneau, F. and Lemke, K. (2008), "Network safety management - from case study to application". Route Roads, n.338, PIARC.

Geus, K.T., & J.R, R. V. E. (2011). Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transportation scenarios, and related social and economic impacts

Gwilliam, K., & Kenneth, M. (2002). Cities on the move: a World Bank urban transport strategy review

Hackl, J. & Adey, B. T. (2019) Estimation of traffic flow changes using networks in networks approaches, Journal of Applied Network Science, Volume 4, Issue 28, pp 1-26.

Hakkert, A.S and Gitelman, V. (Eds.) (2007), Road Safety Performance Indicators: Manual, Deliverable D3.8 of the EU FP6 project SafetyNet, Loughborough University

Hamidov, S. I. (2019) Applying Graph Theory to Some Problems of Economic Dynamics, Discrete Dynamics in Nature and Society, Volume 2019, DOI: 10.1155/2019/7974381.

Huang A., and Levinson, D. (2011). "Accessibility, network structure, and consumers destination choice: a GIS analysis of GPS travel data." University of Minnesota: Nexus Research Group, Working Papers

International Road Assessment Programme (iRAP) (2013), iRAP website, www.irap.org (accessed on 25 June 2013).

Jiang, B. & Claramunt, C. (2004) A structural approach to the model generalization of an urban street network, Journal of GeoInformatics, Volume 8, Issue 2, pp 157-171.

Kansky, K. J. (1963) Structure of Transportation Networks: Relationship between Network Geometry and Regional Characteristics.

Kuhn, B.T., Jasek, D., Carson, J., Theiss, L., Songchitruksa, P., Perkins, J., Yang, Y., and Mwakalong, J. (2011), Research on asset management for safety and operations, Technical Report: FHWA/TX-12/0-6390-1, Texas Transportation Institute

Liu, S., & X. (2004). Accessibility Analyst: an integrated GIS tool for accessibility analysis in urban transportation planning. ENVIRONMENT AND PLANNIG B, 31, 105-124

Ljung, M. (2002), DREAM: Driving Reliability and Error Analysis Method, Master's thesis, from University of Linköping's Web site, http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-2033 (accessed 10 December 2007)

Lynam, D. (2012), Development of Risk Models for the Road Assessment Programme, TRL Report CPR 1293, iRAP and TRL, www.irap.org and www.trl.co.uk.

Mishra, S., Welch, T. F. & Jha, M. K. (2012) Performance indicators for public transit connectivity in multi-modal transportation networks, Transportation Research Part A Policy and Practice, Volume 46, Issue 7.

Modarres, M. & Zarei, B. (2002) Application of Network Theory and AHP in Urban Transportation to Minimize Earthquake Damages, Journal of the Operational Research Society, Volume 53, Issue 12, pp 1308-1316.

Newman, M. E. J. (2005) A measure of betweeness centrality based on random walks, Social Networks, Volume 27, pp 39-54.

Organization for Economic Co-Operation and Development (OECD) / International Transport Forum (ITF) (2008), Towards Zero Ambitious Road Safety Targets and the Safe System Approach: Ambitious Road Safety Targets and the Safe System Approach, OECD Publishing

Perandones, J.M., and Ramos, G. (2008), Road Safety Index. Ranking for European road safety, specific targeted research or innovation project, TREN-04-FP6TR-S07.36996/001678-Final Report D4.2.

Persaud B., Lord D. and Palmisano J (2002), Calibration and Transferability of Accident Prediction models for Urban Intersections, Transportation Research Record 1784, Paper No. 02-3293.– Addendum", FHWA.

20inspection%20guideline%20for%20safety 20checks%20of 20existing 2 0 roads.htm .

Rashidy, E. L., Ahmed, R. & Susan, G. M. (2014) A network mobility indicator using a fuzzy logic approach. In: TRB 93rd Annual Meeting Compendium of Papers. Transportation Research Board, Washington, pp. 114.

Ravulaparthy, S. K. & Goulias, K. G. (2014) Characterizing the Composition of Economic Activities in Central Locations: Graph-Theoretic Approach to Urban Network Analysis, Journal of the Transportation Research Board, No. 2430, Transportation Research Board of the National Academies, Washington, D.C., 2014, pp. 95–104

Rodrigue, J. P., Comtois, C. & Slack, B. (2017) the Geography of Transport Systems, Routledge, Taylor and Francis Group.

Saberi, M., Mahmassani, H. S., Brockmann, D. & Hosseini, A. (2017) A complex network perspective for characterizing urban travel demand patterns: graph theoretical analysis of largescale origin–destination demand networks, Journal of Transportation, Volume 44, pp 1383-1402, DOI 10.1007/s11116-016-9706-6.

Song, Q. & Wang, X. (2011) Efficient Routing on Large Road Networks Using Hierarchical Communities, Transactions on Intelligent Transportation Systems, Volume 12, Issue 1, pp 132- 140.

Tanuja, S. Ivan, W. H. & Chi, K. T. (2018) Spatial analysis of bus transport networks using network theory, Physica A, Volume 502, pp 295-314.

Unsalan, C. & Sirmacek, B. (2012) Road Network Detection Using Probabilistic and Graph Theoretical Methods, Transactions on Geoscience and Remote Sensing, Volume 50, Issue 11.

Yannis, G., Weijermars, W., Gitelman, V., Vis, M., Chaziris, A., Papadimitriou, E., and Azevedo, C. L. (2013), "Road safety performance indicators for the interurban road network". Accident Analysis & Prevention, 60, 384-395.

Yetnayet, B. (2012). Evaluation of transportation network structure of Addis Ababa. The Netherlands, University of Twenty, Specialization: Geo-informatics

Yonca Aydin, N., Duzgun, H. S., Wenzel, F. & Heinimann, H. R. (2018) Integration of stress testing with graph theory to assess the resilience of urban road networks under seismic hazards, Journal of Natural Hazards, Volume 91, pp 37-68.

Zhang, L., Qin, J., He, Y., Ye, Y. & Ni, L. (2015) Network-level optimization method for road network maintenance programming based on network efficiency, Journal of Central South University, Volume 22, pp 4882-4889