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**ADDIS ABABA UNIVERSITY**

**ADDIS ABABA INSTITUTE OF TECHNOLOGY**

**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**MSc. Geodesy and Geomatics Program**

**(Specialization in Geomatics)**

**Assessment of New (Bus Route) Road Accessibility for Public  
Transportation Using GIS in Addis Ababa, Ethiopia**

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**A Thesis Submitted to The School of Graduate Studies of Addis Ababa  
University, in partial fulfillment of the requirements for the Degree of  
Master of Science in Geodesy and Geomatics program (Specialization in  
Geomatics)**

**Addis Ababa, Ethiopia**

**March, 2025**

## DECLARATION

I certify that the research work titled “Assessment of New (Bus Route) Road Accessibility for Public Transportation Using GIS in Addis Ababa, Ethiopia” is my work. The work has not been presented elsewhere for assessment. Where material has been used from other sources, it has been properly acknowledged/referred.

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## ABSTRACT

*Public transport is one of the social facilities since moving from place to place is vital. The transport sector plays an essential role in the country's overall movement, the people and goods mainly depend on transport, and providing adequate and proper public bus service is vital in a town like Addis Ababa. It isn't easy to find suitable routes for new transport infrastructure. Still, there are routes available to be used, notwithstanding the Addis Ababa City Bus Service Enterprise (AACBSE) did not access these new routes as part of the schedules from origin to destination. The objective of this paper is to locate new bus stop areas for the new roads that were not accessible by the public transport service. This paper emphasizes showing these available bus stop areas to be used as part of the AACBSE schedule. This thesis uses Geographic Information Systems (GIS) for spatial analysis by managing data spatially to assess existing accessibility. This study's parameters to evaluate the accessibility index are road density, population served, and a 400-meter Bus Stop buffer. Out of 21 roads constructed since 2020, six roads are not accessible by public transport and not suitable areas for a new bus stop. It is highly recommended that the remaining fifteen roads are not accessible by public transportation and are suitable bus stop areas be used by AACBSE where the new roads will increase accessibility for public users. AACBSE where the new roads will increase accessibility for public users.*

***Keywords:*** Road Accessibility, GIS, Suitability, Bus stop station

## ACKNOWLEDGMENTS

At first, all praise belongs to Almighty GOD, the most merciful, the most beneficent for giving me the ability to complete the study.

I am pleased to acknowledge my deepest gratitude to my advisor, Hamere Yohannes (Ph.D.), Center for Environmental Science Studies at Addis Ababa University, for her continued follow-up, guidance, and prompt comments on my drafts up to the final output.

Then my next gratitude goes to my friend and classmate Manyahelushal Dawit for her unconditional support and advice on this thesis. She has been a driving force when I was really tired since I was pregnant with my third child.

I also express my special thanks to all government offices at AACRA, AACBSE, AACTA, Addis Ababa Land Holding Registration and Information Agency, and CSA that provided me with all the documents I needed for this thesis.

Finally, I would love to thank my dear husband for believing in me, following up on the kids when I could not, and supporting me to continue my education even if we had so many things to pay for; he was very excited that I could get my MSc. I also thank my kids for being patient when they need me the most.

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## LIST ABBREVIATIONS

AACBSE.....	Addis Ababa City Bus Service Enterprise
AACRA.....	Addis Ababa City Road Authority
AACTA.....	Addis Ababa City Transport Authority
AAiT.....	Addis Ababa Institute of Technology
ACBSE.....	Anbessa City Bus Service Enterprise
CSA.....	Central Statistics Agency
DEM.....	Digital Elevation Model
G.I. S.....	Geographical Information System
L.O.S.....	Level of Service

## CHAPTER 1

### 1. INTRODUCTION

#### 1.1 Background of the Study

A city's public transportation system is the backbone of a city and one of the major contributors to the mobility of people in the city. Mass transport facilitates efficient mobility of society in any city with less cost in the developed world. It provides a versatile form of public transportation with the flexibility to serve an unlimited range of various access needs, and unlimited locations throughout a metropolitan area (Berlin and Borndörfer, 2009). The purpose of transportation is to overcome space, human, and physical constraints such as distance, time, administrative divisions, and topography. Urban transportation is thus associated with a spatial form that varies according to the modes used (Rodrigue, Jean-Paul, Comtois, Claude, Slack, 2012). And also, one of the main transportation in Addis Ababa is public transport.

Abate (2007), reported that the Anbesa city bus service needs spatial analysis that considers bus stops for the missing corridors, stops, and other network elements since the users spend more time and money traveling. The existing Addis Ababa transportation network structure is evaluated with network indicators concerning travel demand & and the structure of network supply (BOGALE, 2012). On the other hand (Dawd, 2020) specifically studied the accessibility of Anbessa Bus Service in the Yeka sub-city of Addis Ababa. Kinnnear Susan, Kenea Kelbesa (2017), reported that the accessibility of city bus services is poor due to the inefficient performance of stakeholders & and poor transport operation system.

This paper is concerned with the new roads inaugurated by the client AACRA but the city's public buses do not use them and some roads are not used by city buses. AACBSE does not utilize this newly inaugurated road and also some roads. If we can study the accessibility of the bus stops near the new roads and if the new roads need new bus stops providing the best location for the accessibility of the road, then long and time-consuming trips to mobilize in the city will be minimized.

## 1.2 Statement of the Problem

The capital city of Ethiopia, Addis Ababa is one of the fastest growing cities in the world, yet it is constrained by poor accessibility of City Bus Services due to inadequate infrastructure, poor transport operation, and ineffective performance of stakeholders which resulted in inaccessible service to the users (Kinnear Susan, Kenea Kelbesa, 2017).

The accessibility of bus stops in the Yeka sub-city is studied (Dawd, 2020) but it is limited to one sub-city and shows the existing bus stop accessibility only. The other researcher (BOGALE, 2012) evaluated the road network structure of Addis Ababa but it can't show the existing roads inaugurated and done after 2012 which the research is concerned with. On the other hand (Abate, 2007) evaluated the efficiency of public transport service by using spatial analysis which is concerned with only the existing roads but the concentration of this paper will emphasize showing these available time-saving routes as part of the AACBSE schedule.

The mobility of people from one place to another these days has become time-consuming and spend more money on transportation in Addis Ababa due to the limited extent of buses in Anbesa (Abate, 2007). This paper is concerned with the new roads inaugurated by the client AACRA but the city's public buses do not use them. AACBSE does not utilize this newly inaugurated road. If we can study the accessibility of the bus stops near the new roads and if the new roads need a new bus stop providing the best location for the accessibility of the road, then long and time-consuming trips to mobilize in the city will be minimized.

This study is focused on the accessibility of existing bus stops around new roads and some roads that are not included as routes of public transport with their location and standard stop spacing and determine the optimal location of bus stops to ensure bus service accessibility. In the current study, the parameters to evaluate the accessibility index are road density, trip generation, and population served. Therefore, evaluating the accessibility of existing bus stops is important to identify the spatial information of bus stop locations and determine the optimal locations of bus stops on the roads that are not accessible with AACBSE.

### **1.3 The objective of the Research and Question**

#### **1.3.1 Main Objective**

The thesis's general objective is to study the accessibility of the existing bus stop and identify new bus route and design new bus stop which is accessible for the new bus route.

#### **1.3.2 Specific Objective**

1. To evaluate the accessibility of the existing bus stops around the new roads.
2. Identify new bus route
3. Design new bus stop that is accessible by the new bus route (i.e the routes that access the new roads that have not been used by public transport especially AACBSE)

#### **1.3.3 Research Questions**

1. To evaluate the accessibility of the existing bus stops around the new roads.
  - ✓ How many routes of the road are available to be accessed by AACBSE?
  - ✓ Which factors are essential to consider the best location for bus stops?
2. Provide new routes and best bus stop locations for the roads that have not been used.
  - ✓ Where could be the best location of bus stops for the selected new route?

### **1.4 Significance of Study**

This research tries to emphasize the Addis Ababa roads that have not been used by public transport, especially the AACBSE. The main significance of this study lies in its potential urban mobility, reduce congestion, and enhance accessibility for vulnerable population in Addis Ababa. The roads that have not been used for public transport, can minimize travel time, money and increase the accessibility of the AACBSE for the public users. This study can also be used to facilitate decision makers that can have a lasting impact on the city's public transportation system in the city and also it provides long term assessment of how new bus routes can fit into the city's growth which include improved connectivity, expanded public transport system, and enhancing sustainable urban development.

This study will fill a gap in the existing body of knowledge about Addis Ababa public transport planning, particularly in terms of the applications of GIS. It also promote the use of Geographic

information system (GIS) as powerful tool in planning transportation. By using GIS for the assessment of new bus routes, the study will help decision-makers to adopt evidence-based, data-driven approaches to optimize public transport routes and network design. The study will contribute to enhance public transportation access for underserved and vulnerable population, including low-income communities, the elderly and people with disabilities by evaluating road accessibility, and help identify gaps in existing bus network and purpose new routes that can better serve these groups.

### **1.5 Scope**

This research attempts to study the public transportation accessibility, especially Addis Ababa City Bus Service Enterprise especially around the newly constructed roads after 2020.

### **1.6 Delimitation**

This research only focuses on Addis Ababa City Bus Service Enterprise as the only public transportation next to Public Service Employee's Transport Service Enterprise (PSETSE), because Sheger Mass Transport Service Enterprise and ACBSE are merged. It also will not consider the contribution and effect of service provided by blue taxis, higher buses, supporting transport systems such as ISUZI buses, motor or three-tire (Bajaj) Bus Rapid Transit, Light Rail transit, and private transportation such as RIDE, FERES, ZAY RIDE, etc.

### **1.7 Thesis Structure**

The overall thesis is organized under five chapters as follows, Introduction, Literature review, Methodology, Result and Discussion, and Conclusion and Recommendations.

Chapter 1: explains the necessity of the background of the study and states the problems, Research question, objectives of the study, scope of the study, and limitations of study.

Chapter 2: a literature review was carried out to have a clear understanding of the study. The chapter briefly reviews the list of the literature that is reviewed to develop the concepts.

Chapter 3: describes the study area, and all methodology of the study that denoted step by step procedure following which the study was conducted. In this section, the data collection, processing, and analysis techniques will be elaborated and the procedures of data analysis will be briefly discussed.

Chapter 4: Results and Discussions

Chapter 5: Conclusion and Recommendation includes the recommendations that are stated considering the findings of the study and finally the conclusion which is drawn through the whole research.

## CHAPTER 2

### 2. LITERATURE REVIEW

#### 2.1 Introduction

Addis Ababa, the capital of Ethiopia, has witnessed rapid urbanization and population growth in recent years, leading to increased pressure on the city's public transportation system. The demand for efficient, accessible, and affordable public transport is growing, with the need for new bus routes to address gaps in service and improve mobility across the city. Geographic Information Systems (GIS) have proven to be an effective tool for assessing road accessibility, optimizing routes, and improving service delivery in public transport systems. The availability of road infrastructure affects the business activities, living quality, economy, and business for a region. Transportation plays an essential role in developing countries like Ethiopia because it gives access to markets, schools, health centers, and so on. It facilitates mobility in urban areas and improves quality of life (Gwilliam, 2002).

According to (*Dictionary.com*, 2022) the dictionary online route is defined as, a course way, or road for passage or travel while a transport route is a way from one place to another. Due to the limited extent of the Anbessa bus, insufficiency of the public bus route network, and the deficiency of Anbessa service people spend more time and money on travel as (Abate, 2007) reported in Addis Ababa.

Accessibility in public transportation is a crucial element for sustainable urban mobility, particularly in rapidly urbanizing cities like Addis Ababa, the capital of Ethiopia. Geographic Information Systems (GIS) offer powerful tools for spatial analysis and have been used globally to study and improve transportation accessibility. In this study, the current transportation accessibility will be evaluated by using GIS tools to locate suitable sites for new bus stop locations for the new roads of Addis Ababa, and the literature review is organized in such a way that; it first briefly reviews transport accessibility, second accessibility measures, third part reviews the factors that affect accessibility and the fourth part explains how the bus stop accessibility is estimated.

## **2.2 Accessibility Concepts**

As (Ross, 2000) defined accessibility, “The ease of reaching some destination, and include real or perceived costs in terms of time or money, distance traveled, level of comfort, availability, and reliability of public transport, or combination of these”. Accessibility is defined according to (Curl, Nelson, and Anable, 2011) as the ability of people to access a destination. (BOGALE, 2012) reported that the road length per area and road length per unit population indicate the accessibility of the road network which is important in the context of Addis Ababa where the transport infrastructure affects the accessibility of the road network.

Accessibility for public transport is significant due to it is the default means of travel for the public. According to (Rodrigue, Jean-Paul, Comtois, Claude, and Slack, 2012), accessibility is the measure of the capacity of a location to be reached from, or to be reached by, different locations, that the capacity and arrangement of transport infrastructure are key elements in the determination of accessibility. According to (Iles, 2005), accessibility is described in terms of the distance passengers have to walk from their home to the bus stop.

According to (Litman, 2021) it is mentioned that when people say “location” they mean “accessibility”. It also says that accessibility refers to people’s overall ability to reach desired services and activities (together called opportunities), and therefore the time and money that people and businesses must devote to transportation.

Since transport is a critical component that can impact the economic and social development of the society and the major means of transport in Ethiopia is road, alternative routes from various directions should be studied. This is because transport options are very limited and unattractive to the users (Verseckiene, Meškauskas and Batarliene, 2016),(Molla, 2017).

## **2.3 Transportation Demand of Addis Ababa**

### **2.3.1 Public Transport in Addis Ababa**

Addis Ababa’s public transportation system is primarily composed of buses, taxis, and the Addis Ababa Light Rail (AALRT). Buses are the most common mode of transport,

operated by the Addis Ababa City Bus Enterprise (AACBE), although they face challenges like overcrowding, inadequate coverage, and inefficient scheduling. Additionally, informal transport services, such as minibuses and taxis, supplement the formal system, often resulting in uncoordinated, fragmented service (Mekonnen, D., Aderaw, Z., & Tadesse, 2017)

The expansion of the road network, including new routes to underserved neighborhoods, is essential to ensure equitable access to public transportation. New bus routes in areas that are either under-served or not served at all could alleviate congestion, improve access to economic and social opportunities, and enhance overall mobility for residents, particularly in peripheral and rapidly urbanizing areas (Abebe, A., & Teshome, 2018).

From the interview of the Addis Ababa City Bus Service Enterprise (AACBSE) manager which was formerly called ACBSE which is now merged with the Sheger Mass Transport Service Enterprise in January 2023. They are merged because providing the same service but use different fuel depots, exchange centers, and human resources which results in a huge waste of resources. They are now integrated buses that allow the provision of smooth transportation by avoiding unnecessary duplication of the transportation services on the same route in the city. Therefore, Anbesa and Sheger buses which were providing fragmented manner have been merged into Addis Ababa City Bus Service Enterprise.

Currently, there are 1,150 buses after the two governmental enterprises joined together as AACBSE. As the data attached in Annex 1, the enterprise is serving 131 limited routes and accesses around 600,000 people daily but the service from the total population indicated that few number of populations could get service by bus and still the demand is high with limited supply.

There are 4 Bus Depots where the buses are distributed, early in the morning and during pick hours, namely Yeka depot, Shegole depot, Mekanisa depot, and Semit depot among which the first three were previously Anbesa bus depot while Semit depot was Sheger bus depot.

From the total of 1,150 buses, 756 buses have fixed service numbers while 394 buses are new express buses without fixed service numbers but helping on pick hours the regular bus services. For example, service number 119 goes from Megenagna to Semit with

regular 4 buses, where the 2 start from Yeka depot and 2 from Semit depot, on the route but 10 additional Express buses help on pick hours that 4 are from Yeka depo and 6 from Semit depot.

Attached in Annex 2 is the 1<sup>st</sup> half-year performance report from Sene 21, 2015E.C to Tahisas 20, 2015 shows that before the merge shows that there were 503 Anbesa buses available on average with 954,999 trips serving 96,088,672 people and get total income of 407,616,166 birr.

The density of roads, which is the ratio of the country's total road network to the country's land area, for the 3,820,000 total population of Addis Ababa, is not enough to cover the demand for transportation.

## **2.4 Accessibility of Transportation in Addis Ababa**

According to the Ethiopian Non-Motorized Transport Strategy 2020-2029 (Transport FDRE, 2020), accessibility is defined as facilities offered to people to reach social and economic opportunities, measured in terms of the time, money, comfort, and safety that is associated with reaching such opportunities. The strategy also states that transport investments will prioritize modes used by lower-income groups, including walking, cycling, and public transport, and road space will be allocated equitably to facilitate safe access through these modes and the public transportation is targeted to have 80% of motorized trips in the ten-year target which intern control private vehicle use and reduce greenhouse gas emissions.

There are different relevant constraints to consider for determining accessibility. The constraints that are relevant according to (Litman, 2021) are considered to be relevant in determining accessibility are:

- I. Transportation Constraints: – circumstances behavior by limiting the distances individuals can travel within a particular period using available transportation system (mode, routing timing cost, etc.)
- II. Temporal Constraints: - determines when, and how long an individual must join other individuals (objects) to participate in production, consumption, social and

other miscellaneous activities. Generally, temporal constraints are a subset of coupling constraints.

- III. Spatial Constraints: - determines the availability of activities within geographical areas and the locations of specific activities in which individuals participate.
- IV. Economic, social, and cultural aspects: - determines who has or has no access to specific activities at specific times as a result of cultural rules, laws, income levels, gender, and social relationships.
- V. Coupling Constraints: - that fix individuals at a point in space for some time.

The other authors (Jennaro B Odoki, Henry R. Kerali, 2001) considered the components of accessibility to are

- a. trip coverage - travelers would consider public transit accessible when it is available to and from their trip origins/ destinations,
- b. spatial coverage - travelers would consider public transit accessible when it is within reasonable physical proximity to their home/destination, and
- c. Temporal coverage - a service is accessible when service is available at times that one wants to travel. Spatial accessibility i.e., walking distance and walking time is only considered for the present research work.

## 2.5 Factors Affecting Accessibility

Several factors affect accessibility. According to (Litman, 2021) the following list of factors are described for more comprehensive planning.

**Table 2-1: Summary of factors affecting accessibility**

Name	Description	Current Consideration	Improvements
Transport Demand	The amount of mobility and access that people would choose in specific conditions	Motorized travel demand is well-measured, but other modes are not	More Comprehensive travel surveys, statistics, and analysis of travel demands.
Automobile travel	Automobile travel speeds, convenience, and affordability.	Often consider speed, delay, and parking convenience.	Consider other vehicle impacts including affordability and risk.

Transport system diversity (mobility options)	The quality (speed, convenience, comfort, safety, etc.) of transport walking, bicycling, public transport, etc.	Some models apply multimodal L.O.S analysis, but many factors are often overloaded.	More multi-modal evaluation (speed, convenience, comfort, safety, etc.) of walking, bicycling, public transit, taxi and ride-hailing, etc.
Roadway network connectivity	The density of roadway connections and therefore the directness of travel between destinations.	Some models consider roadway connectivity impacts on accessibility	More comprehensive analysis of roadway connectivity
Transport network connectivity	The degree of integration among transport modes.	Connectivity for automobiles is well measured other modes are often overlooked.	More integrated analysis of connectivity among non-auto modes.
Proximity (Land Use Factors)	The distances between activities, and therefore development density and mix.	Usually considered in land use planning, but less in transport planning	More comprehensive analysis of land use accessibility
Mobility Substitutes	Telecommunications and delivery services that substitute for physical travel	Not usually considered in transport planning.	Consider mobility substitutes as part of the transport planning.
User information	Availability of reliable information on mobility and accessibility options.	Sometimes considered for particular modes or locations, but seldom comprehensive.	More comprehensive and integrated information to help users navigate transport systems
Affordability	The cost to users relative to their incomes	Automobile operating costs and transit fares are usually considered	A more comprehensive evaluation of transport costs relative to user's incomes.

## 2.6 Estimating Bus Stop Accessibility

According to Kaye, Capital, and Walton (2008), pedestrian access to bus stops is estimated using network analysis within a buffer of 400m access around the transit stop to identify its coverage area. From these researchers, the 400m walking distance and a mean walking speed between 80-90m/m were analyzed bus stop service area.

Additionally, there shall be actual road length and actual pedestrian road network measures the number of actual pedestrian road length that originates from the same bus stop to create the actual pedestrian road network.

In this paper, accessibility is studied regarding our country Ethiopia's capital city based on location and distance are going to be considered.

## 2.7 GIS Applications in Transportation planning

GIS is increasingly used in transportation planning to assess accessibility, optimize routes, and improve the efficiency of transport networks. The spatial capabilities of GIS allow planners to analyze transportation infrastructure, such as roads, bus routes, and transit stations, to ensure that new routes will effectively serve residents' mobility needs (Chien, S., Ding, Y., Wei, C., & Wei, 2002) ,(Liu, X., Liu, X., & Yang, 2017)

Key GIS applications in the context of public transport route accessibility include:

- **Network Analysis:** GIS can be used to assess the spatial distribution and accessibility of existing transport routes. By analyzing factors like proximity to public transport stops, road conditions, and travel time, planners can identify underserved areas and design more effective bus routes (Feng, Z., Chen, Z., Zhang, X., & Liu, 2018)
- **Accessibility Modeling:** GIS tools can measure the accessibility of various neighborhoods to existing or proposed bus routes by calculating the travel time or distance to the nearest bus stop or transit hub. This helps to determine which areas benefit from improved access to public transport (Shrestha, R., Pant, S., & Thapa, 2019)
- **Route Optimization:** GIS allows planners to identify the most efficient and accessible bus routes by modeling road networks and analyzing factors like traffic conditions, road capacity, and population density. The aim is to improve overall service coverage while minimizing operational costs (Chien, S., Ding, Y., Wei, C., & Wei, 2002).
- **Land Use and Demographic Analysis:** GIS can integrate data on land use and population distribution to evaluate how new bus routes will impact different

demographic groups, ensuring that vulnerable communities, such as low-income or elderly residents, are adequately served (Duan, Y., & Hwang, 2017)

### 2.7.1 Density Calculations using GIS

The density tool distributes a measured quantity of an input point layer throughout a landscape and produces a continuous surface. For example, for this study, there is a point value population over each sub-city representing the total number of sub-city. The density calculation tools used in ArcGIS can be done using available tools that are described in the following tool sets that can be seen from ArcGIS help are;

- a. Point Density (Spatial Analyst): this calculates a magnitude per area from point features that fall within a neighborhood around each cell and if no points fall within the neighborhood at a particular cell, that cell is assigned No Data.
- b. Line Density (Spatial Analyst): calculates a magnitude per unit area from polyline features that fall within a radius around each cell. The portion of a line within the neighborhood is considered when calculating the density and if no lines fall within the neighborhood at a particular cell, that cell is assigned No Data.
- c. Kernel Density (Spatial Analyst); this calculates a magnitude per unit area from polyline features using a kernel function to fit a smoothly tapered surface to each point/polyline.

The difference between the output of those two tools and that of Kernel Density (Spatial Analyst) is that in point and line density, a neighborhood is specified that calculates the density of the population around each output cell. Kernel density spreads the known quantity of the population for each point out from the point location. The resulting surfaces surrounding each point in kernel density are based on a quadratic formula with the highest value at the center of the surface (the point location) and tapering to zero at the search radius distance. For each output cell, the total number of the accumulated intersections of the individual spread surfaces is calculated.

In this study, the Kernel density calculation is used to calculate the density of road and population density using ArcGIS 10.8 from the inventory of road data found from AACRA and the total area of the city collected from Addis Ababa Land Holding Registration & Information Agency. The road density or road availability has unit  $m/m^2$ ,  $km/km^2$ ,  $mile/mile^2$  etc. This road density explains how dense the road network is.

## 2.8 Empirical Studies

Empirical studies have used GIS to map existing public transport routes in Addis Ababa, identifying gaps in the transportation network and proposing new routes to improve accessibility. The study by (Abebe, A., & Teshome, 2018) applied GIS to assess the accessibility of Addis Ababa's public transportation system, including bus routes. They used spatial analysis to map areas of the city that are underserved by public transport. This analysis revealed that while some central and high-density areas were well-served by buses, peripheral areas, particularly in rapidly urbanizing neighborhoods such as Kolfe Keranio, Gulele, and Nifas Silk, lacked adequate bus access. This finding suggests that new bus routes could provide critical access to underserved populations.

In their study, (Abebe, A., & Teshome, 2018) used GIS tools to analyze accessibility by measuring travel time and distance from residential areas to the nearest bus stops. This methodology allows planners to identify which neighborhoods would benefit most from new bus routes. Additionally, their findings suggested that integrating new routes that connect these underserved neighborhoods with the city center could significantly reduce travel times for residents.

GIS-based studies have also focused on assessing the walkability and ease of access to public transport stops in Addis Ababa. (Mekonnen, D., Aderaw, Z., & Tadesse, 2017) conducted a study that incorporated both GIS and pedestrian infrastructure analysis to assess accessibility in Addis Ababa. They used GIS to evaluate the walkability from residential areas to public transport stations, considering factors such as sidewalk availability, road safety, and overall connectivity.

The study highlighted significant challenges in accessibility, particularly in areas where there was a lack of pedestrian infrastructure. In such areas, residents face difficulty walking to bus stops, which hinders their access to public transportation. Their findings suggest that new bus routes in these areas would need to be paired with improvements in pedestrian infrastructure, such as sidewalks, crosswalks, and safe pedestrian crossings.

Empirical studies on GIS-based assessments of new bus route road accessibility in Addis Ababa highlight the potential of GIS for improving urban transport planning. The studies emphasize that GIS can help identify underserved areas, optimize bus routes, and integrate

public transport with informal transport services. However, challenges related to data quality, informal transport integration, and rapid urban growth remain.

## 2.9 Conceptual Framework

### 2.9.1 Elements of the conceptual framework

The first step involves collecting and preparing spatial data that are crucial for the GIS-based analysis of new bus routes. The following datasets are typically needed:

- ✓ Road Networks: Roads, streets, intersections, and transit corridors.
- ✓ Public Transport Stops: Locations of existing bus stops and terminals.
- ✓ Population Distribution: Demographic and population density data, highlighting areas with high demand for new public transport.
- ✓ Land Use Data: Information on commercial, residential, industrial, and institutional land use that might influence transport demand (e.g., proximity to key destinations such as schools, markets, hospitals, etc.).
- ✓ Traffic and Road Condition Data: Information on traffic volume, congestion levels, and road conditions to assess the feasibility of new routes and potential delays.
- ✓ Pedestrian Infrastructure: Data on sidewalks, pedestrian crossings, and accessibility features for the elderly and disabled.

Once the data is collected, GIS tools are used for several analytical purposes:

- ✓ Network Analysis: GIS can analyze the existing transportation network to understand its efficiency, identify gaps in coverage, and propose new routes. Network analysis tools assess factors like travel time, distance between bus stops, and the service area of each bus route (Liu, X., Liu, X., & Yang, 2017). The goal is to propose new routes that minimize travel time and serve high-demand areas.
- ✓ Accessibility Modeling: GIS-based accessibility models measure the ease of access to public transport, usually by calculating the distance or time it takes for residents to reach the nearest bus stop. These models use road networks and pedestrian walkways to simulate the accessibility of different neighborhoods. Accessibility is often measured in terms of a service area around bus stops, typically in walking distance (e.g., 500 meters) (Shrestha, R., Pant, S., & Thapa, 2019).

- ✓ Equity Analysis: GIS can perform spatial equity analysis by combining transport network data with demographic and socioeconomic data. The analysis determines whether new bus routes would serve vulnerable or underserved populations, such as low-income areas or neighborhoods with a high concentration of elderly people. Areas with limited access to public transportation are prioritized for new routes (Duan, Y., & Hwang, 2017)

## CHAPTER 3

### 3. METHODOLOGY

#### 3.1 Study Area Description

The capital city of Ethiopia, Addis Ababa with an altitude over 2300 meters above sea level and with coordinates  $9^{\circ}01'48''$  N and  $38^{\circ}44'24''$  E located in the central part of the country. Since 2021 the city has been restructured into 11 sub-cities named Addis Ketema, Akaki, Arada, Bole, Gulele, Kirkos, Kolfe, Lideta, Nifas Silk, Yeka, and Lemi cura. The city is subdivided into 120 Woreda. The commercial activities such as the flow of goods and services in Ethiopia are concentrated in Addis Ababa, (Weldeghebrael, 2021).

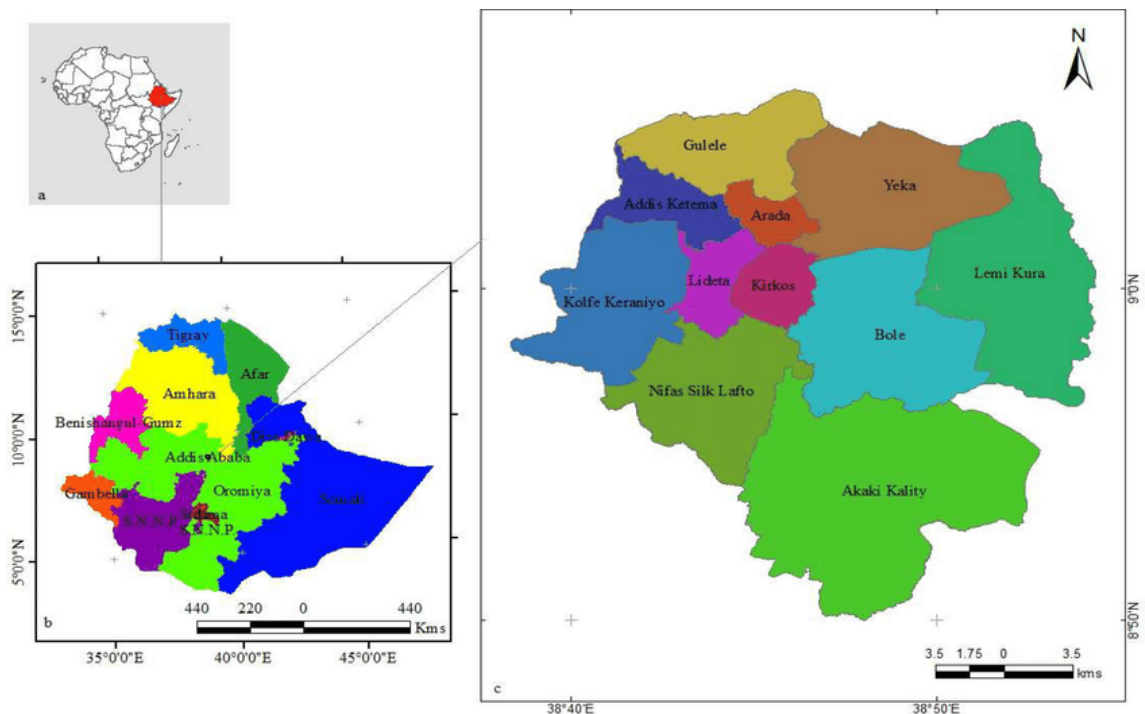


Figure 3-1: Study area, Addis Ababa Source: Ethio-G.I.S (2022)

##### 3.1.1 Demography

According to (CSA, 2013), the population of Addis Ababa was projected to be 3.821 million in 2022 from 2007 census data, and there would be tremendous growth in the number from 2.5 million in 2007 to about 6.4 million in 2037, an increase of about 2.5

times in 30 years. This fast increase in the number of elderly people would create demand for several types of services for them.

**Table 3-1 Distribution of population among the Addis Ababa sub-cities, 2022**

SUB CITIES	Population Estimate of 2022	Proportion of Populations	Area (ha)	Proportion of Area	population density (peoples/ha)
<b>BOLE-SUB CITY</b>	<b>320,536.00</b>	8%	6,371.49	12%	50.31
<b>YEKA-SUB CITY</b>	<b>424,891.00</b>	11%	5,675.62	11%	74.86
<b>LIDETA-SUB CITY</b>	<b>284,208.00</b>	7%	1,500.80	3%	189.37
<b>KIRKOS-SUB CITY</b>	<b>311,762.00</b>	8%	1,475.84	3%	211.24
<b>LEMI KURA SUB CITY</b>	<b>178,536.00</b>	5%	7,952.87	15%	22.45
<b>ARADA-SUB CITY</b>	<b>298,044.00</b>	8%	992.69	2%	300.24
<b>GULELE-SUB CITY</b>	<b>377,031.00</b>	10%	3,609.35	7%	104.46
<b>ADDIS KETEMA-SUB CITY</b>	<b>359,734.00</b>	9%	1,884.28	4%	190.91
<b>NEFAS SILK-LAFTO-SUB CITY</b>	<b>445,684.00</b>	12%	5,163.35	10%	86.32
<b>KOLFE KERANIYO-SUB CITY</b>	<b>604,226.00</b>	16%	4,953.63	10%	121.98
<b>TOTAL ADDIS ABABA CITY ADMINISTRATION</b>	<b>3,860,000.00</b>		<b>51,977.92</b>		

Source: Central Statistics Agency of Ethiopia

### 3.1.2 Transport and Road Network of Addis Ababa

Ethiopian Transportation Master Plan Road Network from 2022 to 2052 (Logistics, 2022) reported that the total road network of Addis Ababa is equal to 3.699 km on an area of approximately 2360 km<sup>2</sup> (about 1.56 km/km<sup>2</sup>), composed of 954 km of asphalt roads, 1,786 Km of cobblestone roads, and 958 km of gravel roads.

The road network until the year 2012E.C which is 2020G.C (it is not updated thereafter) taken from AACRA is shown in the figure below.

Road types according to AACRA inventory, are classified as ring road (RR), principal arterial streets (PAS), sub arterial streets (SAS), collector streets (CS), and local streets (LS).

- a. Ring roads (RR): asphalt pavement that links the city in ring form and vehicles can drive up to 70km/hr. in the section not congested. The total length of these roads is 213.46km.
- b. Principal Arterial Streets (PAS): the second-grade streets next to the ring road with a standard width of 30m to 60m with a total length of 1,509.40km asphalt. These roads extend from the city center and cross the ring road to access the suburbs and are used by a lot of heavy vehicles.
- c. Sub Arterial Streets (SAS): these roads are especially located in the center area which connects each primary arterial street that is shorter than ring road and primary arterial streets. Their total length is 474. 81km. The pavement is expected to be asphalt but actually, there is a 14.69km coble stone
- d. Collector Streets (CS): connect the ring road, primary Arterial Street, and sub arterial streets. Their total length is 655. 41km. The pavement is expected to be asphalt but actually, there is 126.47km coble stone, 105.94 gravel, and 18.24 earth.
- e. Local Streets (LS): these are the lowest grade roads which have a total length of 4,760.5km, longer than other road types, out of which only 517.71km is asphalt.

From the inventory of 2020 (Authority, 2012) AACRA report shows that the total center line length of 7m is 7,613.59km in total of ring road, sub arterial street, local street, principal arterial street, and collector street.

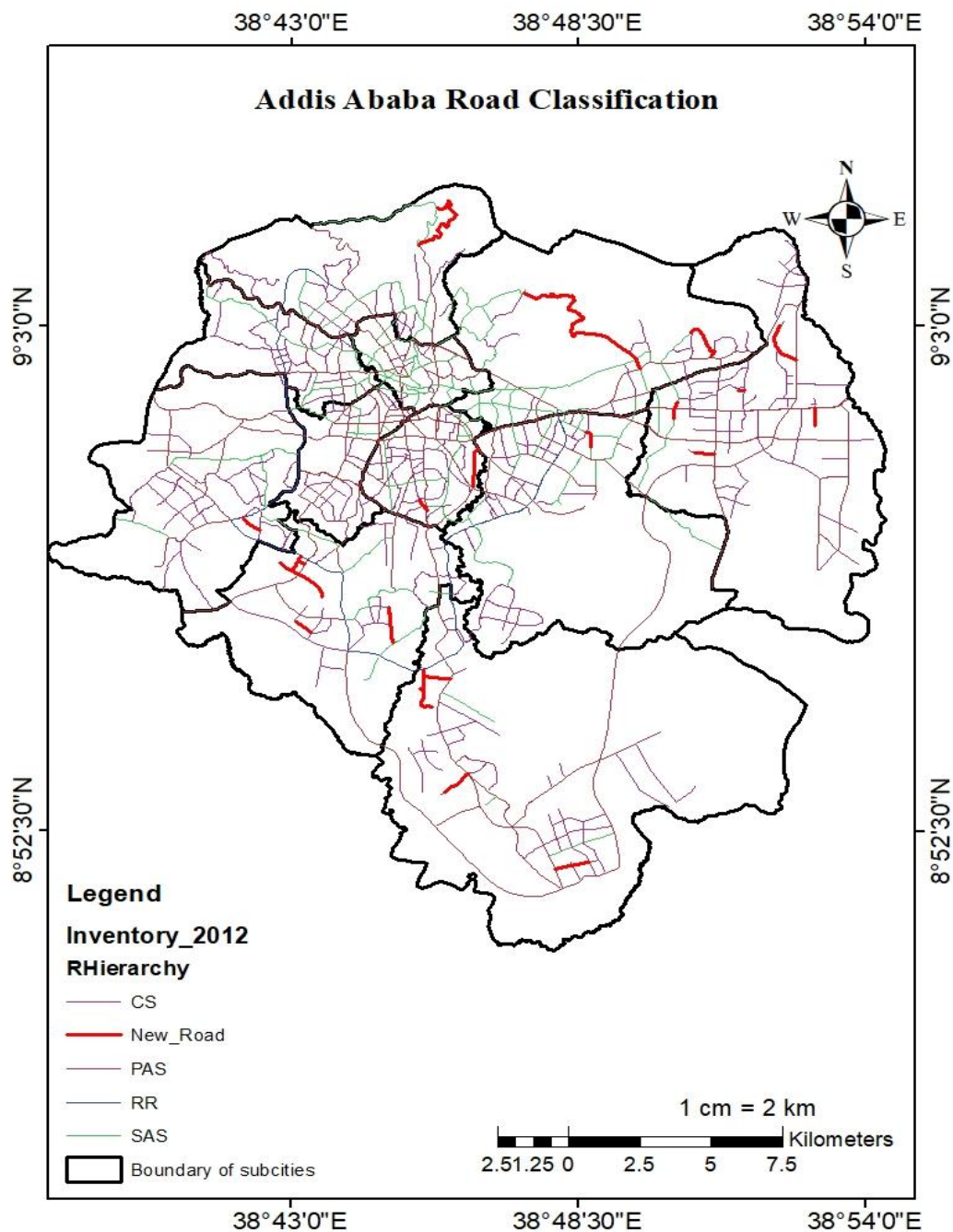


Figure 3-2: Road classification of Addis Ababa with new roads

### 3.1.3 Land use

According to the study by (Moisa *et al.*, 2022) the land use and land cover changed from 1991 to 2021, and the built-up area increased significantly from 96.6km<sup>2</sup> to 227.2km<sup>2</sup>. The land use of Addis Ababa found from Addis Ababa land holding registration and

information agency is shown on Annex E. Some of the sub-city boundary was not included in the land use category.

### 3.2 Data Sources

#### 3.2.1 Data Required

The data required and availability is evaluated before acquiring the data works are commenced. The types of data used in this research are two types, primary and secondary data the following sections describe the data used.

**Table 3-2: Data required**

<b>Data on</b>	<b>Maps required</b>	<b>Source</b>
Travel Demand		
Demography	The existing road network	AACRA
	Sub-city boundaries	Addis Ababa Land Holding Registration and Information Agency
	Building footprints	Addis Ababa Land Holding Registration and Information Agency
	Population of Addis Ababa with each sub-city	CSA
	The road network of the city	AACRA

#### 3.2.2 Primary Data

The primary data collection, it is used oral interviews of three officials of AACBSE who are responsible for giving service, from the Department of Communication; weekly, yearly output of AACBSE that help to see density of population using public transport, from Department of Transport of AACBSE; Location of existing bus stops. The other officials are from AACRA who is the designer of the road three interviewers from the road design department and three from the on-force construction department from each lots. This is to get the assumption they have taken when they constructed the road, and residents of people around the streets that are not accessible by the public bus because they are expected to have problems of accessibility of the streets near them. Moreover, direct observation was conducted on the existing bus stops to count the bus trips around the new existing roads which are not accessed by the city public buses. Structured interviews are conducted with

AACBSE and AACRA officials to get information about the streets that are not accessed by the city buses.

### **3.2.3 Secondary Data**

The secondary data that are necessary for this study are the Road network of Addis Ababa, Existing land use map, bus routes, location of bus stops, and population data. The secondary sources' data formats are as follows,

- Road Network map shape file of Addis Ababa from AACRA
- Existing Land Use map shape file from Addis Ababa Land Holding Registration and Information Agency
- Bus routes from AACBSE
- Location of bus stops from AACBSE
- Division sub-city and Woreda, from Addis Ababa Land Holding Registration and Information Agency
- Population data form at each sub-city CSA to know the transport demand in the surrounding bus stop access coverage area

### **3.2.4 Data Preparation**

The major task after the collection of data is to prepare it for access in Arc GIS. The bus stop location was collected in an Excel file, and the coordinates of new roads of Addis Ababa center line data are in a Microsoft Excel Worksheet file and converted to Microsoft Excel Comma Separated Values File (.csv) file and then to Arc GIS. Since the maps were obtained from different sources, the coordinates were different so it was converted into the working coordinate system used by WGS 1984 zone 37N.

## **3.3 Software Used**

In data analysis, the software used is;

- ✓ ArcGIS 10.8: Geographical Information System

- ✓ Auto CAD: Files from AACRA for the centerline data are used

### **3.4 Method of Data Analysis**

In this research, the analysis is based on the objectives of the study which is evaluating the accessibility of the new roads and providing new bus stations for the new roads by determining using ArcGIS software.

Measurement criteria for accessibility that are used for this study analysis adopted from (Ahsan, 2013) are;

1. Road Density
2. Population served
3. Four hundred (400) Meters Bus Stop buffer

These parameters are selected because the objective of the study is to increase the accessibility of the new roads for the population around them. Additionally, land use, slope, proximity of the old bus stop to the new road, and land cover factors are included to estimate the new bus stop area.

Generally, the analysis is divided into two main parts

1. the first is the estimation of bus stop accessibility around the newly inaugurated roads in Addis Ababa
2. the second providing the best bus stop for accessibility to the new roads

#### **3.4.1 Estimation of Bus Stop Accessibility for the New Roads**

G.I.S Buffering Approach is used to estimate bus stop accessibility using circular buffer analysis with a radius of 400m which is considered in terms of walking distance to the nearest station, according to (Meyer, 2016) access threshold around the stop to identify the coverage because accessing a bus stop is considered to be achieved by walking (Foda and Osman, 2010). Based on an assumed average walking speed of about 1.3 m/s or 80m/minute, 5 minutes of walking is considered reasonable in urban areas, which are about 400meters in terms of walking distance (Foda and Osman, 2010), (D.Edward, Jhon, 1992). According to Salvo and Sabatini, this approach assumes that;

- ✓ all locations within the bus within the buffer are accessible to the route and
- ✓ may overestimate accessibility because the approach does not take connectivity of the pedestrian network and
- ✓ It is commonly used to design future routes for bus stop locations that are not yet known or when they are not available in the G.I.S.

The area covered by the bus stop near each new road is derived from the 400m walking distance (Meyer, 2016) from each bus stop. After the accessibility is measured using the 'geoprocessing' tool of Arc GIS software, the location of new bus stops is designed.

### **3.4.2 Locate a Suitable Area for Bus Stops**

For the determination of suitable areas for bus stops according to (Olowosegun Adebola, 2012) there are criteria to consider;

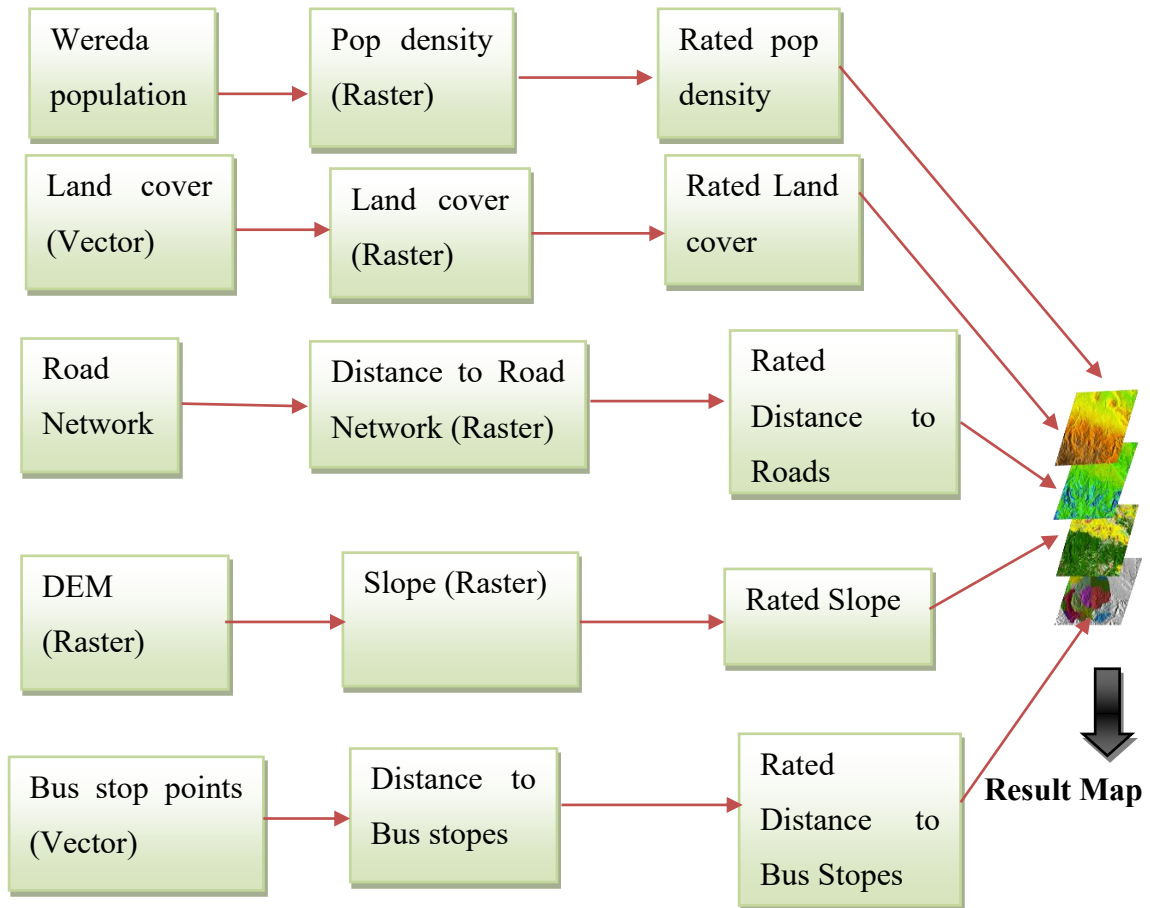
1. Four hundred (400) meters of bus stop buffer is done on all bus stops using GIS then identified the bus stops far from the new roads. This is because it corresponds to a 5-minute walk at 4.5km/h to the nearby bus station, assuming that all locations are accessible within the buffer.

2. Available setback from the road ideal for bus stop shelter: - for this specific research the building along the roadside will be digitized as a polygon feature. An overlay analysis of the polygon features will be carried out using the merge option and classification was used to distinguish different features. The polygon features are the buildings along the roadside and the 8-meter buffer of the road network. Places, where the digitized residential polygon falls inside the 8-meter road buffer, denote that there is no space in that particular location where the bus stop can be located without the bus stop serving as a hindrance to the flow of traffic.

3. Slope: - since slope is the rate of change of elevation, can be derived from the Digital Elevation Model (DEM). DEM is the representation of height values of the terrain at regularly spaced intervals. The DEM values are generated at 50m intervals to reduce interpolation. DEM enables the analysis of terrain characters as slope, aspect, and contour. For this study DEM and slope are generated in raster format; the slope will be re-classed. The Slop map generated will give us a thematic map that represents the slop range.

4. Overlay analysis of these layers (i.e., available setback from the road ideal for bus stop shelter and the slope map) gives us a suitability map for the Bus Stop location.

The general work methodology followed for this specific study is summarized as follows,



**Figure 3-3: Suitability analysis method**

## CHAPTER 4

### 4. RESULTS AND DISCUSSION

#### 4.1 Data Processing Techniques

The data were processed to prepare easily and to analyze the suitability of new roads of Addis Ababa to establish the new route and new bus station using five parameters which are; existing bus route proximity, slope, proximity to the existing bus station, land use, and population served. The 11 sub-cities of Addis Ababa parcel data are exported to ArcGIS 10.8 for analysis.

##### 4.1.1 New roads in Addis Ababa

In this study, the new roads were constructed with an on-force team which means the projects are constructed by AACRA and not given to other construction companies. AACRA on force team has four lots namely lot-1, lot-2, lot-3, and lot-4. The data collected from the on-force team from lots 1-4 for the roads inaugurated in Addis Ababa on the on-force team from 2020 to 2023 is collected from AACRA head office and lot departments were requested to provide each road centerline data to be used for this study. ANNEX-C shows new roads of Addis Ababa.

Out of the data described in the Annex C from Table C-1 to Table C-4, the as-built center line data of the following roads are found from the lot offices to use for this study.

**Table 4-1: New roads used for this specific study**

S. N	Project Name	Length(m)	Width (m)	The year finished	Lot
1.	Agona Cinema-Senegal Embassy	480	12	2020	Lot-3
2.	Djibouti Embassy to Summit Road	670	20	2020	
3.	Tele (77 Mazonia)-Basilious	800	20	2020	
4.	Kadisco-2 (Kadisco Factory to Textile Industry Training Center)	900	25	2020	
5.	Lebu Musika Bet	680	25		
6.	Akaki Kality to Tulu dimtu	1180	20	2021	
7.	Kadisco-1(Kadisco Factory to Crown hotel)	1725	25	2020	
8.	Salogor (Kalite Total-Mebrat Haile)	1120	20	2020	
9.	Anbesa 1 (Nifas Silk Lafto Anbesa Garage)	240	20	2020	
10.	Anbesa 2 ( Nifas silk lafto Anbesa Garage road)	623	15/20	2022	
11.	Hana Mariam-Dama Hotel	1439	30	2021	
12.	Yeka Ayat 2&3	1740	30	2021	
13.	CMC overpass road	680	35	2022	
14.	Ayat Zone5	660	15	2022	
15.	Yeka Sub city Baleseltan Menoriya	200	15	2020	
16.	Nasew Real Estate-Arsema Church Ring Road	1280	30	2020	
17.	Anbesa Garage Jijiga sefer	767	20	2020	
18.	Kotebe Amanuel-Koteba Road	1670	20	2020	
19.	Welo sefer to Urael Road	1100	35	2022	Lot-1
20.	Kuskum to Entoto	3613	16	2022	Lot-2
21.	kotebe 02-ferensay gurara kidenemihret church	7401	20	2021	

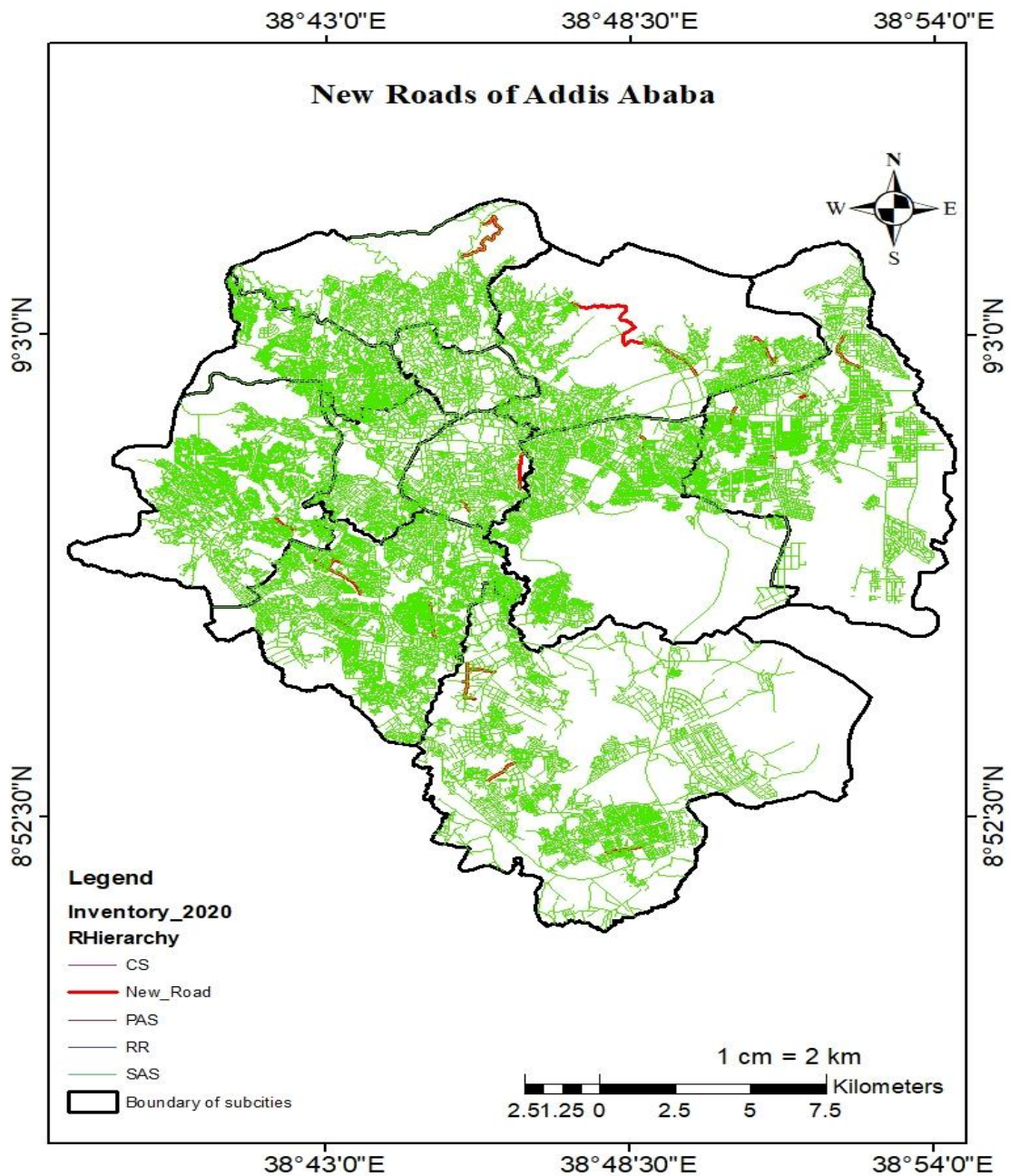
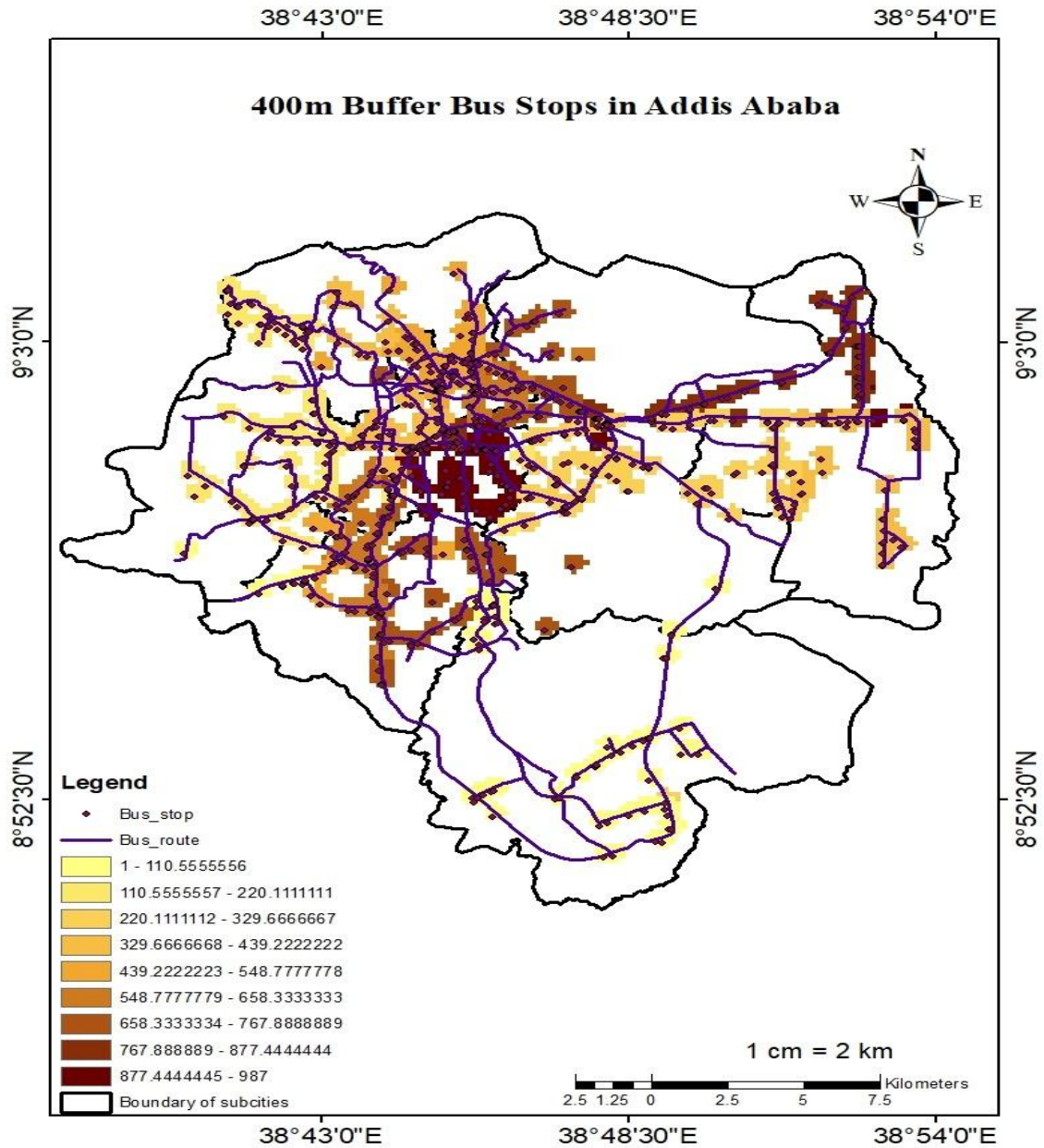


Figure 4-1: New roads of Addis Ababa used for this specific study (shown in red)

#### 4.2 Evaluation of Existing Bus Stop Accessibility

As discussed in section 3.4.1 the accessibility of the existing bus stop is evaluated using a buffer around each bus stop in Addis Ababa.



**Figure 4-2: 400m Buffer around bus stop of Addis Ababa**

The buffer approach of this study assumes that all bus stops locations farther than 400m from the new roads are not accessible. Therefore, the new roads farthest from the existing bus station need a new bus stop to make them accessible which is the major objective of these study.

**Table 4-2: Accessibility of New roads from the existing bus station**

S. N	Project Name	Length(m)	Width (m)	Comment	Reason
1.	Agona Cinema-Senegal Embassy	480	12	Accessible	There are near by the existing bus stops
2.	Djibouti Embassy to Summit Road	670	20	Accessible	There are near by the existing bus stops
3.	Tele(77 Mazonia)-Basilius	800	20	Accessible	There are near by the existing bus stops
4.	Kadisco-2 (Kadisco Factory to Textile Industry Training Center)	900	25	Not Accessible	Existing bus stop is far from this road
5.	Lebu Musika Bet	680	25	Not Accessible	Existing bus stop is far from this road
6.	Akaki Kality to Tulu dimtu	1180	20	Not Accessible	Existing bus stop is far from this road
7.	Kadisco-1(Kadisco Factory to Crown hotel)	1725	25	Not Accessible	Existing bus stop is far from this road
8.	Salogor (Kality Total-Mebrat Haile)	1120	20	Not Accessible	Existing bus stop is far from this road
9.	Anbesa 1 (Nifas Silk Lafto Anbesa Garage)	240	20	Accessible	There are near by the existing bus stops
10.	Anbesa 2 ( Nifas silk lafto Anbesa Garage road)	623	15/20	Accessible	There are near by the existing bus stops
11.	Hana Mariam-Dama Hotel	1439	30	Accessible	There are near by the existing bus stops
12.	Yeka Ayat 2&3	1740	30	Accessible	There are near by the existing bus stops
13.	CMC overpass road	680	35	Accessible	There are near by the existing bus stops
14.	Ayat Zone5	660	15	Accessible	There are near by the existing bus stops
15.	Yeka Sub city Balesetan Menoriya	200	15	Not for public use	
16.	Nasew Real Estate-Arsema Church Ring Road	1280	30	Accessible	There are near by the existing bus stops
17.	Anbesa Garage Jijiga sefer	767	20	Accessible	There are near by the existing bus stops
18.	Kotebe Amanuel-Koteba Road	1670	20	Accessible	There are near by the existing bus stops
19.	Welo sefer to Urael Road	1100	35	Partially Accessible	There are near by the existing bus stops
20.	Kuskuam to Entoto	3613	16	Not Accessible	Existing bus stop is far from this road
21.	kotebe 02-ferensay gurara kidenemihret church	7401	20	Not Accessible	Existing bus stop is far from this road
<b>Total km</b>		<b>28,968</b>			

### **4.3 Determination of New Bus Stop for the New Roads**

To increase the new roads that were inaugurated in 2020-2022 accessibility, the second step is to study the suitability areas on roads to establish a new bus stop. GIS is used to process the five parameters that are used to show suitable locations on the roads. The parameters for the analysis are converted to a raster file and then the special tool 'Reclassing' is used to process every parameter indicated with numbers (0- indicates not suitable, 2 – indicates very low suitable, 4 – indicates low suitable, 6 – indicates medium suitable, 8 – indicates suitable, 10- indicates very high suitable). Then the reclassified parameters which are road density, population served, slope, land use, and bus stop proximity, by using a field calculator in ArcGIS.

#### **4.3.1 Road Density and Proximity of New Road to Bus Route**

The total road length of Addis Ababa in the inventory summary of AACRA on 2020 is shown in ANNEX - D.

The proximity to new roads is reclassified to make sure that each new road is suitable according to section 4.2 and Figure 4-7 a) shows the distance from the bus route which is done to reclassify the map of Addis Ababa with bus route proximity for the new roads. The reclassification in Figure 4-7 b) shows that 0-400m is not suitable for the new bus route because it is near the existing one, 400-1000m is medium suitable, and above 1000m high suitable for a new bus route.

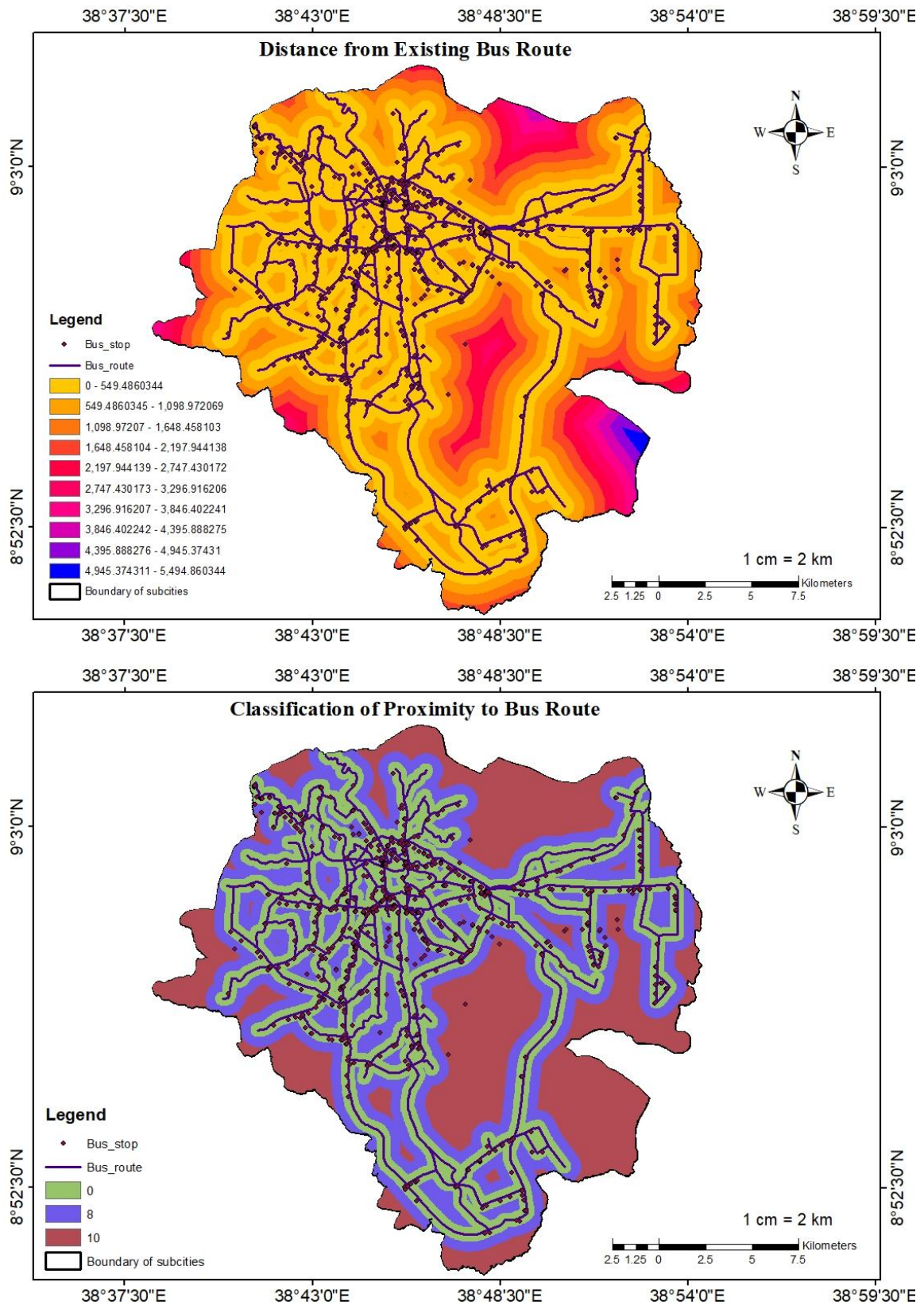


Figure 4-3: a) Distance from Bus route b) Reclassification of Proximity to Bus route

#### 4.3.2 Bus stop proximity

The bus stop proximity to the new roads is calculated using GIS. The reclassified as described in section 4.2.

**Table 4-3: Bus stop reclassification**

<b>Bus stop distance (m)</b>	<b>Suitability score</b>	<b>Suitability class</b>
0 – 400	0	Not suitable
400 – 1000	6	Medium suitable
1000 – 1579.231	8	High suitable
1579.231 – 2379.66	10	Very high suitable
Above 2379.66	10	Very high suitable

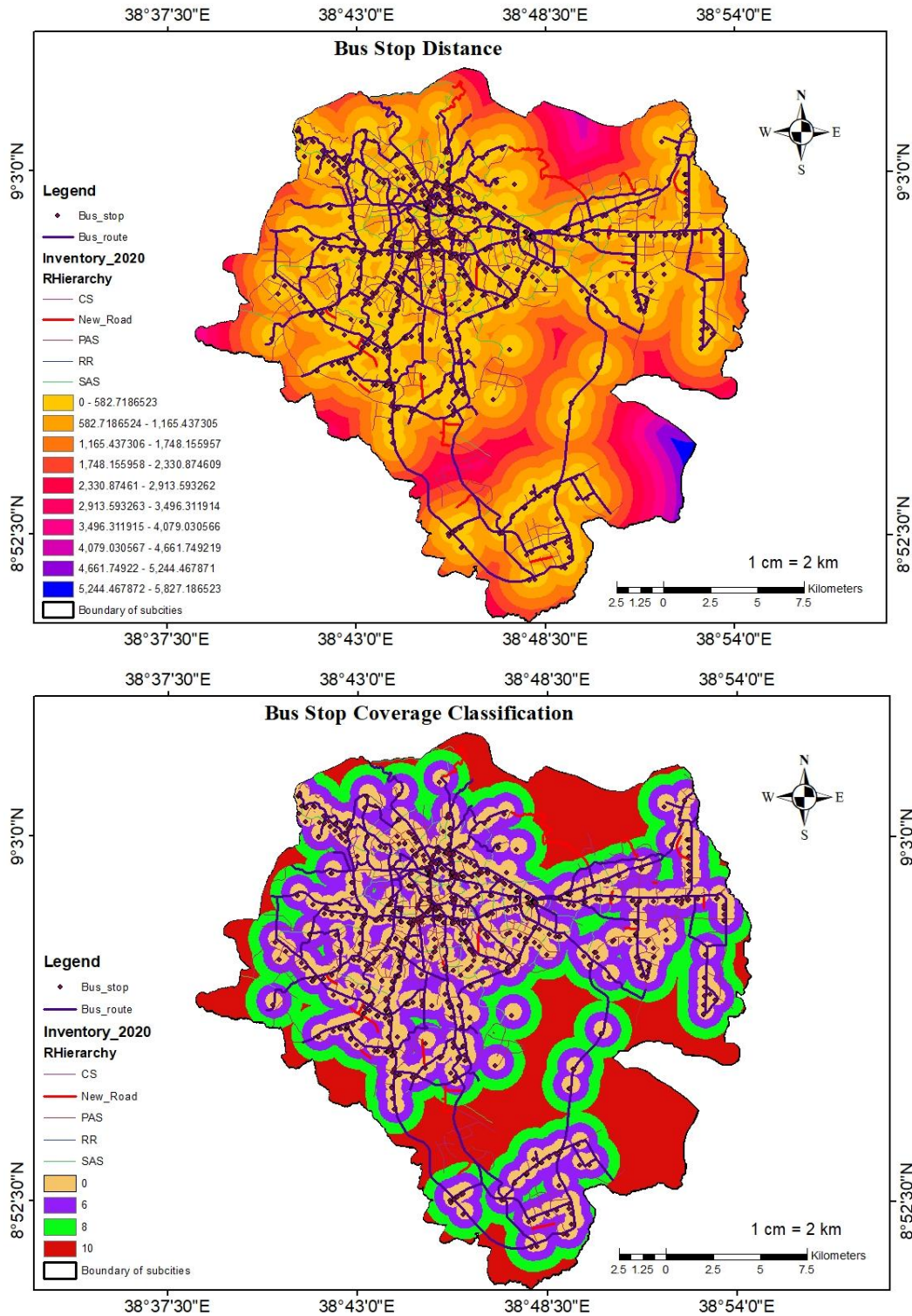


Figure 4-4: a) Distance from Bus Stop b) Reclassification of Proximity to Bus Stop

### 4.3.3 Slope

The slope of the city is derived from the Digital Elevation Model (DEM) that was derived from elevation values extracted at 20m to reduce interpolation. DEM and slope were

generated in raster format; the slope was reclassified as described in section 4.2 to determine the less sloped surface ensuring safety for bus stop location suitability. The DEM, the slope classification and reclassification map of Addis Ababa is attached on Annex E.

**Table 4-4: Slope reclassification**

<b>Slope in percent</b>	<b>Suitability score</b>	<b>Suitability class</b>
0 - 3.032	0	Very high suitable
3.032 - 5.896	2	High suitable
5.896 - 9.435	4	Medium suitable
9.435 – 13.815	6	Low Suitable
13.815 – 20.049	8	Very low suitable
20.049 – 42.962	10	Not suitable

#### **4.3.4 Land Use**

The land use distribution as per the master plan, shows that most of the development of the city is mixed residential. The main commercial center is located in the Addis Ketema sub-city locally called Merkato where the major land freight terminals are located. The land use dynamics of the city with the bus route and new roads are shown in Annex F. The sub-city boundary and the land use classification show some areas of the sub-city are not included in the classification as a limitation of the data received from the Addis Ababa Land Holding Registration and Information Agency.

**Table 4-5: Land Use Reclassification**

<b>Land use type</b>	<b>Suitability score</b>	<b>Suitability class</b>
Social service	10	Very high suitable
Mixed residence	10	Very high suitable
Environmental protection	8	High suitable
Commerce	10	Very high suitable
Manufacturing & storage	10	Very high suitable
Administrative services	2	Very low suitable
Municipal services	10	Very high suitable
Urban Agriculture	8	High suitable
Transport	0	Not suitable
Infrastructure services	4	Low suitable
Special Project	8	High suitable
Historical construction site	2	Very low suitable
Sport Field	10	Very high suitable
Street network	10	Very high suitable
Mixed Environmental protection Residence	10	Very high suitable

#### 4.3.5 Population Density of Addis Ababa

As described in chapter three the population of Addis Ababa density is calculated using a GIS field calculator for each sub-city. The vector data found from the calculation is converted to raster and reclassified. The raster and reclassification map of population is attached on Annex G.

**Table 4-6: Population Density Reclassification**

<b>Population (Number per Hectare)</b>	<b>Density</b>	<b>Suitability score</b>	<b>Suitability class</b>
20.59-22.44		0	Not suitable
22.449-50.3078		2	Very low suitable
50.3078-86.316		4	Low suitable
86.316-121.975		6	Suitable
121.975-211.244		8	High suitable
211.244-300.239		10	Very high suitable

#### 4.4 Suitability of New Bus Stop Area

Suitability analysis for new bus stop areas in Addis Ababa, Ethiopia, is conducted using a GIS-based multi-criteria decision analysis approach. Factors for this research are taken as population density, proximity to existing bus routes, land cover, distribution of bus stops, and topographic slope, which are weighted based on their influence on transportation planning (Mekonnen, T., & Gebre-Egziabher, 2020). Addis Ababa faces significant urban transportation challenges, including rapid population growth and inadequate public transportation infrastructure, which necessitate careful planning and equitable distribution of bus stops (Alemayehu, Y., & Tesfaye, 2019);(Bank, 2018). Integrating land use and transportation planning is critical to addressing these challenges and ensuring sustainable urban development (Feyisa, G. L., & Beyene, 2017)

Based on the above raster calculations, all the criteria are in vector form and converted to the same unit, so the formulation for the suitability of areas for bus stops. Depending on the requirements information combined using weighted combination gives the following result.

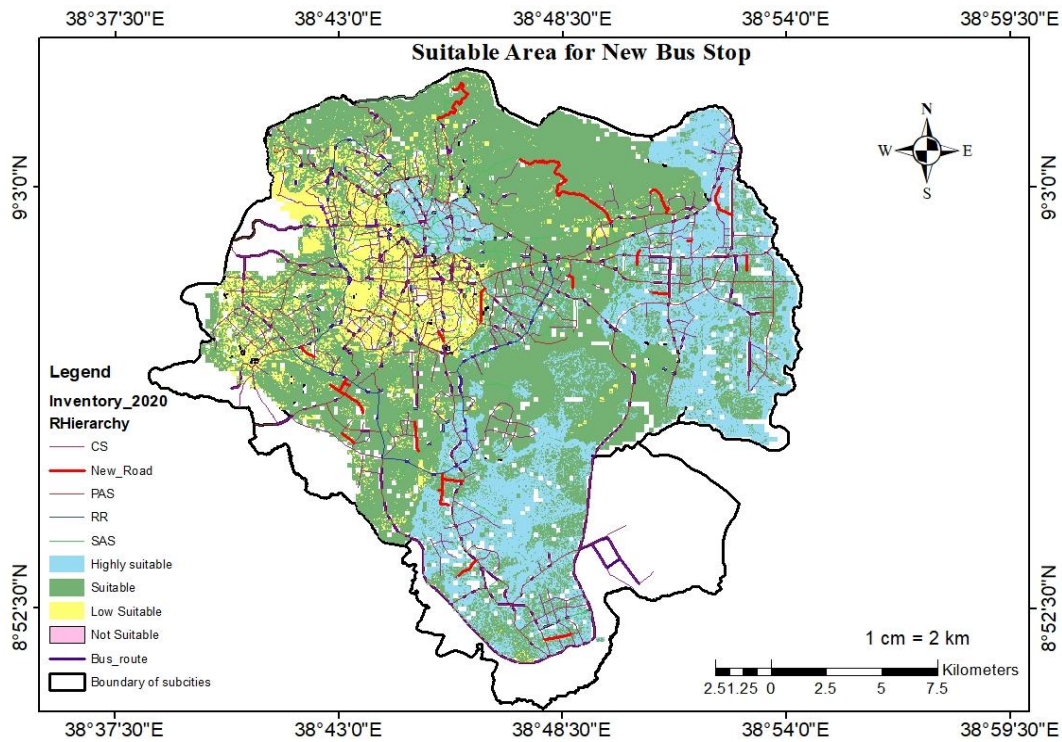


Figure 4-5: Suitability Map

**Table 4-7: Roads that are suitable for new bus stop**

S. N	Project Name	Length (m)	Width (m)	Comment	Remark
1.	Agona Cinema-Senegal Embassy	480	12	Not suitable to establish a new bus stop	
2.	Djibouti Embassy to Summit Road	670	20	Suitable to establish a new bus stop	
3.	Tele (77 Mazonia)-Basilious	800	20	Not suitable to establish a new bus stop	
4.	Kadisco-2 (Kadisco Factory to Textile Industry Training Center)	900	25	Suitable for establishing new bus stop	
5.	Lebu Musika Bet	680	25	Suitable for establishing new bus stop	
6.	Akaki Kality to Tulu dimtu	1180	20	Suitable for establishing new bus stop	
7.	Kadisco-1(Kadisco Factory to Crown hotel)	1725	25	Suitable for establishing new bus stop	
8.	Salogor (Kality Total-Mebrat Haile)	1120	20	Suitable for establishing new bus stop	
9.	Anbesa 1 (Nifas Silk Lafto Anbesa Garage)	240	20	Suitable to establish a new bus stop	
10.	Anbesa 2 (Nifas silk lafto Anbesa Garage road)	623	15/20	Suitable to establish a new bus stop	
11.	Hana Mariam-Dama Hotel	1439	30	Suitable to establish a new bus stop	
12.	Yeka Ayat 2&3	1740	30	Suitable to establish a new bus stop	
13.	CMC Overpass road	680	35	Suitable to establish a new bus stop	
14.	Ayat Zone5	660	15	Suitable to establish a new bus stop	
15.	Yeka Sub city Baleseltan Menoriya	200	15	Not suitable to establish a new bus stop	Not for public use
16.	Nasew Real Estate-Arsema Church Ring Road	1280	30	Not suitable to establish a new bus stop	

17.	Anbessa Garage Jijiga sefer	767	20	Not suitable to establish a new bus stop	
18.	Kotebe Amanuel-Koteba Road	1670	20	Suitable for establishing new bus stop	
19.	Welo sefer to Urael Road	1100	35	Not suitable to establish a new bus stop	Partially Accessible from the existing bus stop
20.	Kuskum to Entoto	3613	16	Suitable to establish a new bus stop	
21.	Kotebe 02-ferensay Gurara Kidenemihret church	7401	20	Suitable for establishing new bus stop	
<b>Total m</b>		<b>28,968</b>			

Therefore, from the above table out of 21 roads, 6 roads are not suitable for establishing new bus stops by the public considering the parameters of the surrounding slope, population density, bus stop, proximity to the bus stop, and land use data.

Best locations are to be specified by the concerned authority of transport service according to its requirements. However, this section of the research will present the measured accessibility of bus stops near the new roads of Addis Ababa shown in Table 4-7 identified as not accessible will be given a suitable bus stop depending on the discussed parameters.

## 4.5 Discussion

### 4.5.1 Evaluation of Accessibility of Bus Stop around the New Roads

In this study, the accessibility of bus stops around the newly inaugurated roads is evaluated using a GIS buffer tool. The buffer tool is used to determine the proximity of the existing bus stops to the new roads. A 400m buffer is used around each bus stop, and the new roads that are not within the buffer zone need additional bus stops to make the road accessible for users.

The evaluation of the accessibility of the roads regarding the existing bus stop found that out of 21 new roads, only 6 roads do not need a bus stop. This shows that 29% of the roads

are accessible, and 71% of the new roads constructed are not accessible by the existing bus stop. This shows that new road projects should be integrated with comprehensive urban planning strategies that prioritize equitable access to public transportation (UN-Habitat, 2017).

Moreover, this study shows that out of the total 28,968m of road constructed from 2020 to 2022 about 24,341m of the road are suitable to establish new bus stops to increase accessibility of the road by the public transportation. About 200m of the road was not constructed for public use and 1,100m of the road from Welo sefer to Urael is partially accessible from the existing bus stop which means the Entrance at Welo sefer and the exit at Urael are nearby bus stops. The remaining 4,627m of the newly constructed roads are accessible by the old bus stops. Additionally, involving local communities in the planning and evaluation of new road projects can help ensure that bus stops are placed in locations that meet the needs of residents (Mekonnen, M. M., & Hoekstra, 2016).

#### **4.5.2 Location New Bus Stops**

From 28,968m of constructed new roads inaugurated in Addis Ababa from 2020 to 2022, 24,341m is suitable for establishing new bus stops depending on the criteria discussed in section 4.3. The suitable areas for the new bus stop are shown in Figure 4-13. Those areas are suitable for locating new bus stops to increase the accessibility of new roads. The new bus stops that can be established on the new roads will increase the accessibility of public transportation for the population of Addis Ababa. Therefore, the suitable areas for new bus stop is indicated on Figure 4-13 depending on the five criteria.

In addition, the suitable areas are showed using GIS software and the authorities of AACBSE are advised to establish new bus station on the areas shown on Figure 4-13.

## CHAPTER 5

### 5. CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

Bus stop selection requires a procedure that involves evaluating different criteria such as road network, population density, slope, land use, and existing bus stops. GIS is used for studying the suitability of location for bus stops. From this study, it is concluded that the new roads of Addis Ababa were inaugurated and have been used since then. Except for 6 roads, the rest are suitable for establishing new roads which are 71% of the new roads of Addis Ababa are not accessible by public transport. These new roads can be used for public transport and the suitability of this road for the bus stop is studied and shown the output of GIS on the map.

The main tools used by GIS are buffers for accessibility measurement and spatial analysis to reclassify the criteria used to study suitable areas to establish new bus stops. GIS is also used to show the different reclassified maps for each criterion as well as add up the criteria to give the required suitable area. The study shows that GIS is a dominant tool in handling and processing large data files regarding spatial information.

This study can be used as input for AACBSE to

- ✓ Establish a new bus stop,
- ✓ Maximize customer service and
- ✓ Maximize customer satisfaction.

## 5.2 Recommendations

From this research, the following recommendations are forwarded.

- The concerned administration offices of transport offices shall work together to have suitable bus stop sites to be used for public transportation.
- Better data quality could have been found if the administration offices had compiled their data with better quality to save time.
- The ratio of the number of total buses 1150 to the population of Addis Ababa is 1:3357 which indicates the AACBSE cannot satisfy the demand.
- More comprehensive research can be obtained by considering route selection analysis.

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APPENDIX A (Weekly report of AACBE)

h 18/10/15 እስከ 24/10/2015										
ለ: አውቶብስ ስምሪት ድልድል፣ ቁጥጥርና መረጃና ትንተና ዳይሬክቶሬት ዳይሬክተር										
ከ: ትራንስፖርት መረጃ ትንተናና ስርጭት ኪዝቲም										
ተ. ቁ.	መለኪያዎች	18/10/2015	19/10/2015	20/10/2015	21/10/2015	22/10/2015	23/10/2015	24/10/2015	ድምር	አማካይ
1	የቀረበ አውቶብስ	810	865	863	836	863	864	852	5,953	850
2	የመደበኛ ስምሪት (ጧት 2:00)	371	704	694	358	635	719	701	4,182	597
3	በሰራ ላይ የነበረ (ማታ 12:00)	736	721	743	723	723	748	678	5,072	725
4	ኮንትራት የተሰማራ አውቶብስ	2	11	15	4	95	16	7	150	21
5	ለድርጅቱ ሰራተኞች ስርገብ	41	40	39	40	39	41	42	282	40
6	የመደበኛ መስመር ርቀት ሽፋን በኪ.ሜ	56,901	89,471	85,665	57,825	89,603	93,613	91,295	564,373	80,625
7	የኮንትራት ርቀት ሽፋን በኪ.ሜ	772	772	772	772	772	772	772	5,404	772
8	በብልሽት ጋራዥ የገቡ	4	43	18	19	37	57	41	219	31
9	ከገቡት ተጠግኖ የወጡ	4	31	22	16	21	44	25	163	23
10	መላ ቀን የሰሩ አውቶብሶች	389	591	619	397	558	626	585	3,765	538
11	ማግኛ ቀን የሰሩ አውቶብሶች ጧት ብቻ	117	139	156	100	136	147	131	926	132
12	ማግኛ ቀን የሰሩ አውቶብሶች ማታ ብቻ	52	63	69	44	89	74	67	458	65
13	ቀጠና ላይ በብልሽት የተመዘገቡ	66	86	88	40	88	64	173	605	86
14	ቀጠና ላይ በጥገና የገኘ ሰዓት	11:10:00	16:40:00	19:45:00	9:10:00	19:45:00	11:10:00	11:20:00	99:00:00	14:08:34
15	የመደበኛ መስመር ገቢ በብር	2,622,871	4,725,338	4,314,397	2,775,288	4,209,695	4,129,522	3,949,208	26,726,319	3,818,046
16	የቆሚ ኮንትራት ገቢ በዕለት	40,653	40,653	40,653	40,653	40,653	40,653	40,653	284,572	40,653
17	የመምህራን ኮንትራት ገቢ በዕለት	189,880	189,880	189,880	189,880	189,880	189,880	189,880	1,329,160	189,880
18	የጊዜያዊ ኮንትራት ገቢ በዕለት	0	0	0	0	0	1,500	0	1,500	214
19	የቅድሚያ ትኩት ሽያጭ ገቢ በአለት	15,028	15,028	15,028	15,028	15,028	15,028	15,028	105,194	15,028
20	<b>ጠቅላላ የዕለት ገቢ በብር</b>	<b>2,868,432</b>	<b>4,970,899</b>	<b>4,559,958</b>	<b>3,020,849</b>	<b>4,455,256</b>	<b>4,376,583</b>	<b>4,194,769</b>	<b>28,446,746</b>	<b>4,063,821</b>
21	የመደበኛ አውቶብስ አማ.ገቢ በቀን	7,374	8,411	7,367	7,609	7,984	6,991	7,171	7,556	7,556
22	የጉዞ ብዛት	3,499	5,794	5,647	3,634	5,888	5,902	5,646	36,010	5,144
23	አማካይ ጉዞ በአውቶብስ	9	10	9	9	11	9	10	10	10
24	ተሳፋሪ ብዛት መደበኛ	269,008	478,569	425,925	280,754	424,417	421,696	397,827	2,698,196	385,457
25	ተሳፋሪ ብዛት ኮንትራት	200	1,100	1,500	400	9,500	1,600	700	15,000	2,143
26	ተሳፋሪ ብዛት መምህራን	94,940	94,940	94,940	94,940	94,940	94,940	94,940	664,580	94,940
27	ተሳፋሪ ብዛት ለድርጅቱ ሰራተኞች	4,100	4,000	3,900	4,000	3,900	4,100	4,200	28,200	4,029
28	<b>ጠቅላላ የተሳፋሪ ብዛት</b>	<b>368,248</b>	<b>578,609</b>	<b>526,265</b>	<b>380,094</b>	<b>532,757</b>	<b>522,336</b>	<b>497,667</b>	<b>3,405,976</b>	<b>486,568</b>
29	የመደበኛ መስመር አማካይ ተሳፋሪ በአውቶብስ በቀን	692	810	688	707	761	674	680	717	717

**APPENDIX B (Monthly report of AACBE)**

የብዙሃን ትራንስፖርት ኢ/ት ከግንቦት 21 ቀን 2015 እስከ ሰኔ 20 ቀን 2015 ወርሃዊ አፈጻጸም

ቀን	የቀረበ አውቶቡስ በአማካይ	ተበላሽተው የተመለሱ	ከተመለሱት ተጠግኖቻቸው የወጡ	በብልሽት የተመዘገቡ	የባክነ ሰዓት	የተሸፈነ የጉዞ ብዛት	አማካይ ጉዞ	የተሸፈነ ርቀት በኪሎ ሜትር	የተጓጓዘ ተሳፋሪ ብዛት	ጠቅላላ የትራንስፖርት አገልግሎት ገቢ በብር
21/9/2015	803	36	27	1	6:00:00	5,513	8	72,318	558,948	4,946,793.00
22/9/2015	804	30	18	1	5:40:00	5,868	8	86,827	555,619	4,606,329.00
23/9/2015	809	28	23	1	7:40:00	5,701	8	86,212	517,170	7,181,572.00
24/9/2015	813	36	30	0	0:00:00	5,832	8	87,114	520,580	4,539,385.00
25/9/2015	814	18	13	2	5:05:00	4,813	7	72,799	459,062	3,842,356.00
26/9/2015	817	18	11	1	3:10:00	5,660	8	84,012	510,295	4,334,420.00
27/9/2015	362	4	3	1	0:50:00	2,975	9	46,797	349,555	2,821,119.00
28/9/2015	804	44	35	3	18:05:00	5,574	8	83,282	518,129	4,631,757.00
29/9/2015	802	46	37	0	0:00:00	5,667	8	85,390	518,628	4,424,352.00
30/9/2015	796	29	19	0	0:00:00	5,745	8	88,510	507,822	4,581,566.00
1/10/2015	805	55	40	7	19:10:00	5,729	8	84,575	520,798	4,467,477.00
2/10/2015	800	36	26	0	0:00:00	5,675	8	84,235	492,944	9,168,342.00
3/10/2015	791	24	20	0	0:00:00	5,692	8	90,668	505,594	4,341,030.00
4/10/2015	404	13	11	2	7:10:00	3,475	10	57,743	359,934	2,874,035.00
5/10/2015	783	26	24	2	10:10:00	5,708	8	90,184	532,714	4,551,413.00
6/10/2015	790	47	34	4	8:35:00	5,703	8	86,057	516,330	4,404,005.00
7/10/2015	766	34	23	0	0:00:00	5,866	8	90,667	526,176	14,310,699.00

Assessment of New Roads Accessibility for Public Transportation Using GIS Addis Ababa, Ethiopia

ቀን	የቀረበ አውቶቡስ በአማካይ	ተበላሽተው የተመለሱ	ከተመለሱት ተጠግነው የወጡ	በብልሽት የተመዘገቡ	የባክነ ሰዓት	የተሸፈነ የጉዞ ብዛት	አማካይ ጉዞ	የተሸፈነ ርቀት በኪሎ ሜትር	የተጓጓዘ ተሳፋሪ ብዛት	ጠቅላላ የትራንስፖርት አገልግሎት ገቢ በብር
8/10/2015	794	30	25	1	5:30:00	5,774	8	90,898	515,038	6,487,348.00
9/10/2015	787	39	30	0	0:00:00	5,903	8	95,246	514,768	4,361,756.00
10/10/2015	785	39	25	2	4:40:00	5,980	8	94,134	508,824	4,264,238.00
11/10/2015	424	4	3	0	0:00:00	3,546	9	58,613	363,210	2,892,158.00
12/10/2015	769	31	29	1	2:00:00	5,403	9	84,954	535,055	4,519,880.00
13/10/2015	771	37	27	1	7:40:00	5,674	9	89,372	520,132	4,887,574.00
14/10/2015	769	49	40	1	1:15:00	5,821	9	92,037	518,114	4,422,373.00
15/10/2015	772	30	22	1	2:30:00	6,085	10	96,553	522,785	4,430,893.00
16/10/2015	776	31	22	1	6:45:00	5,936	10	95,052	543,586	4,603,221.00
17/10/2015	761	31	24	0	0:00:00	5,562	9	88,395	503,603	4,770,512.00
18/10/2015	810	4	4	0	0:00:00	3,499	9	57,673	368,248	2,868,432.00
19/10/2015	865	43	31	1	2:20:00	5,794	10	90,243	578,609	4,970,899.00
20/10/2015	863	18	22	0	0:00:00	5,647	9	86,437	526,265	4,559,958.00
<b>ጠ/ደምር</b>	<b>757</b>	<b>910</b>	<b>698</b>	<b>34</b>	<b>124:15:00</b>	<b>161,820</b>	<b>9</b>	<b>2,496,997</b>	<b>14,988,535</b>	<b>148,065,892</b>

**ANNEX-C NEW ROADS OF ADDIS ABABA**

**Table C-1:2012E.C inaugurated roads by AACRA On-Force**

2012 የተጠናቀቁ (2020 G.C)				
ተ.ቁ	የፕሮጀክቱ ስም	ርዝመት በሜትር	የመንገዱ ስፋት	ሎት
1	ቀራኒዮ አምቦ Phase II	888	30	ሎት-1
2	ሜክስኮ አደባባይ አፍሪካ ህብረት (ቡልጋሪያ መዘሪያ)	440	30	"
3	ሸጎሌ ድልድይ መቃረቢያ	100	30	"
4	ጉራራ ኪ/ምህረት-ፈረንሳይ አቦ	1860	20	ሎት-2
5	5 ኪሎ አንበሳ ግቢ አፍ.ቢ.ኤ ካምባስ ግብጽ ኤምባሲ	1051	15	"
6	የካ ሚካኤል መብራት - በግ ተራ -ሚሊኒየም መንገድ	473	25	"
7	መቄዲያ የአረጋዊያንና የአጃምሮ ህሙማን መርጃ ግቢ ስራ	1379	20	"
8	ኢትዮ ፓረንት ት/ቤት - ዩኒቲ ዩኒቨርስቲ - አንበሳ ጋራጅ	721	15	"
9	ዲያስፖራ አደባባይ ታክሲ ተርሚናል	200	10	"
10	ከቃሊቲ ቶታል - መብራት ኃይል	1290	20	ሎት-3
11	አጎና ሲኒማ-ሴኔጋል ኤምባሲ	480	12	"
12	ንፋስ ስልክ ላፍቶ አንበሳ ጋራዥ	883	15/20	"
13	ቦሌ ክ/ከተማ አያት ዞን 5	5000	8፣10&15	"
14	ካዲስኮቀለም ፋብሪካ ክራውን ሆቴል	1725	25	"
15	ካዲስኮቀለም ፋብሪካ ማሰልጠኛ	900	25	"
16	አቃቂ ቃሊቲ ቴክኒክና ሙያ	1180	20	"
17	ቴሌ ጫፍ (77 ቁጥር ማዘርያ) - ባስልዮስ መንገድ	800	30	"
18	ጀም ሞክ ፍሪ መንገድ	2800	14	"
19	ጀም ሚካኤል አየር ጤና መንገድ ማሻሻያ	790	7	
20	ወርቁ ሰፈር - ውሃ ልማት መንገድ ማሻሻያ	1200	8	
21	ጦር ኃይሎች ቀጠና 2 - ሙሉ ወንጌል ቤተክርስቲያን	300	8,6	
22	ሪቨንቲ	400	10	
23	ቃሊቲ አንበሳ ዴፖ	360	10	
24	ጂቡቲ ኤምባሲ	680	20	ሎት-3
25	አዲሱ ገበያ አካባቢ	320	10	

Source: AACRA

**Table C-2: 2013E.C inaugurated roads by AACRA On-Force**

2013 የተጠናቀቁ				
ተ.ቁ	የፕሮጀክቱ ስም	ርዝመት በሜትር	የመንገዱ ስፋት	ሎት
1	ፒኮክ ፓርኪንግ	600		ሎት-1
2	ሲኤምሲ-ሰሚት ማስፋፊያ	2,400.00	7.00	"
3	ከየረር በር መብራት ሀይል - ማዕድን ሚኒስቴር	1960	25	ሎት-2
4	ሸሮ ሜዳ - ቁስቋም መንገድ	633	30,40	"
5	ከሲቪል ሰርቪስ ዩኒቨርሲቲ--ጉርድ ሾላ	1040	20	ሎት-3
6	ሀፍ ማርያም ዳማ ሆቴል ላፍቶ ሚካኤል	1439	30	"
7	የካ አያት 2 እና 3 መንገድ	1700	30	"
8	ቃሊቲ ቀለበት መንገድ ማሳለፍ ቱሉዲምቱ አደባባይ ሎት-1 አገናኝ መንገድ	183	10	ሎት-4
9	ቅመማ ቅመም መንገድ	583	15	"
10	ኃይሌ ጋርመንት አትክልት ተራ ፕሮጀክት	953	16	ሎት-1

Source: AACRA

**Table C-3: 2014E.C Inaugurated roads by AACRA On-Force**

2014 የተጠናቀቁ (2020 G.C)				
ተ.ቁ	የፕሮጀክቱ ስም	ርዝመት በሜትር	የመንገዱ ስፋት	ሎት
1	ከጅማ መንገድ - ረዲ ገኛ ደረጃ ት/ቤት (ስልጤ ሰፈር) አለም ባንክ	2800	20	ሎት-1
2	ወሎ ሠፈር -ኡራኤል መንገድ ፕሮጀክት	1100	35	"
3	ወይራ ቤቴል	1416	20	"
4	አምበሳ ጋራጅ -ጅጅጋ ሰፈር	767	30	"
5	እንጦጦ ፓርኪንግ	297	17	"
6	ከአሚጎ ካፌ ሚካኤል ቀለበት መንገድ	1018.5	15	"
7	ኢዩቤልዩ ቤተ-መንግስት	480	5	ሎት-2
8	ከሮባ ዳቦ - ገርጂ መብራት ኃይል	973	20	"
9	ቁስቋም -እንጦጦ	4297	16	"
10	ቦሌ ክ/ከተማ አያት ዞን 5	1100	10 & 15	ሎት-3
11	ሲኤምሲ-ተሸጋጋሪ ድልድይ	680	35	"
12	ጉለሌ ዕፅዋት ማዕከል	840	10	ሎት-4

Source: AACRA

**Table C-4: 2014E.C Inaugurated roads by AACRA On-Force**

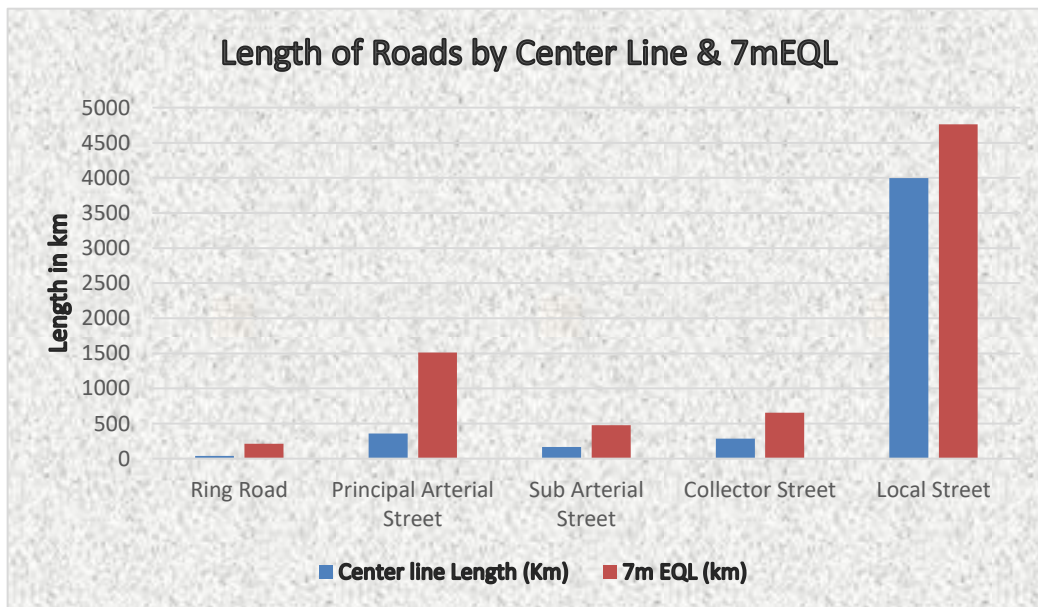
2014 የተጠናቀቁ (2020 G.C)				
ተ.ቁ	የፕሮጀክቱ ስም	ርዝመት በሜትር	የመንገዱ ስፋት	ሎት
1	መነን ት/ቤት ግቢ	339	3.5 & 2.5	ሎት-2
2	ወዳጅነት አደባባይ መንገድ ግንባታ	271	-	"
3	አያት ጣፎ ማስፋፊያ	3800	7	ሎት-3

Source: AACRA

## ANNEX D ROAD HIERARCHY OF ADDIS ABABA

**Table D-1: Centerline & 7m Equivalent Length Road data**

Road Hierarchy	Center Line Length (km)	7m EQL (km)	Area (sq., km)
Ring Road	37.98	213.46	1.49
Principal Arterial Street	357.43	1,509.40	10.57
Sub Arterial Street	166.49	474.81	3.32
Collector Street	284.74	655.41	4.59
Local Street	3,996.51	4,760.50	33.32
Grand Total	4,843.15	7,613.59	53.30



**Figure D-2: Length of roads in Addis Ababa Centerline & 7m Equivalent Length**

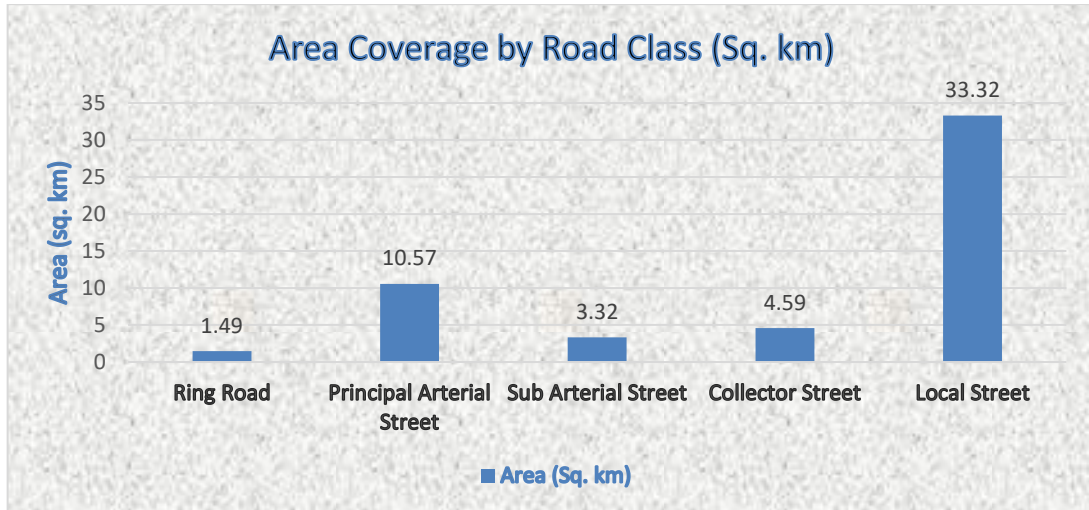


Figure D-3: Roads of Addis Ababa classification with area

Table D-2: Percentage of road classification center line & 7m Equivalent Length

Road Hierarchy	Center Line Length (km) in %	7m EQL (km) in %
Ring Road	0.78	2.80
Principal Arterial Street	7.38	19.83
Sub Arterial Street	3.44	6.24
Collector Street	5.88	8.61
Local Street	82.52	62.53

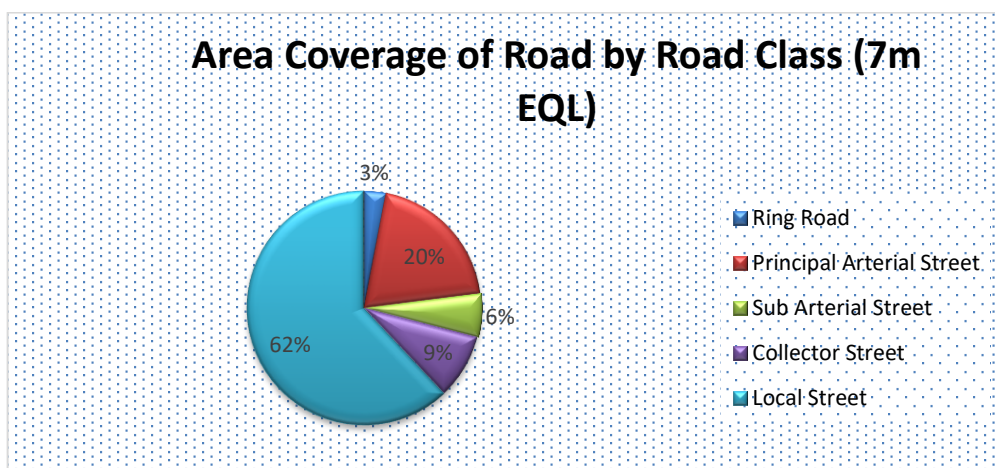


Figure D-4: Area coverage of road by 7m Equivalent Length class in Addis Ababa

The road density is calculated using a Spatial Analyst tool called line Density which gives us which locations of the city have high dense and low-density roads.

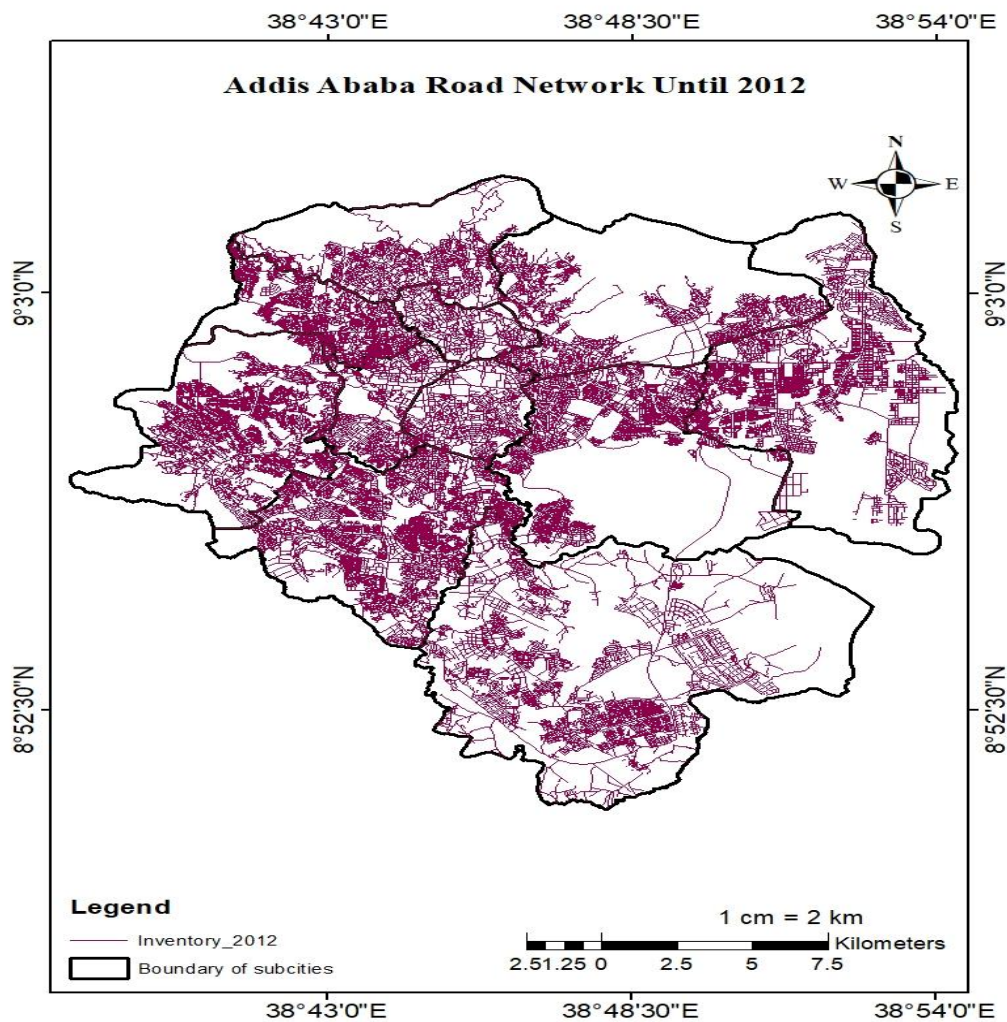
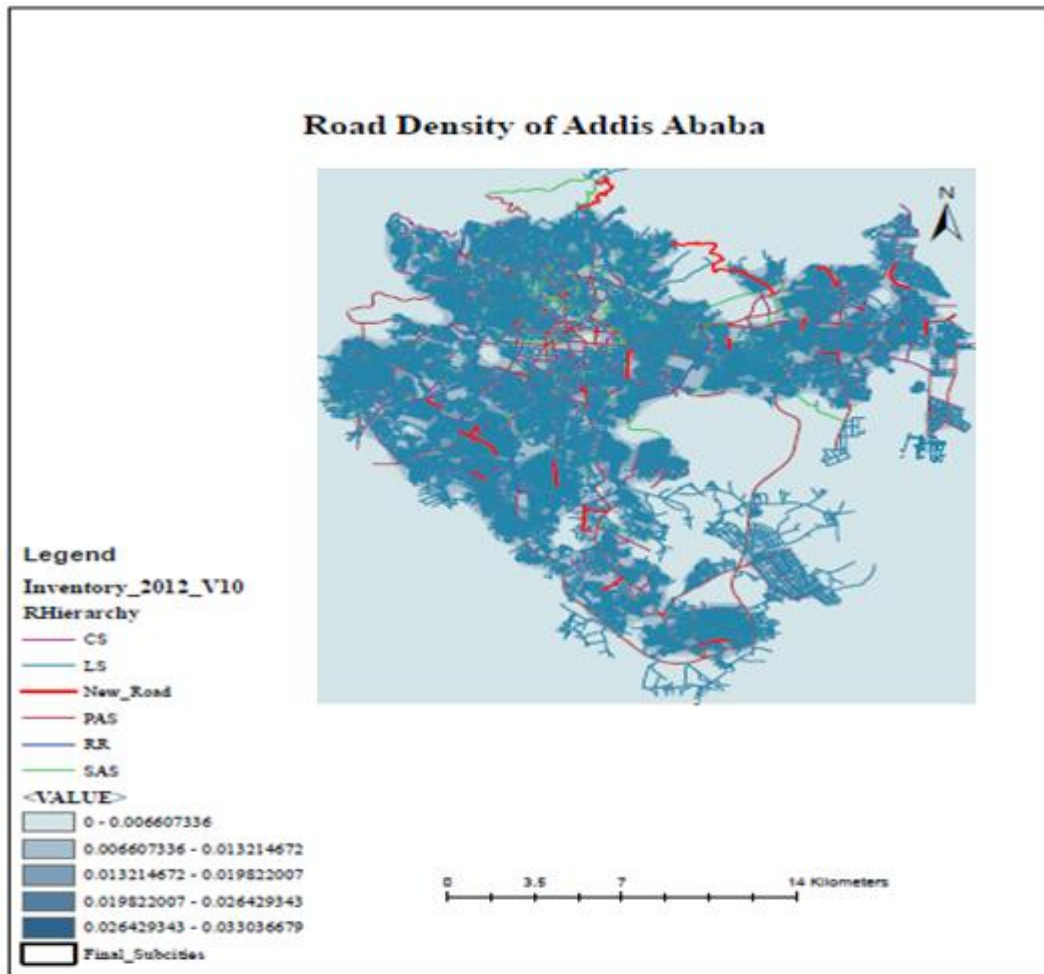


Figure D-5: Area coverage of road by 7m Equivalent Length class in Addis Ababa

Table D-3 Centerline roads length by class and pavement type in Addis Ababa

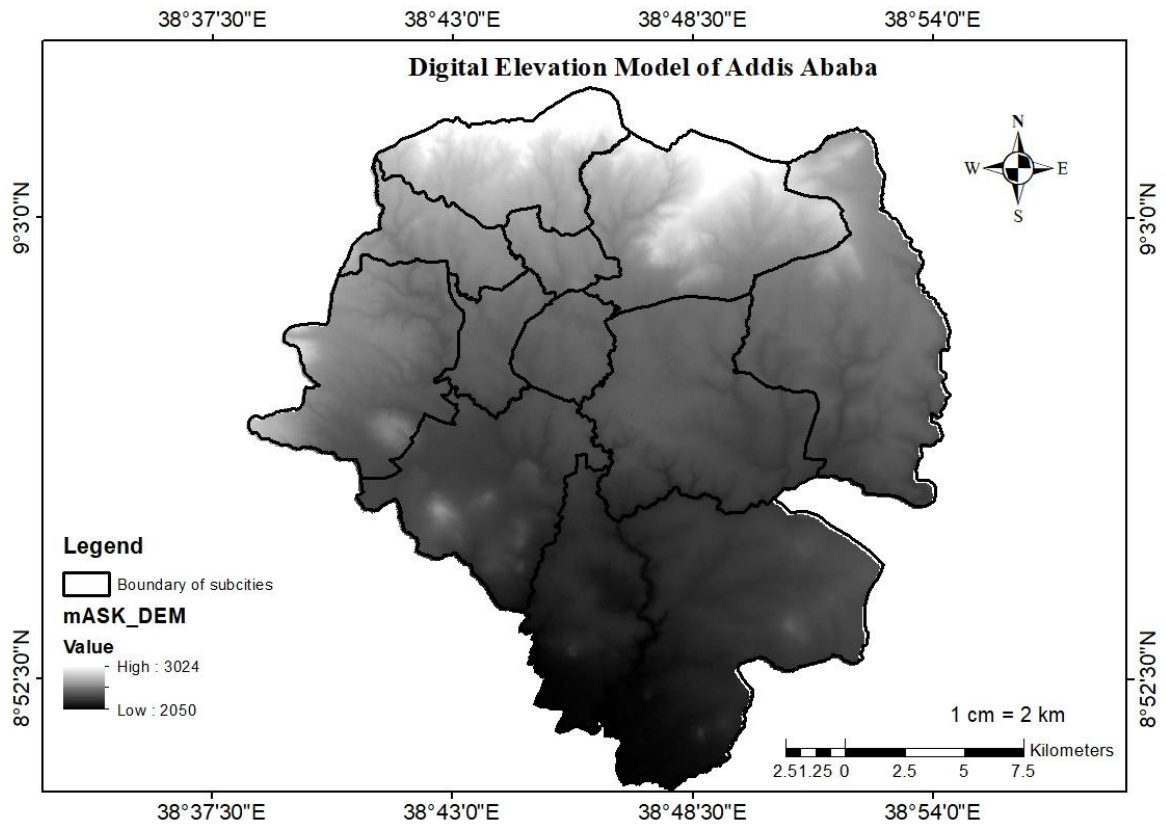
Road Hierarchy	Asphalt	Cobble	Care Stone	Gravel	Earth	Grand Total
Ring Road	213.46	0.00	0.00	0.00	0.00	<b>213.46</b>
Principal Arterial Street	1,509.40	0.00	0.00	0.00	0.00	<b>1,509.40</b>
Sub Arterial Street	460.12	14.69	0.00	0.00	0.00	<b>474.81</b>
Collector Street	404.76	126.47	0.00	105.94	18.24	<b>655.41</b>
Local Street	517.71	2,524.59	144.90	856.01	717.29	<b>4,760.50</b>
<b>Grand Total</b>	<b>3,105.46</b>	<b>2,665.75</b>	<b>144.90</b>	<b>961.94</b>	<b>735.53</b>	<b>7,613.59</b>

Source: AACRA, 2020E.C Inventory

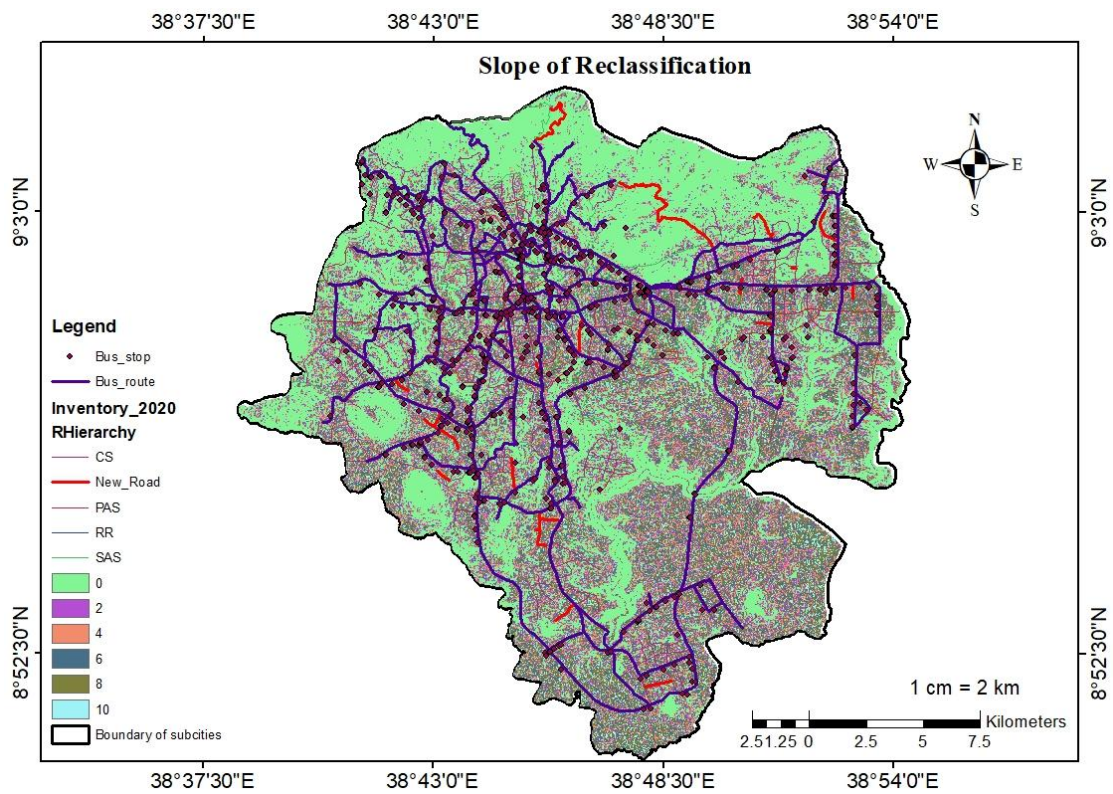
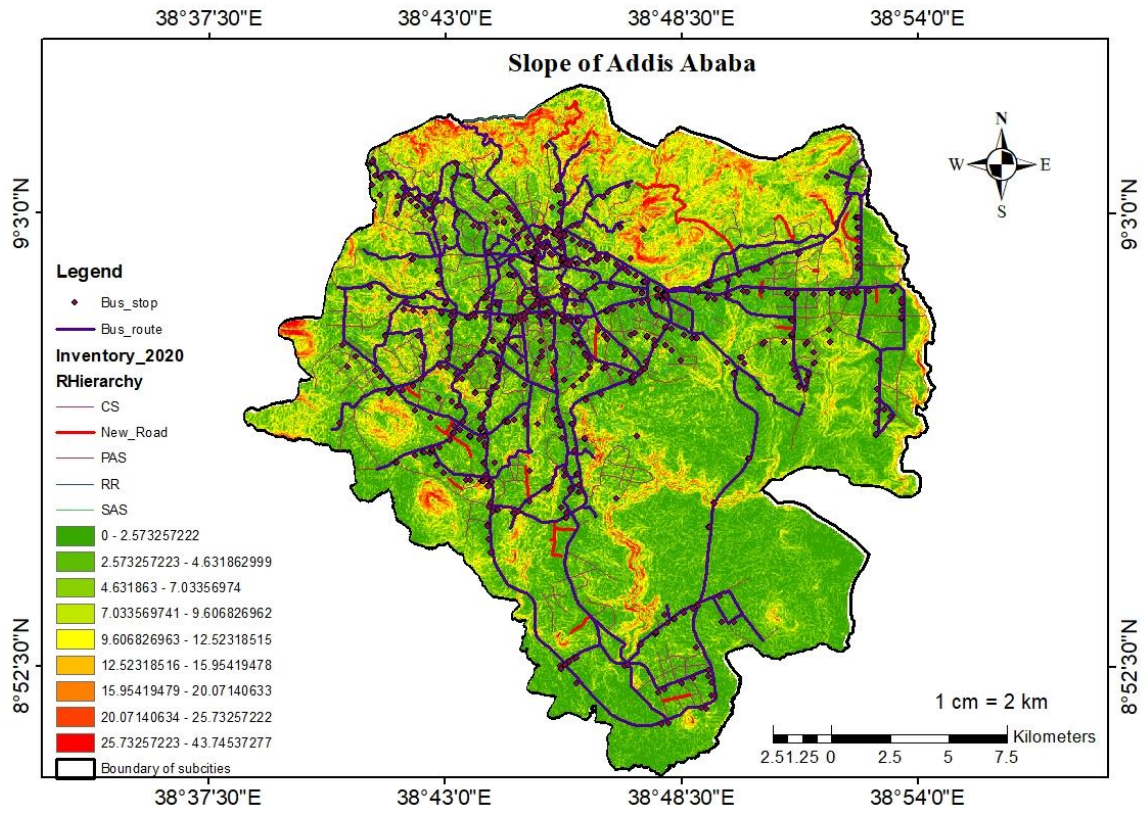


**Figure D-6: Road Density of Addis Ababa**

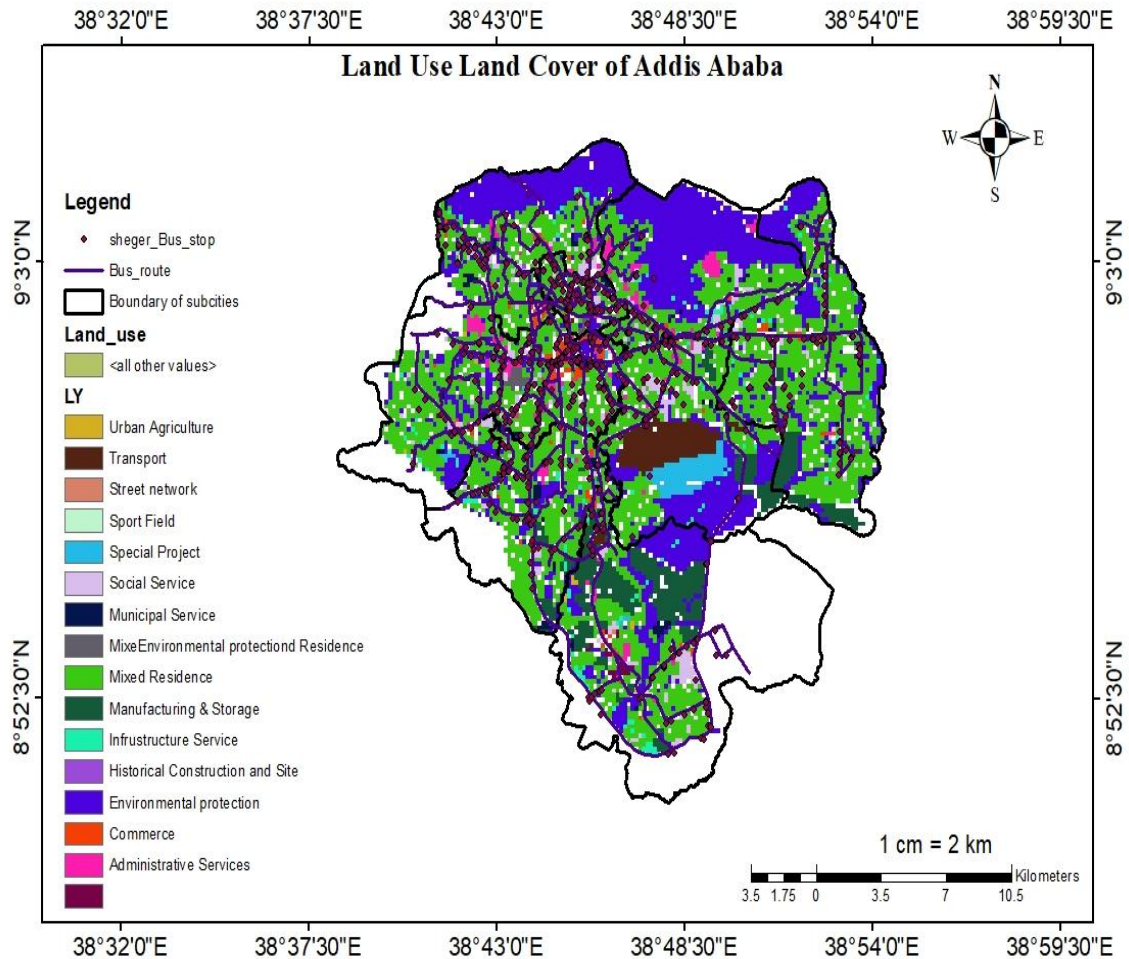
## ANNEX E EXISTING DEM AND POPULATION OF ADDIS ABABA WITH RASTER AND RECLASSIFICATION



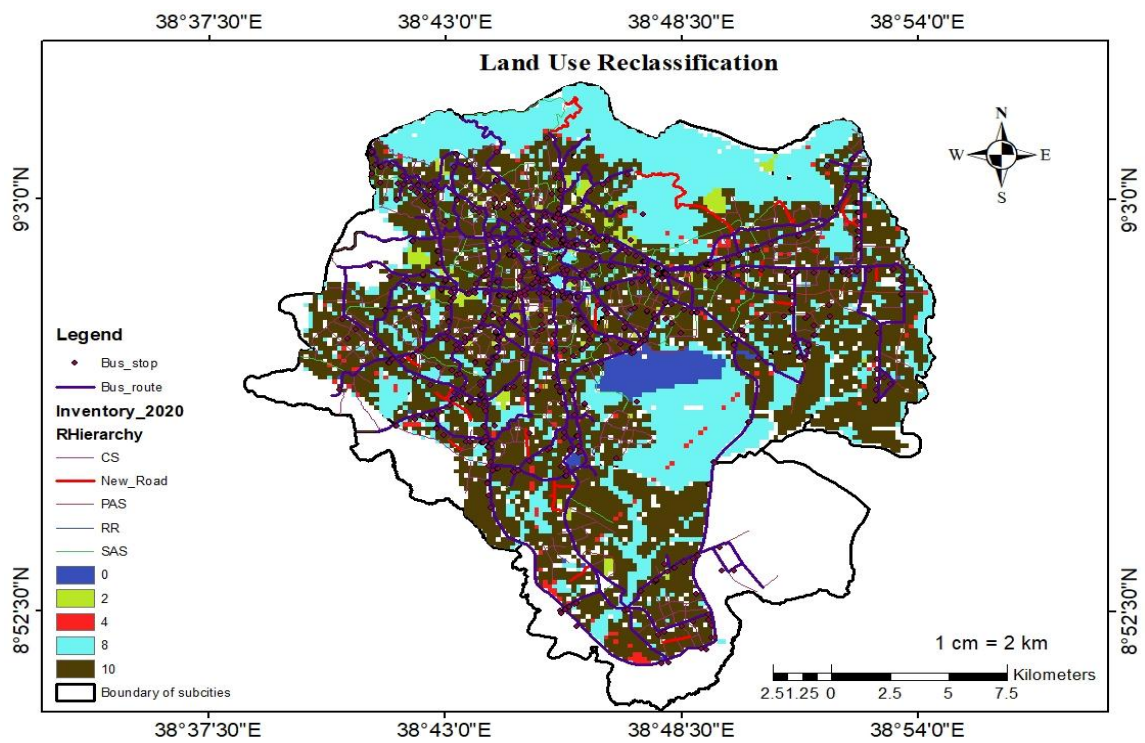
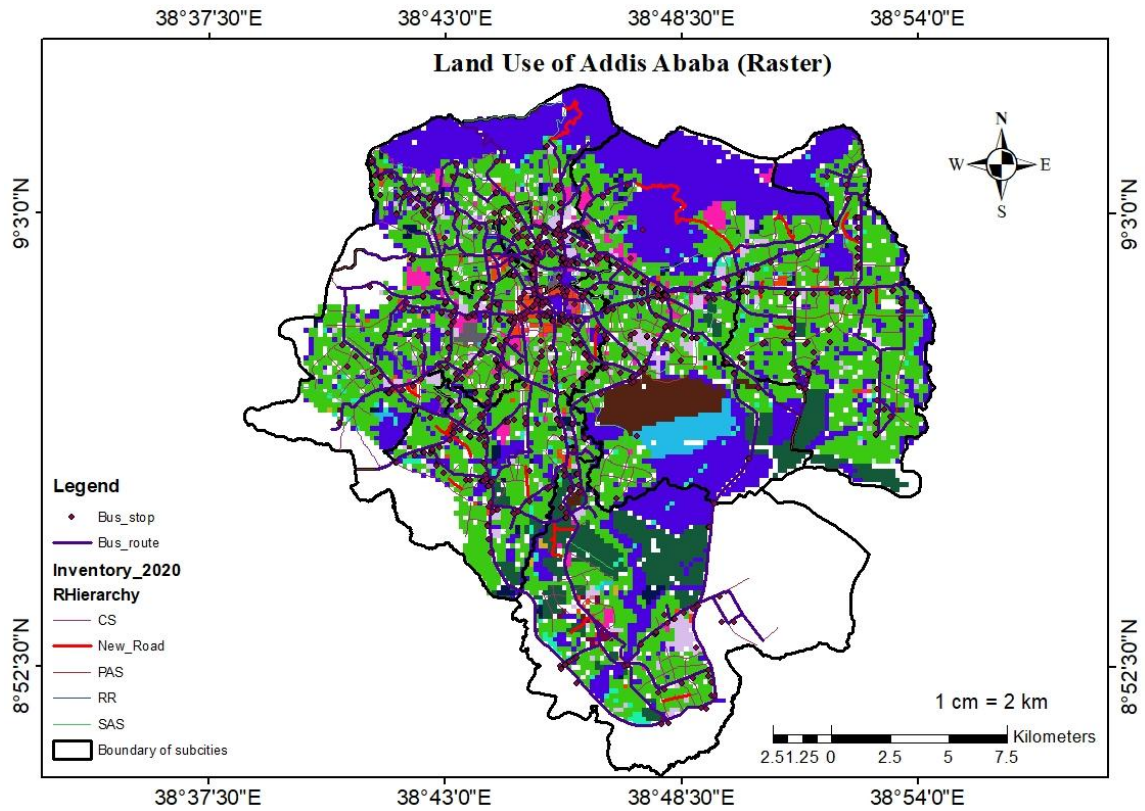
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## ANNEX F LAND USE AND LAND COVER OF ADDIS ABABA WITH RASTER AND RECLASSIFICATION

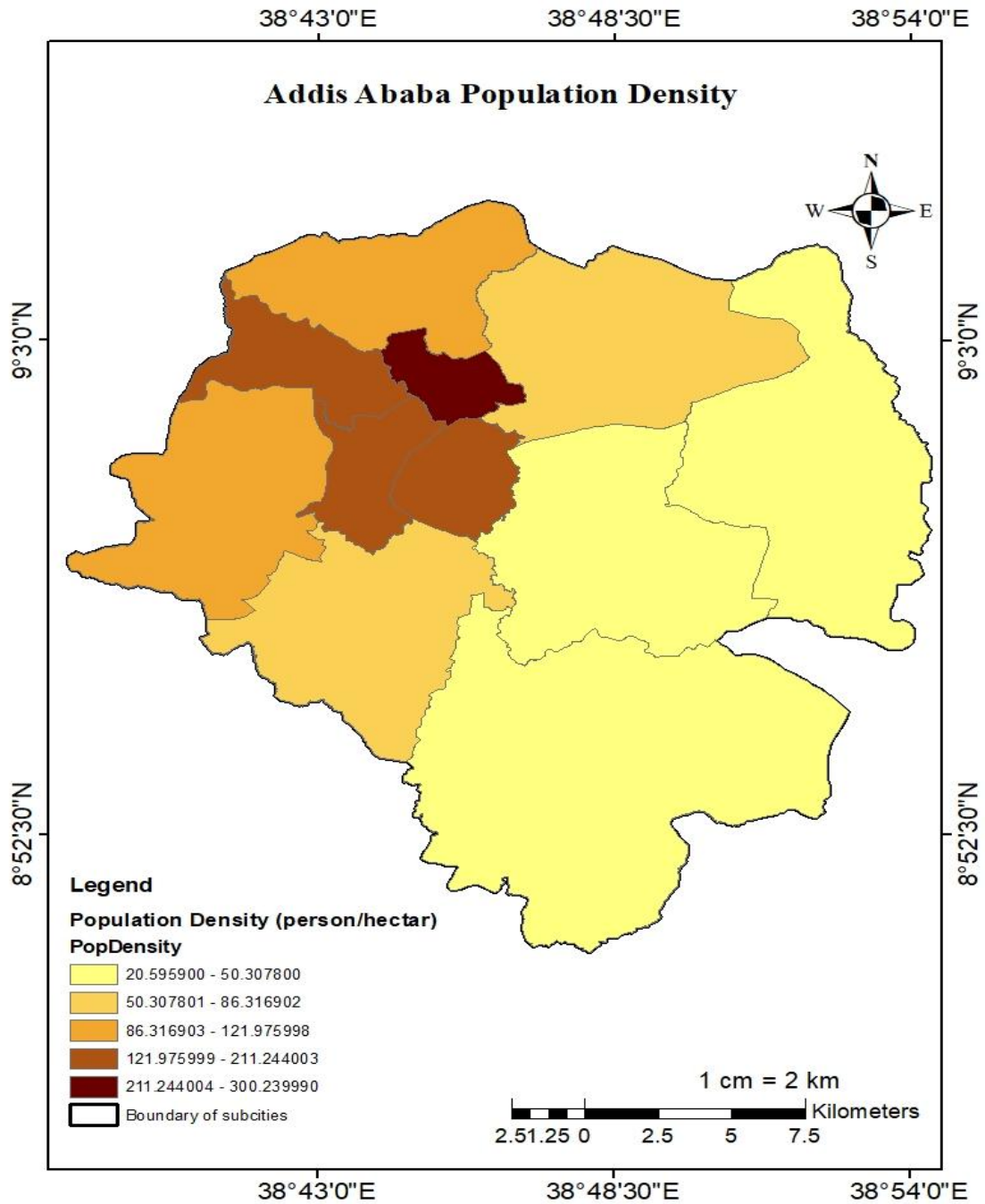


Assessment of New Roads Accessibility for Public Transportation Using GIS Addis Ababa, Ethiopia





## ANNEX G EXISTING POPULATION DENSITY PER HECTAR OF ADDIS ABABA WITH RASTER AND RECLASSIFICATION



# Assessment of New Roads Accessibility for Public Transportation Using GIS Addis Ababa, Ethiopia

