GIS Based Road Network Analysis: In the Case of Gondar City, North Gondar, Ethiopia

Anbaw Tigabu Nibret
Lecturer at Kebri Dehar University, College of Social Sciences and Humanities
Department of Geography and Environmental Studies

Abstract
Road network has been view as a major dynamic force in influencing quality of life and shaping cities all over the globe. Network analysis is an operation in GIS, which analyses the datasets of geographic network or real world network. Network analysis examines the properties of natural and manmade network in order to understand the behavior of flows within and around such networks and location analysis. The major problems of road network are poor road quality, a lack of pedestrian walkways, a low accessibility level, and narrowness. Lack of segregated bikeways, insufficient street parking, excessive use of off-street parking, poorly built road intersections, inadequate terminals for passenger and freight transit, difficult bus and taxiways, and a lack of adequate road network relative to the size of the city. Then to solve this problems this project to develop the main of objective of analyzes the road network in the study area. This project used primary and secondary sources of data, the primary data GPS point's field observation and the secondary data received road network data from Gondar city municipality office. Based on these data the projectors develop different road connectivity models including the shortest route selection model to selection of closest facility service area. In addition to this the results show that the highest road network connectivity and accessibility area of the study Marakie subcity is the first ranked and the lowest ranked sub-city is Jantekel due to connectivity measurement parameters.
Keywords: Road network, Road network Analysis, connectivity, accessibility, route, model
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1. Introduction

1.1 Background of the Study

The city's lifeblood and a crucial part of urban infrastructure is the transportation system. It is essential to that region's economic development. It also demonstrates the region's economic situation and the commitment of the planners to the area ((Arora & Pandey, 2011; Zuidgeest & Huisman, 2012).

We collected, standardized, and merged almost 60 geospatial datasets on road infrastructure into a worldwide roads dataset as part of the Global Roads Inventory Project. Over 21 million km of roads make up the resulting collection, which spans 222 nations and is two to three times longer than the finest country-based global roads datasets currently available (Meijer et al., 2018). However, the total length of roads in African nations was only about 2.06 million km in 2001, giving the continent a road density of 6.84 km per 100 sq. km. There is a significant geographical diversity despite the continent's average road-to-population ratio of 26 km per 10,000 people. The highest road density was found in Central and Southern Africa, with 49.5 and 56.3 kilometers of roads per 10,000 inhabitants, respectively. Only 580,066 km, or 22.7%, of Africa's total road network were paved in 2005 (Fekadu kassa and Tegegn Gebre Egiziabeher, 2013).

In recent years, the Ethiopian government (GOE) has steadily increased the size of its road system. Ethiopia had 138,127 kilometers (85,825 miles) of all-weather roads as of the end of 2018–19, representing about 39% of the needed road network in the nation. In the upcoming year, the Ethiopian Roads Authority intends to construct 10,000 extra kilometers of road at a cost of 41 billion Birr ($1.24 billion). Through Ethiopia's Road Sector Development Programs (RSDP), the GOE has been actively engaged in new road building as well as the expansion of the existing road network over the past fifteen years (Dar, 2018).

Every nation's economic development depends in large part on its road networks. To provide reliable connections between the various areas of a geographical territory, it is vital to foresee a deliberate and continuous expansion and adequate maintenance of these networks. They make it possible for people to access jobs, institutions of higher learning, hospitals, and other facilities around the world. By raising standards of living and enhancing country effectiveness and efficiency, road infrastructure makes people's lives easier (Aparco-cardenas et al., 2022).

The urban road network is crucial to the urban spatial organization; claim (Weiping & Chi, n.d.) (2018). It is the primary provider of transportation and social-economic activity in the city. More and more experts are now focusing on the road network. How to assess the accessibility of the road network is one of the most significant issues.

Recent years have seen a rise in the popularity of geographic information system (GIS) technology as a research tool and as a high-tech monitoring tool (Kumar & Kumar, 2017). It has been demonstrated to be reliable and effective for addressing issues in the real world, such as responding to and handling emergency circumstances (Ahmed et al., 2016). An information system that is relating to a specific location on the surface of the planet is known as a Geographic Information System (GIS). It consists of computer software, hardware, data, and employees that enable data entry, manipulation, analysis, and presentation. This system's components software, hardware, data, and personnel—allow for the entry, manipulation, analysis, and presentation of information related to a specific location on the surface of the earth (Ali, 2020).

Network analysis is helpful for organizations that manage or use networked facilities, such as utility, transmission, and transport networks, according to Kumar & Kumar (2017). Businesses utilize networks to plan and optimize the distribution of goods and services, whereas municipal public works departments use them to model, analyze bus and waste routes. Planning for retail stores can also include network analysis. For instance, the determination of retail shop trade regions can be aided by the solution of the driving times. Therefore, network provides the movement of people and goods, the delivery of services the flow of services as well as communication of information. Three Principal types of network analysis are network tracing, network routing and network Allocation.

A network is a linked collection of lines that represents a particular geographic occurrence, generally one related to transportation. Almost anything can be carried as "items," including people, cars, and other vehicles over a road network, commercial goods via a logistic network, phone calls along a telephone network, and water pollution along a stream/river network. This kind of analysis looks at the effectiveness of networks like the road system, utilities, infrastructure, power, and sanitation, and other networks' tracks (Edges, Joints) are represented by distinct forms of search (Sarkar, 2013).

Network analysis aids in determining the best locations to deliver services (Sabitha, 2013). The theoretical underpinnings of the mathematical sub-disciplines of graph theory and topology form the theoretical bedrock of network analysis in GIS. The networks that a large portion of the public regularly interacts with are representing by the most popular and well-known network implementations: the transportation and communications networks (Sabitha, 2013).

Network analysis is an operation in GIS, which analyses the datasets of geographic network or real world network. Network analysis examines the properties of natural and manmade network in order to understand the behavior of flows within and around such networks and location analysis. It focuses on edge-node topology to represent real life networks of information. Its function based on the mathematical sub disciplines of graph theory and topology (Team et al., n.d.).

In Gondar, city road networks are importance for different purpose, that means importance for connectivity of different location and produce linkage of the area or place in the sharing of goods and services between the people. Then due to this reason, this project analyze the road network connectivity and accessibility of Gondar city by using GIS software and operation for the development of route selection model, closest facility service area and the analysis the sub-cities road connectivity and accessibility between them.

1.2. Statement of the problem

One of the main obstacles to Africa's economic growth and competitiveness in the global market is the high cost of transportation. The Ethiopian government has prioritized the development of the road sector in its development strategy and has carried out two significant road programs for sector growth from 1997 to 2009. In this time frame, the number of roads per The area of 1000 km2 has increased by more than 70%, and the percentage of roads that are good and serviceable Additionally, the percentage of conditions has increased from 22% to 54% (Shiferaw et al., 2012).

The Gondar city road network, according to Zuidgeest & Huisman (2012), has a number of deficiencies, including poor road quality, a lack of pedestrian walkways, a low accessibility level, and narrowness. Lack of segregated bikeways, insufficient street parking, excessive use of off-street parking, poorly built road intersections, inadequate terminals for passenger and freight transit, difficult bus and taxiways, and a lack of adequate road network relative to the size of the city. The primary factors causing these issues include a lack of facilities, particularly in the road and public transportation networks, a lack of interaction between land use and transportation planning, and a lack of coordination between city planning for urban development and road transportation. The majority of the city's outlying areas suffer from the aforementioned issues. There are locations that provide agricultural goods for the city and newly constructed real estate.

Then network Analysis any method of solving network problems such as Travers ability, rate of flow or capacity using network connectivity .It is use for identifying the most efficient routes or paths for allocation of services. This involves finding the shortest of least-cost manner in which to visit a location or a set of location in a network such as people, resources, and goods tend to travel along networks: cars and trucks travel on roads in Gondar city.

1.3. Objective

1.3.1 General Objective

The main objective of this project is to analyze the Road network of the Gondar city using GIS.

1.3.2 Specific Objective

In order to achieve the general objective, this project establishes the following specific objectives:

- ✓ To identify the connectivity and accessibility parameters of road network in the study area.
- ✓ To create a road network-based model for the research area's transportation demand.
- ✓ To create a map that displays the network analysis of the study area's roadways, including the best path and the closest facility.

1.4. Significance of the project

This project would be significant in identifying the indicators that are used to analysis the current road network structure of the Gondar city. It would be identify the city road connectivity and accessibility, to use the reference for the further studies to analysis the shortest facility service area, and cost minimizing route selection systems. In addition, it can be use as a reference for further studies. The city road authority may use it as a reference while they are preparing their route map.

1.5. Scope of the project

This project focused on Gondar city to analysis the road network mainly emphasizes on the road network coverage of both central area of city. GIS is a spatial technique, which is particularly use in this project. The parameter used by this project to analysis road network and prepared of shortest or closest facility service areas, route and OD cost facility matrices models.

2. Material and methods

2.1. Description of the Study Area

The city of Gondar is located in the Amhara Regional State in Northwestern Ethiopia. Its coordinates are 37° 24' 0″-37° 30′ 00″ E and 12° 32' 00″-12° 38′ 00″ N. Gondar is situated 120 kilometers from Bahir Dar, the capital of the Amhara National Regional State, and 727 kilometers from Addis Ababa, the seat of Ethiopia's federal government. Gondar has a total size of 192.3 km2, and its geography is rugged and undulating. Gondar has 50, 817 dwelling units, according to the 2007 National Population and Housing Census. The North Amhara region's political and economic activities are center in Gondar, which is also the largest city in the North Gondar Zone. The city is divided into 12 administrative sub-cities, each of which has its own judicial, executive, and legislative branches(Tegegne et al., 2020).

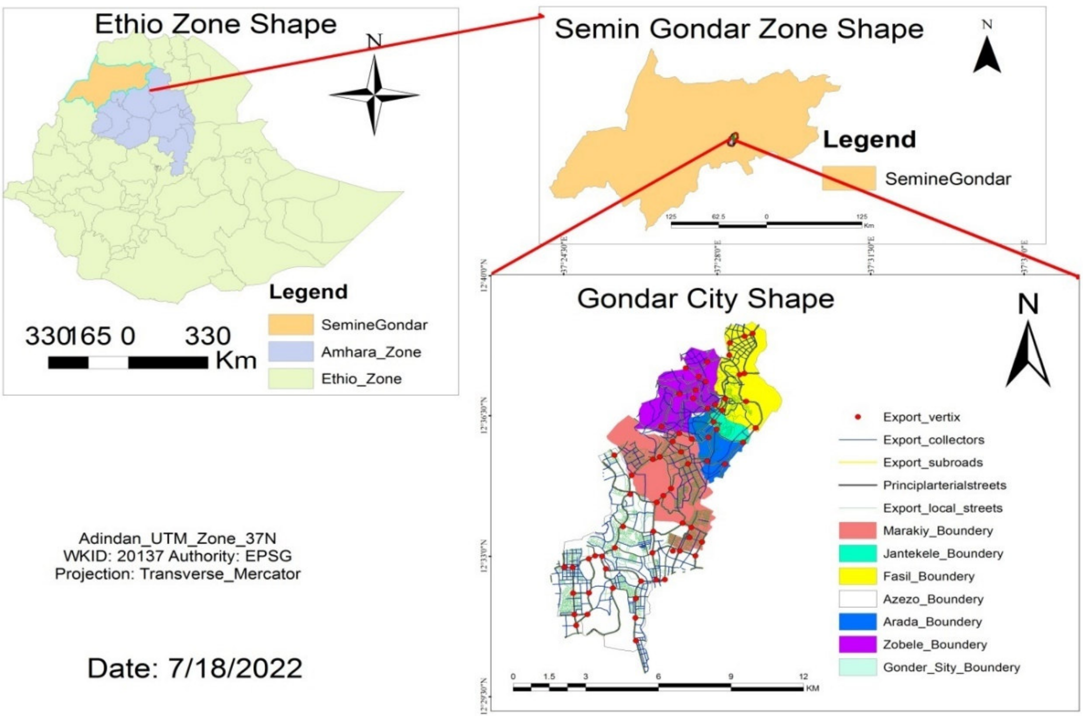


Figure 2.1 map of the study area

Source; ArcGIS 10.3.1

According to Ferde (2011), Gondar, the imperial capital of Ethiopia, is said to be centered on a collection of castles constructed in the 17th and 18th centuries. Gondar's son, Fasiledes, the son of Gondar's founder, Susenis, considerably extended the city in 1635. Fasiledes imported workers from Portugal, India, and maybe Turkey to Gondar for building his palace. The city of Gondar is located in the hills of northern Ethiopia along a ridge. The historic capital of Ethiopia from 1632 to 1868 was Gondar. Additionally, Gondar's city government is divided into 6 sub-cities.

Gondar has a rich cultural heritage today thanks to the presence of the remarkable historic heritage of the Fasiledes castle, stunning churches like Debre Birhan Selassie, and other age-old heritages. Gondar is noted for its intangible heritage in addition to its tangible heritage, and it has functioned as a tourist destination like Timqet (epiphany). These historical sites have been recognizing as UNESCO (United Nations Education, Science, and Culture) world heritage sites since 1979 (Firdyiwok, 2012). Gondar is currently the administrative center for Central Gondar in the Amhara regional state. The CSAG office reported that there were 750,044 people living in Gondar overall. 90.2 percent of the population identified as Ethiopian Orthodox Christians, 8 percent as Muslims, and 1.1 percent as Protestants. The majority of residents professed Ethiopian Orthodox Christianity.

The commercial and touristic center of North-West Ethiopia is Gondar. Fasiledes Castles, located inside the city, and Semen National Park, which is 120 kilometers to the north-west of Gondar, are two of the city's many tourist attractions. The hotel and tourism industries contribute significantly to the city's revenue. Another important economic activity in Gondar is trade. The surrounding regions, such as Metema and Humera, which grow cotton and sesame, are responsible for the city's success in trade. Manufacturing, in comparison, not only contributes the least to its GDP (only 7%), but also creates the fewest jobs (Tegegne et al., 2020).

Biophysical characteristics: The projected population for major Ethiopian cities in 2015 indicates that Gondar will have a total population of 750,044 (CSA, 2015 as cited in Animut, Eden, Bayew, &Zelalem, 2020). There are 22 kebeles in the city (the smallest administrative unit). This city is one of the oldest and most populous in the nation. Eight public health centers and one referral hospital are currently available in Gondar. The city is located at an elevation of 2,200 meters, and a crown of mountains rising to 3,000 meters high surrounds it on three sides. Its climate is classified as zone, with an average annual temperature of 20°C and rainfall of 1,172 mm. Its total area is 11.058 square kilometers (Gondar city communication office, 2022). To the south, the landscape opens to a valley and distant views of Lake tana, source of the Blue Nile.

The rainfall pattern in Gondar City is unimodal, as shown by a single maximum rainfall pattern with maxima in July and August, according to data from a meteorological station. Summer, which lasts from June/July until August/September and represents 80% to 90% of the mean annual rainfall, is the main rainy season. Rainfall varies significantly over time, especially during the beginning and end of the main rainy season. Rainfall data spanning 51 years indicates that Azezo Airport experiences an average yearly precipitation of about 1,172 mm. The yearly temperature ranges from 12.9 to 26.40 c. (Ferede, 2011).

2.1.1. Road Network

Road Network means all types of roads, including international roads, national highways, district roads, feeder roads, urban roads, mule tracks/ trails. Roads not under the authority of the Department, such as but are not limited to forest roads, farm roads, power tiller roads, telecommunications road, power roads, mining and exploration roads, industry roads, health roads, education roads, public roads, private roads, project roads and all the types of bridges on that road.

A Road Network is a system of interconnecting lines and points on a map that visualize a system of streets for a certain area. It always comes with analysis, where one can study the best route for travelers and the ideal place to build service areas.

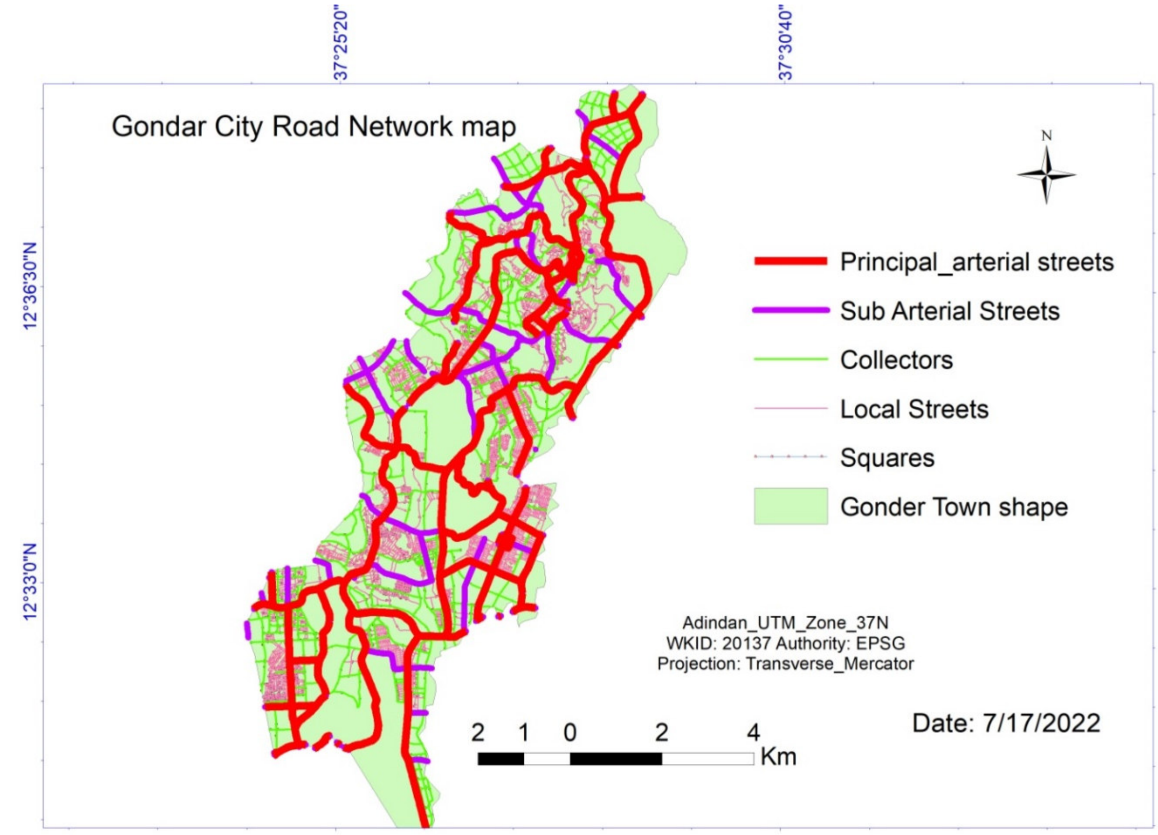


Figure 2.2 Road Network and hierarchy
Source;arcGIS10.3

According to (Zuidgeest & Huisman, 2012), A road hierarchy is a means of defining each roadway in terms of its function such that appropriate objectives for that roadway can be set and appropriate design criteria can be implemented. There are four level road hierarchy, as presented herein, expands the use of the road hierarchy as a tool for a broad spread of uses ranging from network/land use planning to asset management.

Road hierarchy, a usual measure and form of classification of road in which each kind of roads has a ranking with respect to the whole set of kinds, is a vital part of the design of urban road network (Ye et al., 2015).

Based on the explanation, there are four-road hierarchy are available in Gondar town, these are:

Principal arterial streets or arterial roads: As per the master plan, these roads varying with width range from 30m to 60m. These roads are expect to provide fast movement of traffic due to physical segregation of local and bus/public vehicle traffic from the general traffic stream. Due to traffic movements, it has high capacity road that carries longer distance traffic movements or flow between important centers of activity. It has the primary freight and dangerous goods routes and regional cycle movements (off road) (Eppell et al., 2001).

Sub_arterial streets or roads: These roads are links of lower hierarchy with proposed the widths of 20m to 25m. The sub-arterial roads are operates as single or dual carriageway roads with constrained lane widths of 3m, having direct implication with the speed and capacity. These roads seem to be of lower width than expected for the nature of traffic operation expected from roads of this category(Zuidgeest & Huisman, 2012). Additional characteristics of these roads are to connects between local areas and arterial roads, connections for through traffic between arterial roads, access to public transport, through movement of public transport regional – local cycle movements (off road) and pedestrian movements (Eppell et al., 2001).

Collector streets: Collector streets are located within the specific area, providing indirect and direct access for land uses within the specific area to the road network. These streets should carry no traffic external to the specific area. The environmental cells within the specific area are bounds by the collector streets, and contain local streets with low speed environments and pedestrian priority. Their function is to provide direct property access. Within environmental cells, considerations of amenity and environment dominate. The width of these roads are proposed 15 meters (Ye et al., 2015).

Local Road or Street means and refer to local roads or streets accepting traffic from collector streets and distribute the traffic through subdivisions, neighborhoods and business areas to individual homes, apartments, business sites, and industrial sites.

2.2. Methods and Material Used

GIS is increasingly becoming the useful tools for the analysis of road network for the connectivity of different place and the showing of the shortest road service or rout path in the world. For the network analysis of Gondar city, a street base map is added in Arc GIS software from the Google Earth satellite imagery or city municipality and geo-referenced to get the co-ordinates. Geo-referencing involves image alignment in a co-ordinate system.

2.2.1. Data acquisition

Before the data use in this project, the data are useful the types of data and the availability of the data evaluating before starting of the project work. In this project, use both primary and secondary data acquisition methods. The primary data are collecting from Gondar town administrative office and collecting of data by using GPS. In addition, other hands secondary data are use arc GIS software, documenting shape file of road network and download from Google earth.

2.2.2. Data Preparation

After, gathering all the necessary data the first equipment is to prepare the data for analysis. Since data collected from different sources and period, converting them to some form and analysis period is essential to obtain the accurate result. This is doing by unifying the data and changing the data format to building the road network. Using the GIS software to analysis, the available data of road network in the study area by correct the coordinate system of the road shape file WGS1984 in the zone of 37 in Ethiopia.

Flow char of Method of the project

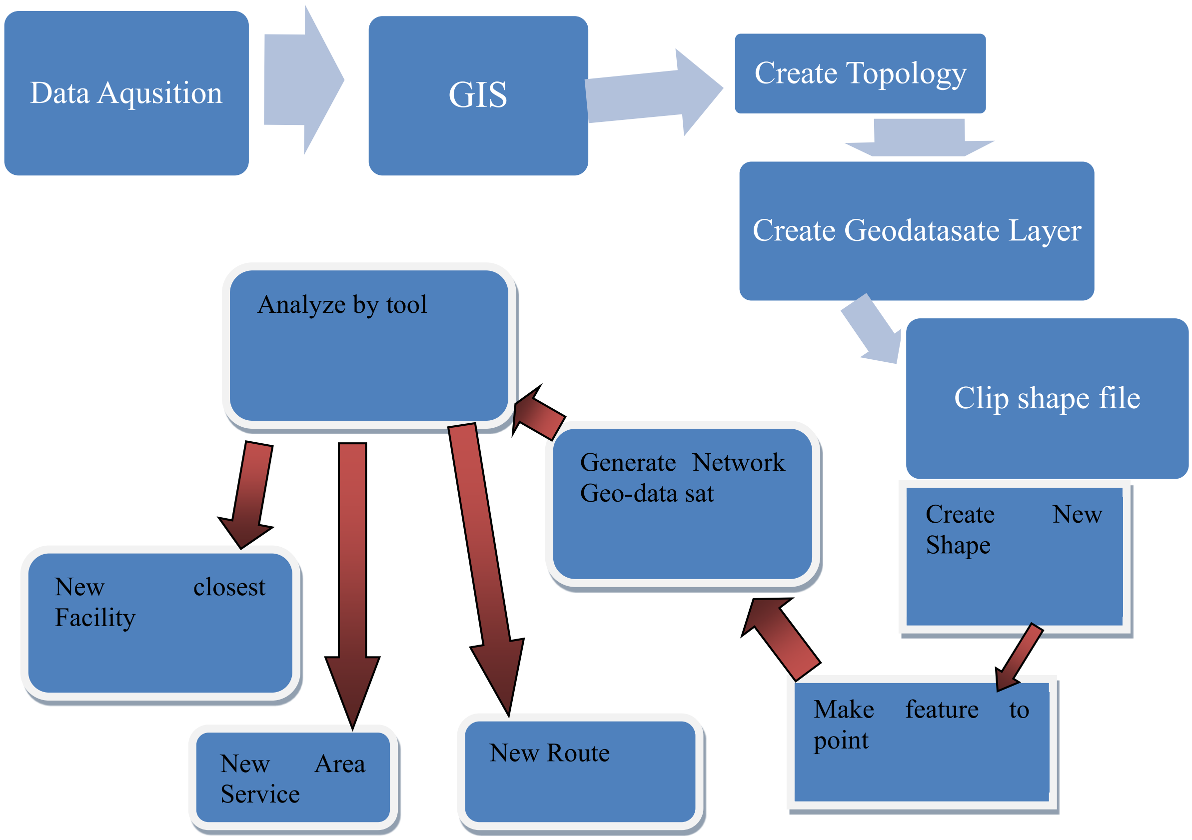


Figure 3.3 Flow char of Method of the project

2.2.3. Building of Network modeling

A formalization that enables the modeling of key elements of a road network's infrastructure is the road network data model. Such a notation might be use to build the infrastructure schema for the road network. Then, as information is adding to this schema, a representation of the components of a specific road network may be creating (Ahmadzai et al., 2019; Arora & Pandey, 2011).

The core purpose of a network data model is to provide an accurate representation of a network as a set of links and nodes.

A network model is a database model that is designing as a flexible approach to representing objects and their relationships. A unique feature of the network model is its schema, which is viewed as a graph where relationship types are arcs and object types are nodes.

2.2.4. Routing Model

Network data models are use to find optimal paths and assign flows with capacity constraints in a network. This requires a topology in which the relationship of each link with other intersecting segments is explicitly specify. Impedance measures (e.g. distance) are also attribute to each link and will have an impact on the chosen path or on how flows are assigned in the network (Arora & Pandey, 2011; Das et al., 2019; Mohammed et al., 2017; Nicoară & Haidu, 2014).

This project use different secondary and primary data are gathering and analysis in order to achieve the objectives of this project. Temporally sequential maps, documents and different related project works are consulting. In order to get the data adequately analysis and presenting, different analytical techniques and indices are employing. Firstly, the existing topological maps are digitization by using Arc GIS tools (Das et al., 2019; Deresso & Mesfin, 2022). The spatial extent of areas and lengths of each road segments are computed from the digitized by using Arc GIS techniques. Similarly, Arc GIS tools are uses to exactly identify and quantify the nodes and arcs of roads in the region. Then the nodes and arcs are carefully count to compute the Beta Index, the Cyclometer Number, and the Gamma Index, the Alpha Index, Shimbel Index and the road density of the region (Sarkar, 2013).

2.3. Methods of Data Analysis

2.3.1. Connectivity and accessibility model of road network

This project has use two evaluation indicators to establish my model:

1. Accessibility index

It is a normalized index for the shortest travel time and the weighted average travel time. The formula is:

$$\mathrm{Ai} = Ai/[\sum_{i=1}^{n} \mathrm{Ai/n}\,]$$

In the formula, Ai is the accessibility index; Ai is one node's accessibility value; ' $\sum_{i=1}^{n} \mathrm{Ai/n}$ is the mean value of accessibility.

2. Connectivity

The study availed graph theory measures like alpha index (α), beta index (β), gamma index (γ), Cyclomatic number (μ), and ATS to analyze the road network connectivity. These measures are quantified for all locations at each radius. The greater value of these indices, the higher the connectivity of the road network. ATS is the sum of the alpha index, beta index, gamma index, and Cyclomatic number. Therefore, ATS can be able to interpret the overall connectivity of a region or location (Sahitya & Prasad, 2021).

Beta Index (β)

One of the simplest measures of connectivity is beta index (β) which can be found dividing the total number of arcs of a network by the total number of the nodes. Beta index ranges from 0.0 to network which consist just of nodes no arcs. If the value of beta index is greater than 1, the networks are well connected and higher values indicate higher the complexities of the networks.

$\beta = \frac{\mathrm{e}}{v}$ Higher values indicate more connectivity.

Alpha Index (α)

The alpha index is a ratio measure of the number of the actual circuits, to the maximum of in a given network. The range of the index is from a value of 0 for a minimally connected network to a value of 1 for a maximally connected one. The district has been divided into four regions based on obtained alpha values.

$\alpha = \frac{e-v+1}{2\mathrm{v}-5}$ The Higher values indicate more connectivity.

Where, V is a set of vertices and E is a set of edges.

Gamma Index (γ)

Connectivity as measured by the Gamma index is expressed in terms of a graph theoretic range, that varies from a set of nodes having no interconnection of one centre to a set of nodes in which every node has an edge connecting it to every other node in the graph (Shing, 2003). Simply Gamma index is a ratio between the observed number of edges and vertices of a given transportation network. The numerical range for the Gamma Index is between 0 and 1. Higher the value indicates higher the development of network.

$\gamma = \frac{e}{3(v-2)}$ The Higher values indicate more connectivity.

Where, V is a set of vertices and E is a set of edges.

Cyclomatic Number (μ)

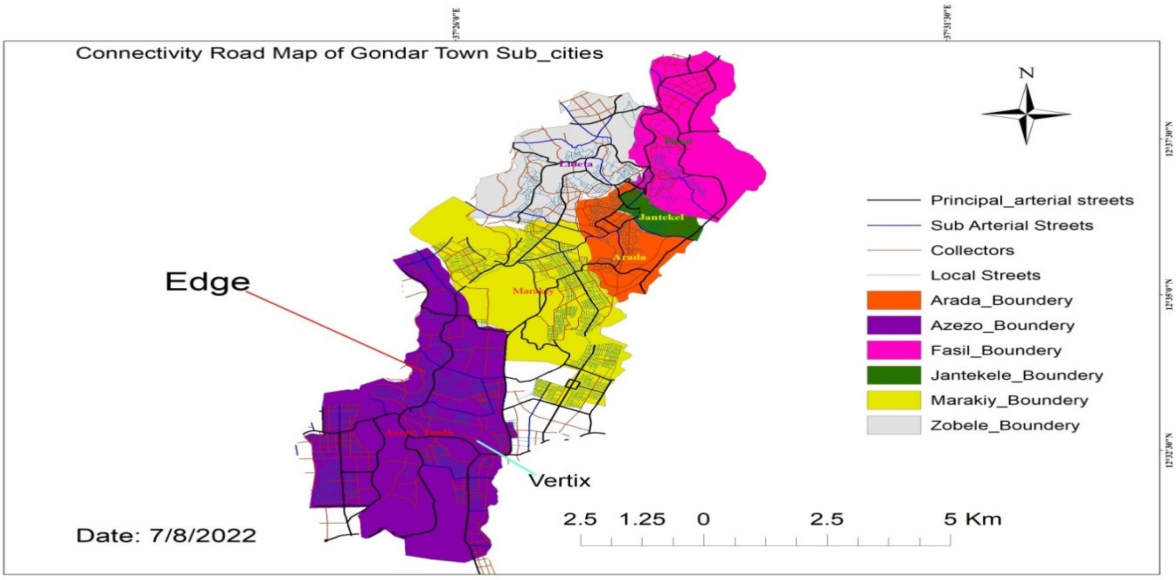
The cyclomatic number is based on the assumption that once a connected network has enough arcs or links to form a tree, additional arcs will result in the formation of circuits. The cyclomatic number 0 indicates a tree-type graph, whereas as the graph gets closer and closer to the completely connected state, the cyclomatic number increases. A disadvantage of this method is that networks with very different forms may have the same cyclomatic number (J.-P. Rodrigue et al., 2019).

$\mu = e - v + 1$ The Higher values indicate more connectivity.

Where, V is a set of vertices and E is a set of edges.

Shimbel index is the sum of the values for each row in accessibility short path matrix, which is more powerful than the associated number.

Figure 2.4 Road network connectivity by edge and vertex



Source; arcGis software10.3.1

2.4 Types of Materials to be use

Types of software I have use road network analysis are ArcGIS10.3.1, for creating shape file, analysis of road network and for produce the black spot location map, GPS Collecting X,Y and Z data of historical site point and Google earth for Generating of land use land cover. In addition, the software used for this project is mendeley desktop for the use of reference or citation system.

3. Results and Discussion

The Arc GIS Network Analyst extension allows you to solve common network problems, such as finding the best route across a city, finding the closest emergency vehicle or facility, identifying a service area around a location, servicing a set of orders with a fleet of vehicles, or choosing the best facilities to open or close. The key to network representation is to represent nodes, arcs and network topology efficiently. Once the nodes, arcs, and network topology are efficiently represent, other data and information associated with nodes, arcs, stops and turns can be represent as attributes associated either with nodes or with arcs. When a geometric network is created, ArcGIS9.3 also creates a corresponding logical network, which is used to represent and model connectivity relationships between features (Das et al., 2019; Fadlalla et al., 2016).

In this section, I can be discuss the road network in Gondar town by using GIS tools (Arc map, Arc catalogue, arc toolbox) to analysis the road network. The road networks are analysis using accessibility measurements, connectivity measures (alpha, beta, and gamma and cyclomatic index), weighted average travel time, selecting of short distance or routing road and building of the model of road network.

3.1 Model

According to (Duran-Fernandez & Santos, 2014), model is useful for estimating the shortest route between any two points linked to the road system. Model estimates the average speed for every section on the network according to its hierarchy (Principal arterial streets or roads, sub arterial streets or roads connecting inner cities with the peripheral sub cities. Moreover, between the main centers and their feeders, and two main routes connecting the Azezo sub city Marakie and the 4 sub cities with the each others).

3.1.1 Connectivity and Accessibility Road Network Model

Accessibility is a place's convenience degree, which arrives from other place. It can be a spatial distance, topological distance, trip distance, travel time or transportation costs. The accessibility has both spatial and time features. It displays the convenience degree of a place as a spatial entity. Moreover, time is the main impedance factor of accessibility (Arora & Pandey, 2011; Wang et al., 2021).

There are many evaluation indicators are propose by project. I have use three evaluation indicators to establish the model:

Graph: A graph G is a set of vertexes (nodes) v connected by edges (links) e. Thus G = (v, e). Vertex (Node), A node v is a terminal point or an intersection point of a graph. It is the abstraction of a location such as a city, an administrative division, a road intersection or a transport terminal (stations, terminuses, harbors and airports). Edge (Link), an edge e is a link between two nodes. The link (i, j) is between initial extremity i and terminal extremity j. A link is the abstraction of a transport infrastructure supporting movements between nodes. It has a direction that is commonly represent as an arrow. When an arrow is not used, it is assume the link is bi-directional (J. P. Rodrigue et al., 2016).

3.1.2. Connectivity and connectivity model

Network model is a line graph, which is composed of links representing linear channels of flow and nodes representing their connections. In other words, a network takes the form of edges or arcs) connecting pairs of nodes or vertices). Nodes can be junctions and edges can be segments of a road or a pipeline. For a network to function as a real-world model, an edge will have to be associated with a direction and with a measure of impedance, determining the resistance or travel cost along the network(Thesis, 2007).

Connectivity: Transport terminals provide connectivity within a transport network, as they are the only locations where a network can be entering or exit. For instance, subway stations are the connecting elements of a transit network (J.-P. Rodrigue et al., 2019).

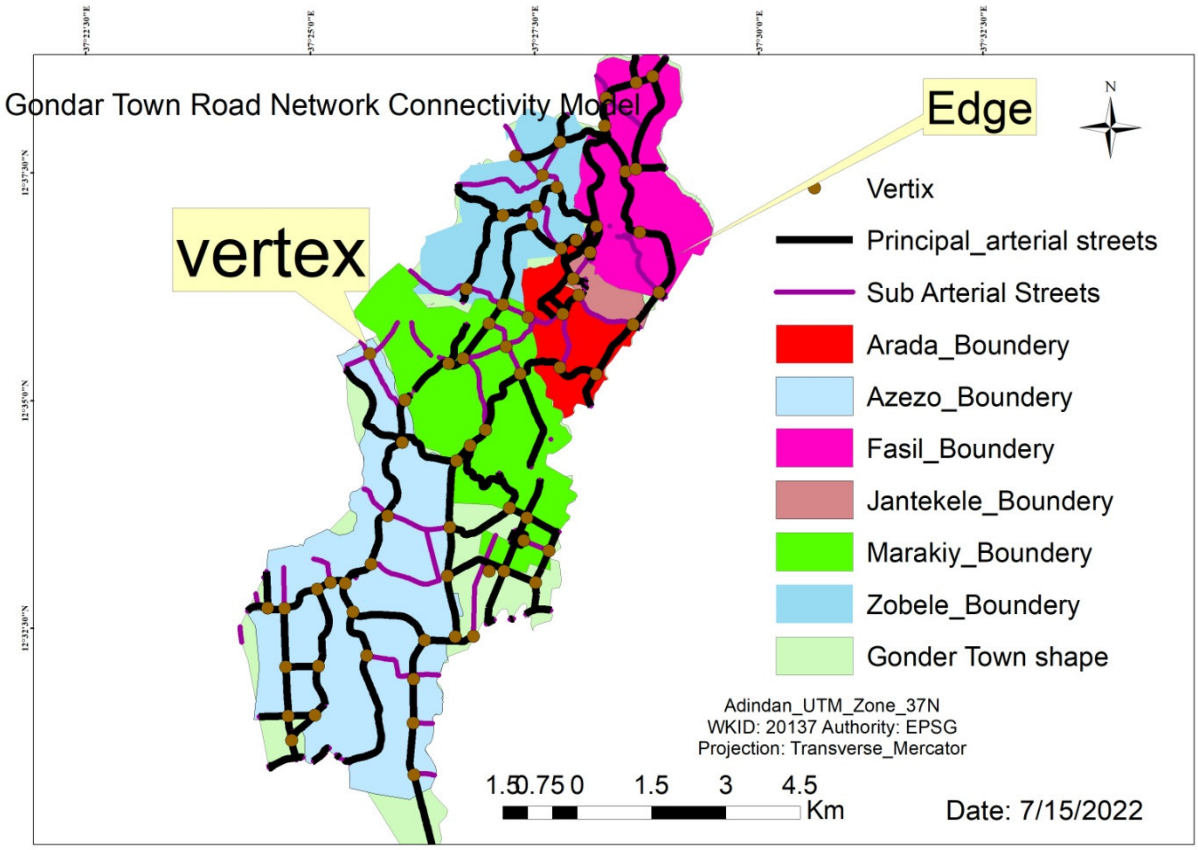


Figure3.1 Road Network connectivity model

Using the figure 3.2, calculate the road connectivity of Gondar sub-cities by using the alpha index, beta index, gamma index, cyclomatic index and shimbel. I have counted the edge and vertex from the road network of Gondar city. The highest value of the index it has the highest connectivity of road, but the lowest value indicate the lowest road connectivity. Then calculate the index value of the road by using the table below.

Table, 3.1 Gondar sub city road network connectivity table

No	Sub_city Name	Node	edges	Alpha(α) Index	Beta(β) Index	Gamma(γ) Index	Cyclomatic(μ) Index	Shimbel Index
1	Zobele sub city	11	17	0.41	1.54	0.407	7	9.357
2	Azezo sub city	27	35	0.18	1.29	0.466	9	10.936
3	Marakie sub city	15	27	0.52	1.8	0.69	13	16.01
4	Arada sub city	8	11	0.3636	1.37	0.733	4	6.466
5	Jan Tekel sub city	4	6	1	1.5	1	5	8.5
6	Fasil sub city	13	22	0.476	1.69	0.666	10	12.83

Beta index; According to (J. P. Rodrigue et al., 2016), beta index measures the level of connectivity in a graph an d is expressed by the relationship between the number of links (e) over the number of nodes (v). Trees and simple networks have beta index values of less than one. A connected network with one cycle has a value of one. More networks that are complex have a value greater than 1. In a network with a fixed, number of nodes, the higher the number of links, the higher the number of paths possible in the network. Complex networks have a high beta index.

Depend on the above explanation, the above table show that the highest road network connectivity, Marakie sub city is the first one from the rest of the other sub cities of Gondar town. The bata index result is greater than one. Using the formula $\beta = \frac{e}{v}$ $\beta = \frac{27}{15}$=1.8, Marakie Sub city. In addition to this the 2nd, 3rd, 4th, 5th and the least are Fasile sub city, Zobele, Jan Tekel, Arada and Azezo sub city, which accounts 1.69, 1.54, 1.5, 1.37 and 1.29 respectively. Because the Marakie sub city center of the transportation system and has highest number of paths in the road network and highest connectivity of road network that feeding from other sub cities.

The **alpha index** is a ratio measure of the number of the actual circuits, to the maximum of in a given network. The range of the index is from a value of zero for a minimally connected network to a value of one for a maximally connected one (Sarkar, 2013).

From standing the above concept, the table show that the alpha index value of the road connectivity is approach to one the area is higher connectivity. Then using the formula $\alpha = \frac{e-v+1}{2v-5}$ $\alpha = \frac{6-4+1}{2*4-5} = 1$, Jan Tekel sub city value is 1 it has highest road network connectivity compared to the other sub cities. The second highest road network connectivity area is Marakie sub city, which account (0.52) it approach to one and the others sub cities are low road network connectivity the values are approach to zero.

Gamma index is a ratio between the observed number of edges and vertices of a given transportation network. The numerical range for the Gamma Index is between zero and one. Higher the value indicates higher the development of network.

$\gamma = \frac{e}{3(v-2)}$ $\gamma = \frac{6}{3(4-2)} = 1$, Jan Tekel sub city value is 1 it has highest road network connectivity compared to the other sub cities. The second highest road network connectivity areas are Arada and Marakie sub cities, which accounts 0.733 and 0.70 respectively. The value it approaches to one and the others sub cities are low road network connectivity the values are approach to zero.

Finally, calculate the Shimbel index; the shimbel index is the sum of the values for each row in the accessibility short path matrix, which is more powerful than the associated number. Then I add the above table beta, alpha, gamma, and cyclomatic indexes. The values are the greatest number. The area has the highest road network connectivity and accessibility. Then from the given sample, the greatest or highest connectivity sub city is Marakie sub city in Gondar town, where the value is 16. The second and the third highest connectivity road network areas are Fasil and Azezo sub-cities, which account for 12 and 11 values, respectively.

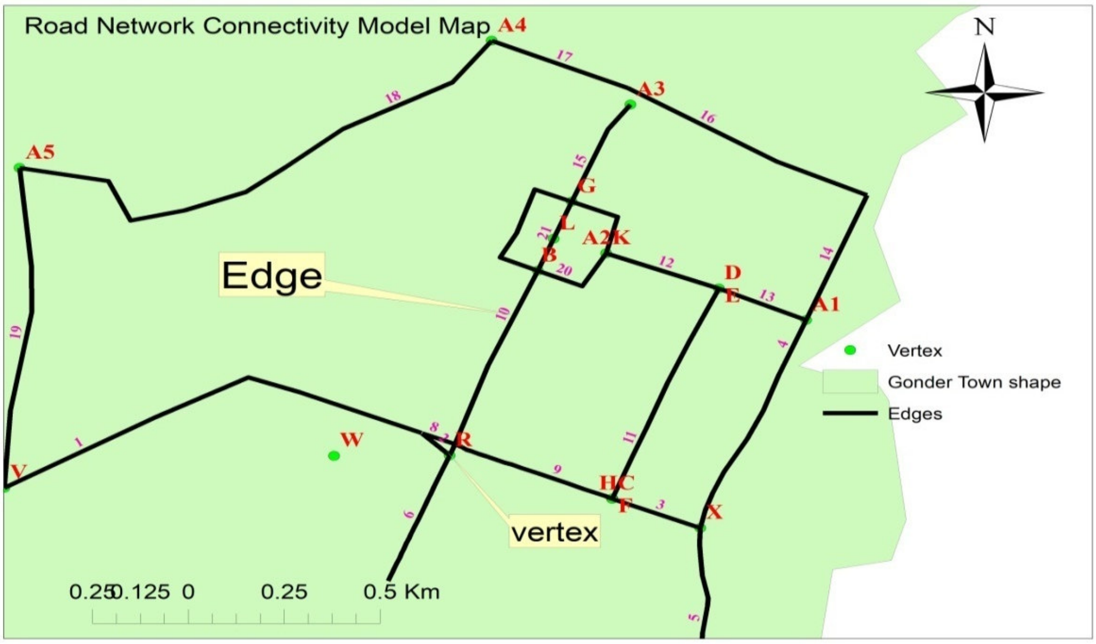


Figure 3.2 Digitating Road Network Map
Source; arcGIS software 10.3.1

3.1.2 Route

According to (Khalid et al., 2017), the Network Analyst can find the best way to get from one location to another or to visit several locations. The locations can be specified interactively by placing points on the screen, entering an address, or using points in an existing feature class or feature layer. If there are more than two stops to visit, the best route can be determined for the order of locations as specified by the user. Alternatively, the Network Analyst can determine the best sequence to visit the locations.

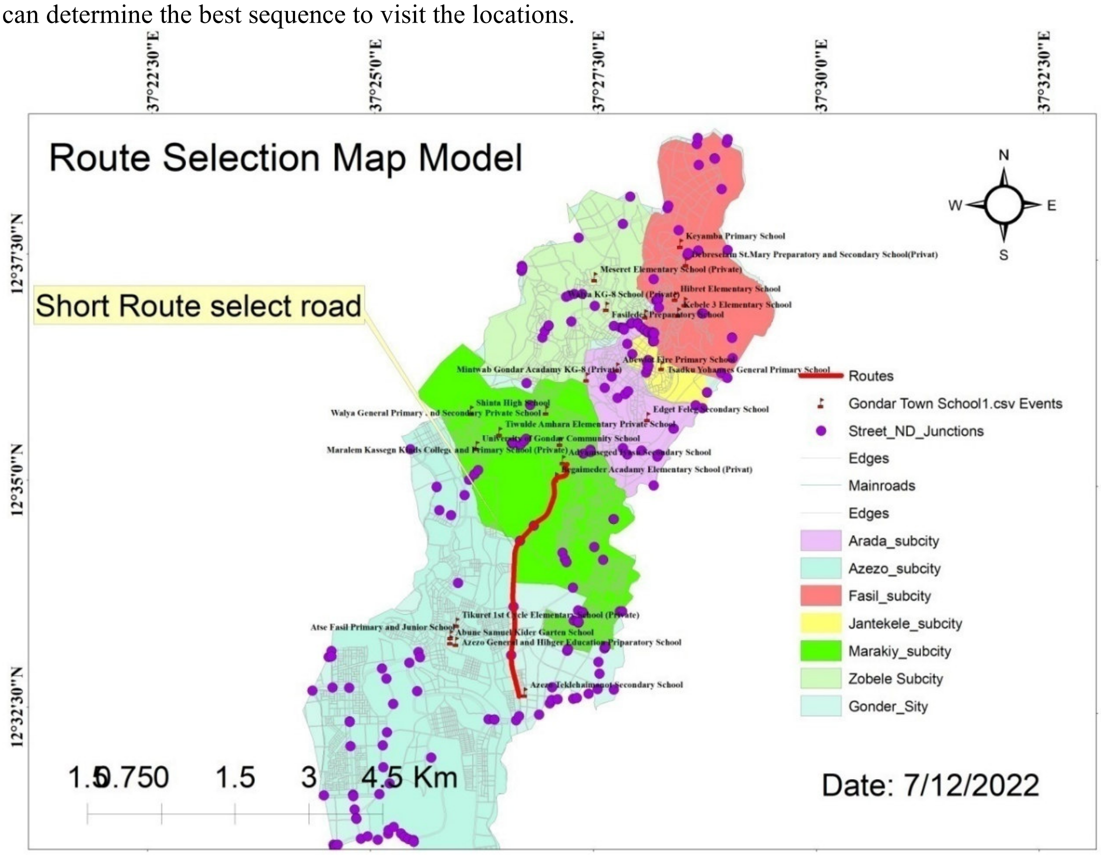


Figure 3.3 the route selection model
Source:ArcGIS software10.3.1

The above figure3.3 displays the best route between the same two locations. In this analysis, I have chosen the road's travel time as the impedance factor, and this analysis is perform at the same time and over 5 minutes as the shortest route analysis.

In my assumption, I have selects, draft the shortest road network, or route select road by create network selection tool take appoint in Azezo Teklehaymanot secondary school to Begimder academy elementary school. In addition, to identify the junction points in the study area road network models.

3.1.3 Accessibility Road Network Model

The Network Accessibility Analyzer performs an analysis of a road network, determining what effect barriers have on the accessibility of the arcs on the road network.

A. Service Area Model

In ArcGIS, this is the OD Cost Matrix, which measures the least cost path from multiple origin points **to** multiple destinations**.** OD Cost Matrix type of network uses two sets of locations to find the distances between all of the locations in two sets.

Service areas created by Network Analyst also help evaluate accessibility. Concentric service areas show how accessibility varies with impedance. Once service areas are creating, we can use them to identify how much land, how many people, or how much of anything else is within the neighborhood or region.

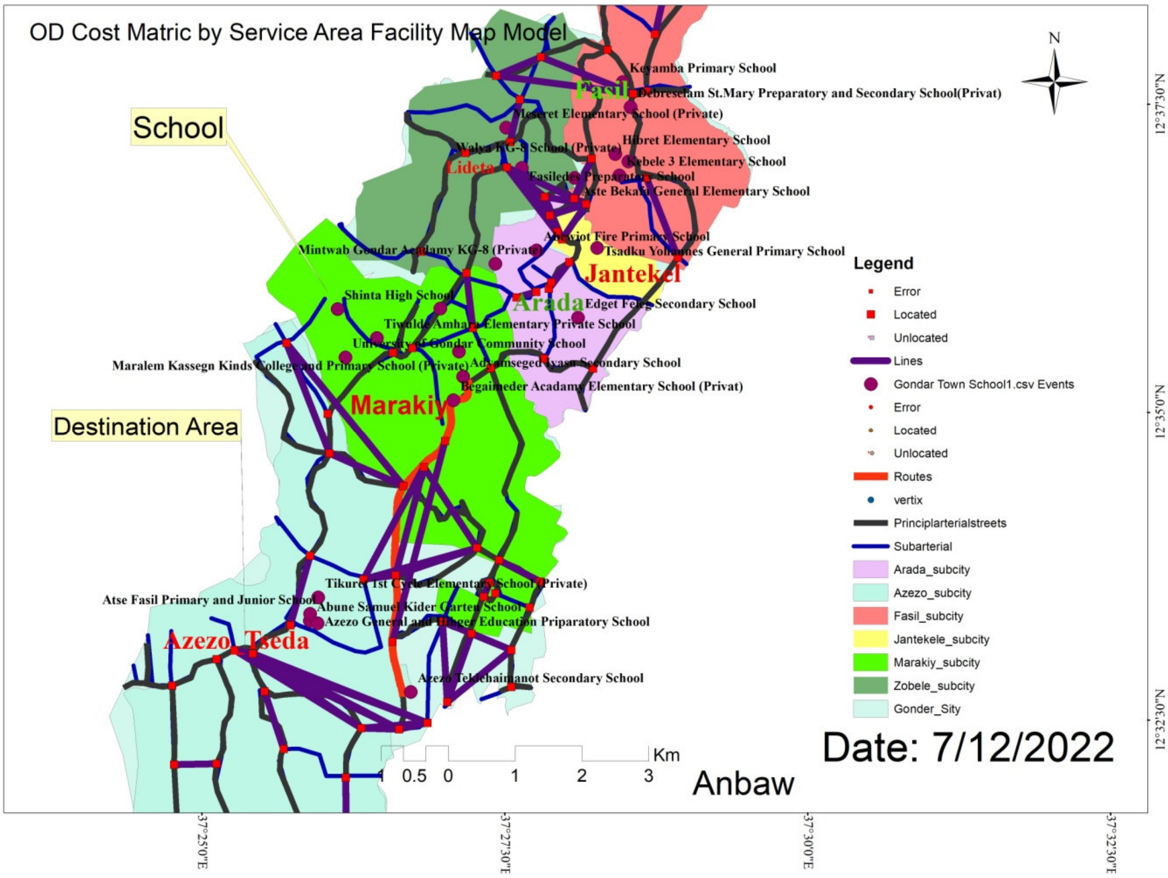


Figure3.4 matrices of service area facility model map

By using network analysis tools "new route" is create between two different locations, which is more efficient in terms of less time and subsequently, cost consumed in travelling. Shortest route analysis finds the route with minimum cumulative impedance between nodes on a network. The route may connect just two nodes – an origin and a destination or have specific stop between these two nodes, figure 3.4 represent map of new route between two locations and map of optimum route between two nodes. This model created using network analysis tool select the new route from the network analyze tool and to click the solved button after some process the closest facility nodes or different locations are appear. The above map shows that the closest facility nodes.

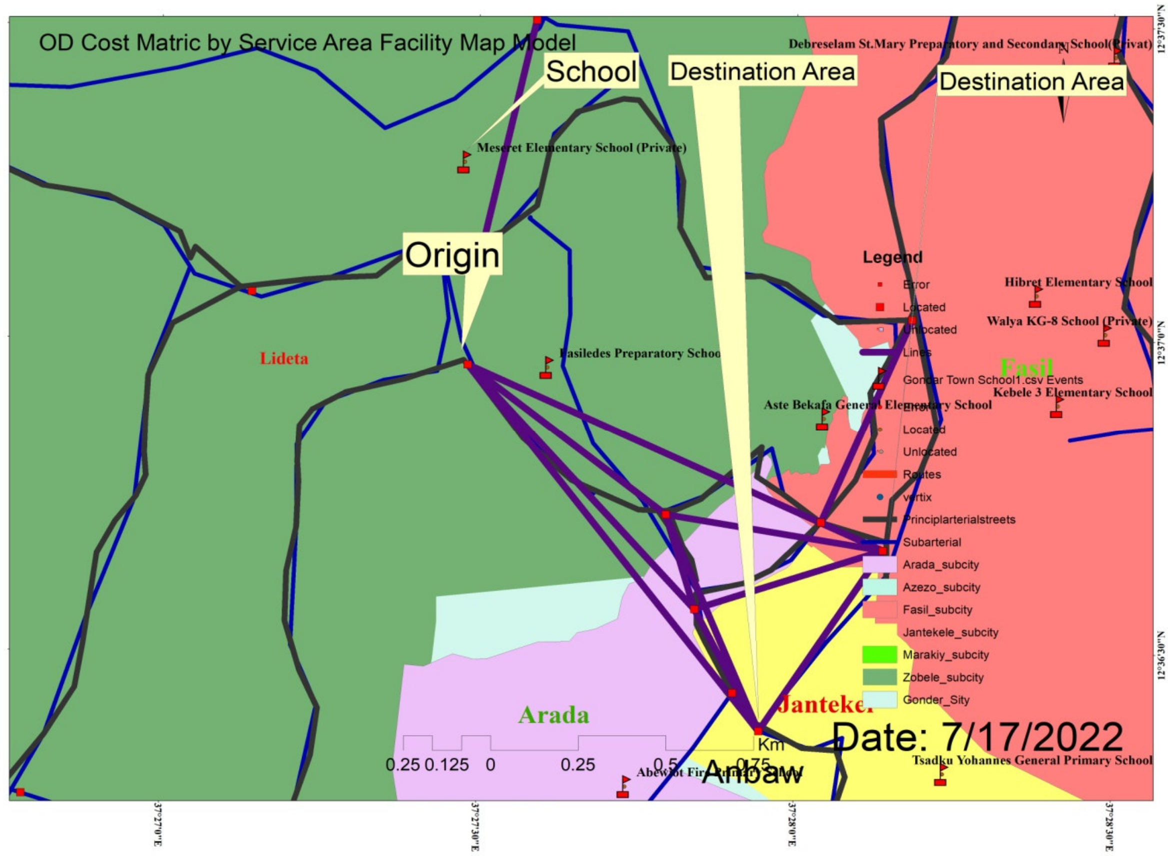


Figure3.5 OD Map

B. Closest Facility Service Area

Closest facility: Measures the cost of traveling between incidents and facilities and determines which are nearest to one another. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. The closest facility solver displays the best routes between incidents and facilities, reports their travel costs, and returns driving directions. Optimized analysis Origin Destination Cost Matrix: Creates a cost matrix from multiple origins to multiple destinations.

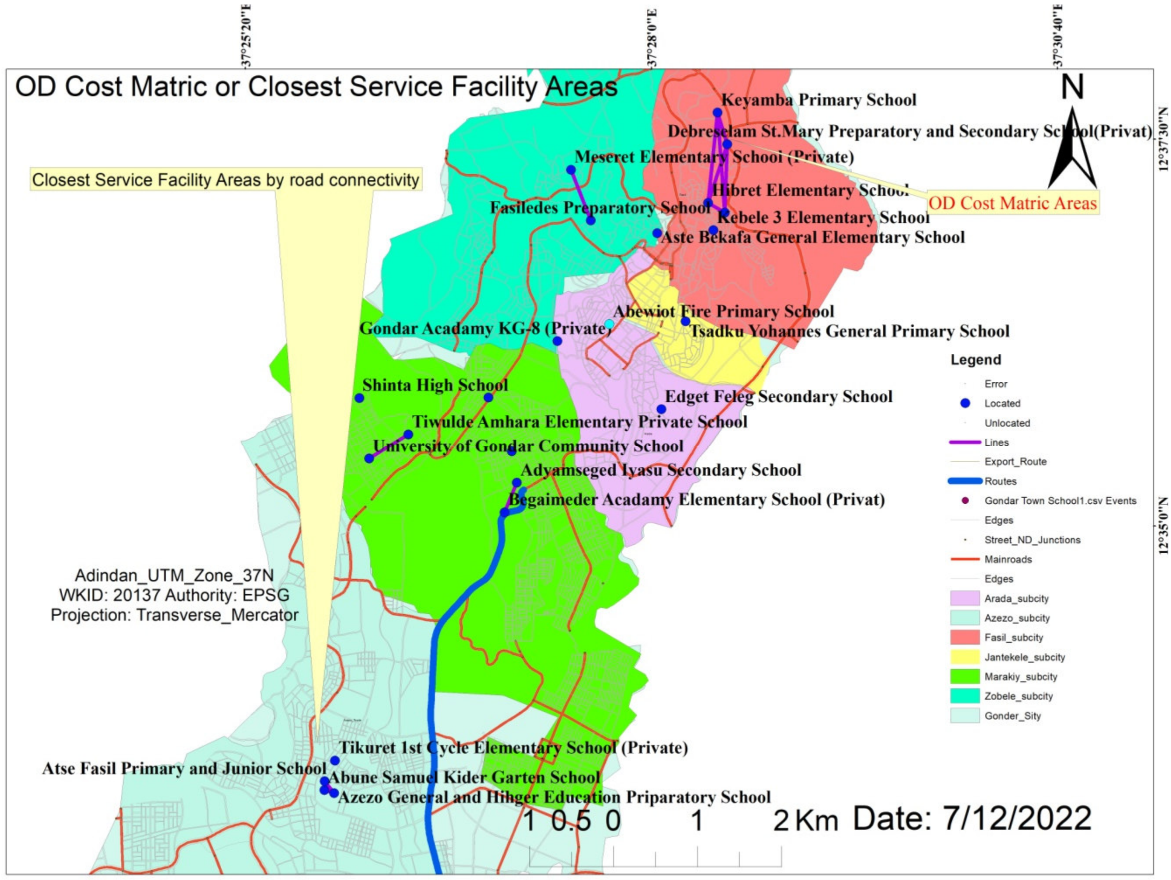


Figure 3.6 OD Cost Matrices or closest Service Facility Area Map

Using a 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 (that is, streets that are within specified impedance). For instance, the 5-minute service area for a point includes all the streets that can be reaching within five minutes from that point. 25 Service areas created by Network Analyst also help evaluate accessibility. Accessibility refers to how easy it is to go to a site. Accessibility can be measure in terms of travel time, distance, or any other impedance on the network.

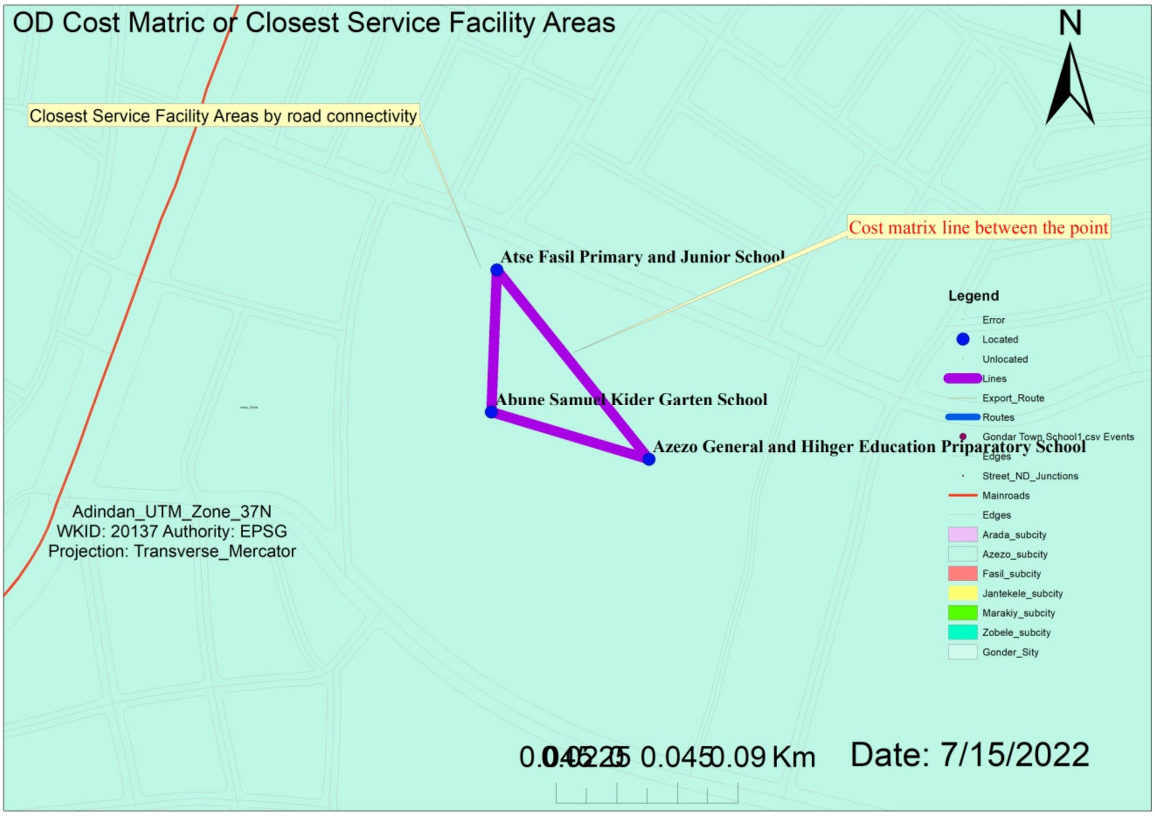


Figure 3.7 Closest service facilities Area Map

The above map show that the closest service area facility are Atse Fasile primary and Junior school, Azezo general and higher education preparatory school and Abune Samuel King garden school and are the closest facility area to provides service for the sharing of information each other. For example the distance between Abune Samuel king garden and Atse Fasile primary and junior school are 98 meters measured by using GIS tool click the measurement tools measured the distance between the two location line.

3.3. Model Building

A. Geo-processing Model for Spatial Analysis

According to (Bajjali, 2018), Analyses can be systematized graphically using the geo-processing model. This suggests that you may automate your study as a workflow through the geo-processing model rather than repeatedly executing the tools from the Arc Toolbox. Because the model is a process, each tool has input and output components that go together. Each of the four states in the procedure has the corresponding color:

1. Not ready to run White
2. Ready to run Yellow
3. Running Red
4. Has been run Yellow (drop shadow added to tools and outputs elements)

The user should have full-write access to the generated toolbox where the model is save, which can be placed in any folder or at the root level of any geo-database. A model tool is creating from the model that was saved in the custom toolbox. You can use the Model Builder in ArcGIS, which is a chained-together collection of tools and data. One tool's output is use as the input for another. A model becomes a model tool when it is saving. Models are kept in a user-made toolbox with complete write access. Setting the environment is advice while working with models because it establishes numerous factors, including the output workspace, output spatial reference, and the processing extent.

This model shows that the shortest route, the service area and the closest facility area of the road network area of Gondar city. As above map shows that the closest service facility area are found in Azezo sub-city based on GPS point observation or collecting the three schools are closest are and mutual benefits each other due to time saving and related each other rather than the other schools of Gondar city.

In addition to this, I have built up Gondar sub-cities model based on closest area facility and road network connectivity and accessibility compared each other. Due to the road, connectivity parameter the center of the city is has the highest road connectivity and accessibility area. Because of the center of the city, have higher feeding road and node and highest accumulations of transportation system available. That means different cars, vehicles, people and others displaced or moved from the peripheral area to the center of the point or place.

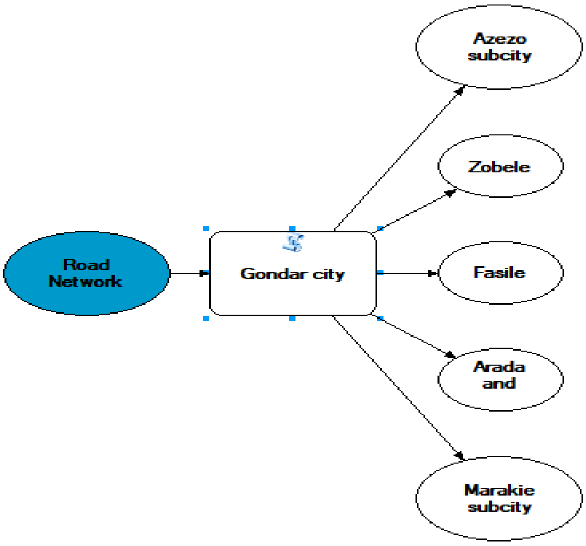


Figure 3.8 Model of Gondar sub-cities

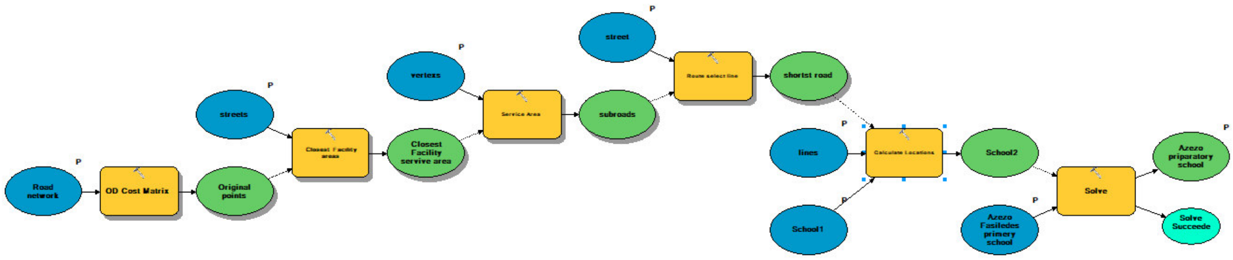


Figure 3.9 Model of the Road network

As shows the above model the closest facilities service areas are building by using arc toolbox. This model building by using the following steps;

1. On the Standard toolbar, click the Show/Hide Arc Toolbox Window Button to show the Arc Toolbox Window.
2. Right-click Arc Toolbox in the Arc Toolbox window and select New Toolbox

Step:

1. Click the Catalog window button on the Standard toolbar. The dock able Catalog window opens.
2. In the Catalog window, expand Toolboxes.
3. Right-click My Toolboxes and choose New > Toolbox.
4. Name the newly added toolbox “Network Model”.
   Type Network Model and press ENTER to name the newly added toolbox
5. Right-click on Network Model toolbox, select New and then Model. A new model appears in the Network Model toolbox and in the map window.

Based on this step I have create the closest facility service area model building select from the road edge up to the closest facility service area. In my finding, the shortest or closest facility service areas are the three schools found in Azezo sub-city based on GPS point collecting or gathering. These point enter in the make network layer after some process connect the closets service area.

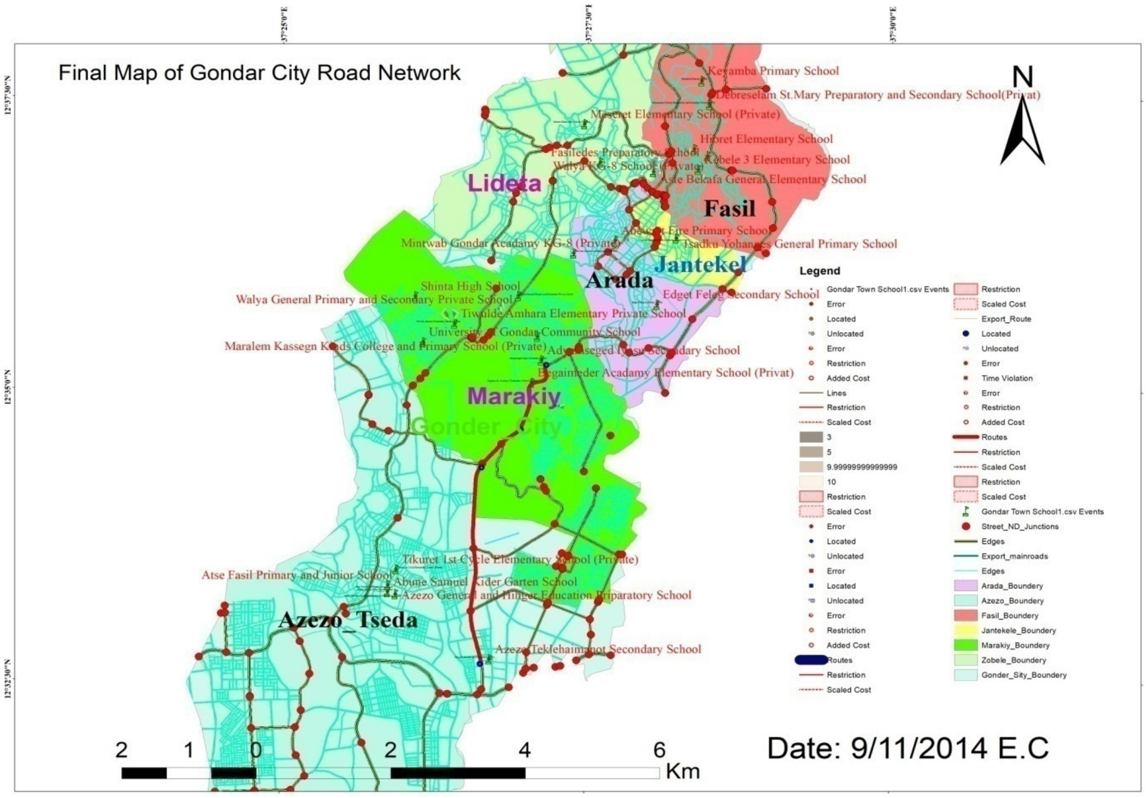


Figure 3.10 the Final Road Map of Gondar City

4. Discussion

For the investigation of the road network in the city of Gondar, models for the connectivity and accessibility of the roads were constructing for this project. The connection models demonstrate, using various measurement parameters, such as alpha index, beta index, gamma index, cyclomatic index, and shimbel index measurements, the highest connectedness sub-cities of the metropolis. When the four indexes are added together, or when the city has the lowest road network connectivity, the area has higher road network connectivity. This justification explains why the Jantekel sub-city has the lowest RNCA and the Marakie sub-city has the highest road network connectivity area (16.01) and (8.9).

In this project, we provide analysis and comparison of the results of the network analysis using two different methods. To navigate from one location to another, the route with the least length (shortest route) will be select. The route with the least travel time (best route) will be select depending on the impedance factor you choose to solve for. Figure 3 shows the shortest route between a source location (Azezo Teklehaimanot secondary school) and a destination location (Begimder academy elementary school). In this analysis, the shortest facility service area has been chosen as the impedance factor. The distance of the route obtained from the shortest route analysis represents the accumulated lengths of the road segments over which agents will travel. In a similar manner, the total time of the route obtained from the shortest route analysis represents the accumulated time in minutes for each route segment over which agents will travel.

5. Conclusion

The urban road network is crucial to the urban spatial organization to provide the transportation and economic growth of the city. Network analysis is helpful for organizations that manage or use networked facilities, such as utility, transmission, and transport networks. The problems of road transportations are low access of road network, inadequate finance of the people, low infrastructure accessibility, low road network connectivity of the city and lack of people attitude for the importance of road network and lack of skilled of people for the analysis of road network by using new technology. Then to fill of the gab or minimize the problem this project to analysis the road network in Gondar city by using GIS software.

The Arc GIS Network Analyst extension allows you to solve common network problems, such as finding the best route across a city, finding the closest emergency vehicle or facility, identifying a service area around a location, servicing a set of orders with a fleet of vehicles, or choosing the best facilities to open or close. The key to network representation is to represent nodes, arcs and network topology efficiently. Once the nodes, arcs, and network topology are efficiently represent, other data and information associated with nodes, arcs, stops and turns can be represent as attributes associated either with nodes or with arcs.

Analysis is the systematic close investigation of anything in detail in order to better comprehend it or draw conclusions from it. A network is a collection of interconnected parts that represent potential routes from one site to another. Network analysis is any approach to leveraging network connectivity to solve network issues such Travers ability, rate of flow, or capacity. It is used to determine the service allocation process's most effective routes or paths. This entails determining the quickest and least expensive route to go between two points in a network. For example, people, resources, and things frequently move through networks: automobiles and trucks move along roads, airplanes fly following established flight patterns, and oil moves via pipelines. Consequently, that Arc GIS Network Analyst extension allows we to build a network dataset and perform analyses on a network dataset and analytically interface networks (systems of lines and points.

Networks are an important part of everyday lives and analysis of these networks improves the movement of people, goods, services and the flow of resources. To demonstrate the use of network analysis, this project focused on determining the best route between two destinations based on a specific distance (impedance), 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 impedance in order to find the best route and the closest facility and that of travel time is taken as impedance in order to find the service area. A Geographical Information System (GIS), which is 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 analysis was 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.

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