ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

“GIS-based cycle Network Planning and Evaluation Of Home to School Trips: A Case of Addis Ababa City, Ethiopia,"

A Thesis in road and transport engineering

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06/11/2023

Addis Ababa

A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Road & Transport Engineering.

The undersigned have examined the thesis entitled **'GIS-based cycle Network Planning and Evaluation Of Home to School Trips: A Case of Addis Ababa City, Ethiopia** presented by **Zewdu Habte Lemma,** a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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UNDERTAKING

I certify that research work titled "GIS-based cycle Network Planning and Evaluation Of Home to School Trips: A Case of Addis Ababa City, Ethiopia" is my own 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

A city's quality of life is worsened by increasing usage of motorized transportation and accompanying infrastructure, which results in traffic congestion, environmental pollution, and traffic crashes. To improve mobility on those streets, reduce traffic congestion, improve public health, and make the city more environmentally friendly, non-motorized transport like cycles should have given more attention to the improvement of facilities and the number of cycle users.

Engineers and planners in Ethiopia don't, however, have a common procedure for figuring out whether a road is suitable for allowing cycles to operate effectively. As a result, certain circumstances render the transportation system irreversibly unsustainable.

In order to improve mobility, a lot of time and effort is put into developing a GIS-based cycle network-planning tool for comparison with the actual state of the planned cycling network. In the example of Addis Ababa city, this study focuses on using a new, highly dependable cycle network design and analysis for home-to-school activities.
Utilizing ArcGIS Software which is spatially compatible for network planning activities, the study's methodology was combined with an analysis of the road network utilizing the best route, service area, and closest facility criteria for residents (incidents) and schools (facilities).

The data for network development was primarily gathered through site investigation and accounting the ground truth from Google Earth Pro in collecting coordinates of selected Sample of Residence and school locations of the Study area in Addis Ababa city as well as converting to the local coordinate system to fit with the Road network of the Study Area. The study makes use of secondary data, such as the road network from the Addis Ababa City Government Plan and Development Commission (.Shp), as well as reports from various agencies.

The closest facility analysis location with the shortest total travel time was RDLocation 7(Shola condominium) -SCL 27(New grand school) where the travel time was 0.309 minutes, and the location with the longest total travel time was RDLocation 4(signal condominium) -SCL27(New grand school), where the travel time was 1.696 minutes. Based on analysis, this study's best facilities network has a total length of 13028.36 m and a total minutes of 202.46. The network service area analysis extension tool used in this study also satisfies the case study area.

Finally, the present study evaluates the results from the logical network analysis with the planned cycle network and also with the normal network condition of the road network.

Keywords:- ArcGIS software, bicycle network planning, best route analysis, closest facility analysis service area analysis, non-motorized transport

ACKNOWLEDGMENTS

I want to begin by thanking the Almighty God for all of His gifts. and for giving me the courage to finish this study. I want to sincerely thank my adviser, Dr. Eng. YONAS MINALU, for his support, direction, and insightful criticism during the development of the document. Not only for his contributions to academic success but also for highlighting my areas of weakness and empowering me to maximize my abilities. He did this to bring out the best in me.

Additionally, I would like to express my gratitude to the various organizations, managers, and staff members of all levels who provided the data for this study.

Finally, I would like to express my sincere gratitude to my dear wife Bethlehem J., my family, and anybody else who has assisted me in any way during this study for their encouragement, support, and help from the start to the finish.

List of Abbreviations

AACRA	Addis Ababa City Road Authority
AATB	Addis Ababa Transport Bureau
AASHTO	American Association of State Highway and Transportation Officials
CS	Collector Street
ESRI	Environmental System Research Institute
FSM	Four-Stage Model
GIS	Geographic Information Systems
NACTO	National Association of City Transportation Officials
OSM	Open Street Map
PAS	Principal Arterial Street
NMT	Non-motorized transport
RDL	Residence location
ROW	Right of way
SCL	School location
SAS	Sub-Arterial Street
TMA	Addis Ababa Traffic Management Agency

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CHAPTER 1 INTRODUTION

1.1 Background

Urban planning and design have emerged as crucial disciplines in establishing lifestyles, finding solutions to issues, and introducing new ways of living in cities on a global scale. A high quality of urban life can be realized through a good urban environment, and this quality of the urban environment can be attained by several mechanisms in urban planning and design, the largest portion of which is the creation of a quality public realm with a harmonious constructed environment. The roadway is the most crucial component of the urban environment in the interim public space. (Saelens,Brian,Sallies,James,Frank,Lawrence, 2003).

With a population of more than 5.228 million (Addis Ababa, Ethiopian metro area population, 2022).Addis Ababa is the country's largest urban center. Addis Ababa is having trouble due to its rapid growth and limited ability to manage that growth, including the provision and administration of mobility infrastructure, which has a significant negative impact on the city's transportation system (NW, The World Bank Group1818 H Street, 2015).

The current metro area population of Addis Ababa in 2022 is 5,228,000, a 4.43% increase from 2021. The metro area population of Addis Ababa in 2021 was 5,006,000, a 4.42% increase from 2020. The metro area population of Addis Ababa in 2020 was 4,794,000, a 4.4% increase from 2019.

Only a small percentage of Addis Ababa city residents—15% using private transportation and 31% using public transportation—are represented by the bulk of road designers and engineers who have prioritized motorized transportation improvements in recent years. However, the citizens who live in Addis Ababa above 50% are not use-motorized transportation in their daily activities, indicating that the city road administration is ignoring the vital necessity for citizens in a transportation system. (Bureau, Addis Ababa City Administration Road and Transport, 2018). In addition, the majority of drivers of motorized vehicles reside in Addis Ababa, which is bad for the city's environment and public safety because most of the cars imported into Ethiopia are used or old models, which pollute the environment, cause serious traffic crashes, and cost money to maintain and replace parts (Akloweg, 2011).

In comparison to motorized transportation projects, the city of Addis Ababa's bicycle network projects are largely unattended. (Aregawi, 2018). As a result, the overall perception of the riding environment is one of frustration due to the traffic flow situation. Currently, no academics have attempted to evaluate the operational circumstances of on-street cycles in Ethiopia by taking into account various traffic flow situations, the driver's behavior and existing geometric constraints. The planning measures for cycling in developing cities cannot be compared with those in industrialized ones.

Hence, it has to be emphasized, that still, a high majority of people do not own a car, and pushing towards more cycle-friendly cities will have great benefits for the environment, health, livability, and a more equal society.

1.2 Statement of the Problem

The transportation system and road network in Addis Ababa were unable to meet the city's high travel demand. Traffic crashes, longer delays, and environmental degradation are prevalent because of the high traffic levels on most routes. The system's dependence on automobiles is the main cause of the issues.

For a variety of factors, cycling makes up a small portion of the city's modal transportation. As was previously noted, the goal of the city officials was to build a roadway for motorized traffic rather than non-motorized. While the city government has attempted to enhance the environment for non-motorized transportation (NMT), the focus on bicycling and bicycle infrastructure is almost nonexistent (Getu Segni Tulu, 2019). This includes inadequate bicycle infrastructure, hazardous intersections where bicyclists cross, and poor maintenance because the majority of transportation funding has historically gone toward the construction of motorized traffic infrastructure (The federal democratic republic of ethiopia ministry of transport, 2011).

The direct and indirect costs of transportation as well as travel time must be reduced because sustainable transportation systems should be viewed as economic production and market systems that demand efficiency. Any sustainable transportation plan should prioritize cycling. It assists in reducing local air pollution, traffic congestion, and greenhouse gas emissions.

However, cyclists today have a lot of challenges and discontent when riding a bicycle in urban Ethiopia, particularly in Addis Ababa. As a result, the percentage of people who use cycles is decreasing in Addis Ababa, making the transportation system unsustainable in the long run.

Now, Ethiopian traffic engineers and transportation planners are unable to assess the suitability of a specific roadway for accommodating both bicycles and motor vehicles efficiently. Determining how current traffic operations and geometric conditions affect a cyclist's decision to use or not use a particular roadway is difficult due to the complexity involved in making streets bicycle-friendly.

Therefore, it is essential in cycle network planning to enhance mobility and evaluation of home to school trips to find a design solutions that will promote active living and equitable mobility and that enhance healthy public life, social life, and economy in the case of Addis Ababa city.

1.3 Objective of the study

1.3.1 General Objectives

The main goal of this thesis is to use an object-oriented method based on geographic information systems (GIS) and apply it to the existing road network to find cycle-friendly networks for home to school activities in the case study of Addis Ababa City.

1.3.2 Specific Objectives

- To find the best route and closest facilities analysis from the nearest cycle network residential location to school facilities.

- To choose optimum sites of cycle network in the study area by using service area Analysis types particularly maximizing coverage for home-to-school activities.
- Comparing /evaluating the logical network plan with the planned cycle network situation also including normal road network conditions for the case study area.

1.4 The research Question

In parallel to these objectives, this study raised the following basic research questions.

- What are the methods used for finding the best route cycle network and closest facilities from a place of Home to School Activities?
- Which method is used for finding the optimum location of the cycle network to maximize service area coverage of the study area activities?
- How to compare the logical network plan with the planned cycle network?

1.5 Significance of the Study

Significance of the study will be

- The study will be useful for transportation planners, road agencies, government, and communities for planning, identifying and designing cycle network planning for home to school activities in the city or specific area.
- It will help to identify the main factors that affect cycle network planning for home to school activities in the specified area.
- The importance of this study is not limited only to this paper but also to the concerned stakeholders they look at will be beneficial. For example, the result of this study is very useful for Addis Ababa city government plan and development commission while designing public facilities and infrastructure for population growth. In addition to this, the methodology and procedures used in the study will be used as a reference to conduct further research about the activities in other places for the other researcher.
- It will show some good ideas for the future researchers to look in detail the factors that influence cycle network planning for the specified activities.

1.6 Scope of the study

Addis Ababa is one of the biggest cities in Ethiopia and it has a total area of 540 sq. km2 (Abnet Gezahegn Berhe, Dawit Benti Erena,, 2017). The scope of the study was GIS-based network analysis for locating cycle networks for Home to school activities in the case of Addis Ababa city. This study mainly performs finding advanced network analysis extension tools for cycle network analysis including service coverage Area, best route, and closest facilities in the case of Addis Ababa city.

1.7 Organization of the thesis

This thesis consists of five chapters which are arranged as follows: Chapter One: Introduction: This chapter includes the introduction of the research, statement of the problem, research objective, research questions, significance of the study, limitation of the study, the scope of the study and structure of thesis format. Chapter Two: Present a literature review of the previous literature appropriate for this study topic also discuss their common term and related terminology. Chapter Three: Methodology and Material: elaborate on the data methodology and general implementation to achieve the objective of the study. Chapter Four: Data Analysis, Result, and Discussion: shows the main data analysis undertaken for the study, detailed discussion, and interpretation of the result. The candidate site selection and advanced network analyst extension tools are applied in this chapter. The final section is Chapter Five: Conclusion and Recommendation: which provides answers to research questions, generalizes the obtained results, and indicates future work to another researcher. Reference: A list of sources used in this study is attached at the end of this paper.

CHAPTER 2 LITRATURE REVIEW

2.1 Definition of Terms and Concepts

The researcher delivers literature on the subject in this section, which is given from a broad perspective to a specific perspective. The goals of the study are the foundation for this literature. As a result, it relates to several beliefs and ideas about riding.

2.1.1 Definition cycling

The fundamental idea of cycling theory is the word "cycle." a cycle refers to a vehicle with two wheels of equal diameter, one on the front for guiding and one on the back for powering the entire pedal and chain assembly ((baseb., 1993).

2.1.2 Definition of cycling lane

A cycle lane is a legally designated driving area on the road that visually separates cyclists from oncoming cars. It is advised to drive along a moderately busy road when there are a lot of cyclists. On existing roadways, cycle lanes offer a visible, quick, and adaptable option that just calls for road markings. When there is not enough room for a cycle track, a cycle lane may be an option, but only if safety can be sufficiently ensured (Officials, American Association of Highway and Transportation, 2019)

2.2 Type of cycling lane

2.2.1. Sharrows

A combination of the words "share" and "arrow," sharrows are proposed to serve as a visual reminder that space on the street is meant to be shared by bikes and cars. Sharrows do not offer dedicated space on the street for people biking (meaning cars can still use a lane with sharrows in it); they indicate a general area on the road in which it should be safe for people to bike. (Yusfida Ayu Abdullah1, Syifa'Azwa Ahmad Razi2, Na'asah Nasrudin3, Zulkifli Ahmad Zaki4, 2017))

Figure 1 Sharrows cycling lane

2.2.2 Striped cycle lanes

Striped bike lanes aim to offer a clearer sense of where bicyclists should be on the street by creating a lane for bikes. Typically, these lanes are striped with white paint and are often located on the far-right side of the road. They may be painted a separate color to draw more attention and the drivers are not permitted to drive or park in bike lanes of any kind. (Yusfida Ayu Abdullah1, Syifa'Azwa Ahmad Razi2, Na'asah Nasrudin3, Zulkifli Ahmad Zaki4, 2017)).

Figure 2 Striped bike lanes

2.2.3. Buffered cycle lanes

Buffered bike lanes make a dedicated lane for bikes, with the additional benefit of putting extra space between bicyclists and passing cars, usually with a painted safeguard area of one to two feet. Drivers must drive on the left side of the buffer while driving and can only cross the bike lane when making a turn or entering an adjacent property - after checking to be sure no people are biking in the lane, of course. (Yusfida Ayu Abdullah1, Syifa'Azwa Ahmad Razi2, Na'asah Nasrudin3, Zulkifli Ahmad Zaki4, 2017)

Figure 3 Buffered cycle lanes

2.2.4 Protected cycle lanes

This kind of bike lane costs more money than other cycle lanes and street markings, protected cycle lanes delineate space on the street for cycles and prevent vehicles from infringing on that space. Installing physical barriers such as plastic bollards on-street parking or even planters offers the greatest degree of safety for people riding bikes in on-street bike lanes. (Yusfida Ayu Abdullah1, Syifa'Azwa Ahmad Razi2, Na'asah Nasrudin3, Zulkifli Ahmad Zaki4, 2017)

Figure 4 Protected bike lanes

2.3 Advantages of Cycling

A well-connected cycle network can encourage people to switch from using motorized transportation to riding, which has several advantages for both cyclists and the community at large (Addis ababa transport bureau ,Institute for transportation and development policy , United nations human settlements programme, 2023).

- Equitable transportation can be enhanced through well-connected cycle infrastructure by facilitating access for those without access to motor vehicles.
- Economic advantages: Compared to motorized modes like vehicles and public transportation, cycling is less expensive.
- Safety: By installing cycle infrastructure designed for slower speeds, the danger of fatalities and injuries from collisions can be decreased.
- Health advantages: Exercise lowers the risk of obesity, diabetes, cancer, heart disease, and other diseases, making communities healthier and happier.
- Environmental advantages: Cycling can lower emissions of harmful local pollutants and greenhouse gases by replacing trips in polluting motor vehicles.
- Life quality: People who live in areas where cycling is encouraged report feeling more at home, having more flexibility to move around, and having better social interactions.
- Gender equity: Women benefit from cycling by saving time and money because they experience time poverty because of the unequal gender-based division of labor.

2.4 Cycle Network Planning

Cycle network planning is a vital part of developing a cycle transport strategy .It is an element of a city's comprehensive mobility plan and takes into consideration the connectivity of various activity centers (e.g. residential, education, jobs, public Transit, shopping, etc.

Creating connected routes and facilities based on the needs of bicycle users is the process of cycle network design, which aims to increase community mobility (Bach, B and

Diepens, J, 2000). It attempts to offer riders direct, safe, and comfortable routes from all points of origin to all points of destination that:

- connect to create a network
- keep the current cyclists
- Promote cycling among more individuals.

2.5 Cycle Network Planning Principles

Cycle facilities must be able to accommodate a variety of riders, including not only those who are already cycling but also more cautious users who would be inclined to ride if there is a well-thought-out and comprehensive network of bicycle lanes. The cycling network needs to provide safe, logical, appealing, direct, secure, accessible, and comfortable routes ((Bicycle design manual, 2016)) for residents of Addis Ababa, notably women, kids, individuals with disabilities, and the elderly.

Regarding their safety, knowledge, income, physical capability, and time availability, potential users of the cycle network have a variety of requirements and worries. Travelers with different needs and expectations include women, males, people with impairments, the elderly, pregnant women, and caretakers. Infrastructure that is accessible to everyone is needed for vulnerable groups, along with security precautions.

2.5.1 Safety

Cycle paths should be secure, safe, and accommodating of both cycles and other road users. The experience of cycling and the number of cyclists are influenced by vehicle speeds and volume. Stress levels grow whenever inexperienced cycler encounter "near miss" crashes. Women cyclists are often more impacted by these issues than are men.

Riding a bicycle next to flowing traffic gets uncomfortable at 40 km/h. To protect the safety and comfort of cyclists, motor vehicle volumes and speeds should be restricted on smaller streets where cycles and motor vehicles share the same space. If there is no cycling track and daily vehicle numbers approach 1,000 (about 50 cars per direction during peak hours), then speeds shouldn't go over 30 km/h. The speed of moving vehicles can be decreased with the help of devices that reduce speed, such as neckdowns, chicanes, tabletop crossings, and speed bumps.

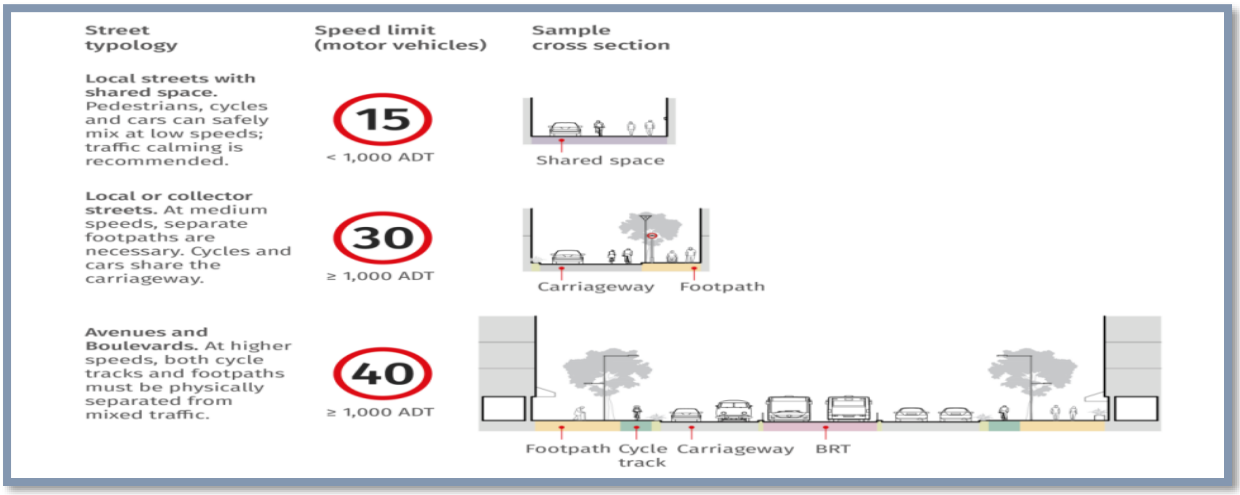

Figure 5 Street typologies and corresponding traffic speeds for safe cycling.(source : Addis Ababa cycle network plan, 2023-2032 report)

2.5.2 Coherence

All potential sources and destinations should be connected by cycle routes, which should also be logical and continuous and provide a uniform level of protection throughout. At junctions and other high-traffic areas, cycle facilities should not suddenly disappear because this deters potential riders and threatens the network's success. Cycle facilities should adhere to uniform standards and designs to be recognizable. They ought to be simple to grasp at crossings. Reducing the number of crossings along the route will help minimize delays caused by stopping and waiting on commuter routes by physically separating the infrastructure from vehicles.

2.5.3 Directness

Based on planned lines, cycle routes should be as direct as feasible to reduce delays or detours. Shortcuts should be made available, and intersection delays should be kept to a minimum via signal designs. On important cycling routes, footbridges should be avoided since they lengthen travel times and may require cyclists to dismount and walk their bikes over the facility. If the cycle facility takes a longer path, fewer people will use it to travel to important locations.

Large urban blocks may occasionally need to be divided into smaller pieces throughout the development process to accommodate cycling and pedestrians. As a result, physical mobility is an appealing alternative to using motorized forms of transportation and cuts down on journey times. The cycle network must cross rail tracks and waterways as well.

2.5.4 Attractiveness

Environments for cycling should be enjoyable and fascinating. Beginners, tourists, and leisure bikers can all benefit from attractive routes. Cycle paths should blend in with their environment, improve safety for everyone, have a pleasing aesthetic, and generally make cycling more enjoyable.

Additionally, urban design is important because streets with play areas, active edges, and organized street vending can develop into important public spaces. The local context of the street or neighborhood should be taken into account when designing the NMT network.

2.5.5 Comfort and Security

Designing, constructing, and maintaining cycling infrastructure with everyone's comfort in mind is important. Gentle slopes, good surfaces, enough width, and lighting are requirements for cycling routes. They ought to be built to prevent difficult maneuvers. For a comfortable riding experience, shade and lighting are essential. Using CCTV to monitor public areas could significantly improve women's security.

All users, including those with disabilities, should be able to access cycle routes, and elements that hinder accessibility should be avoided, such as potholes, physical barriers, and narrow cycle tracks.

To avoid walkers crowding the road or fighting for space with cyclers, separate facilities for walking and cycling are essential. It is important to consider how parking and road width interact, with preference given to cycling.

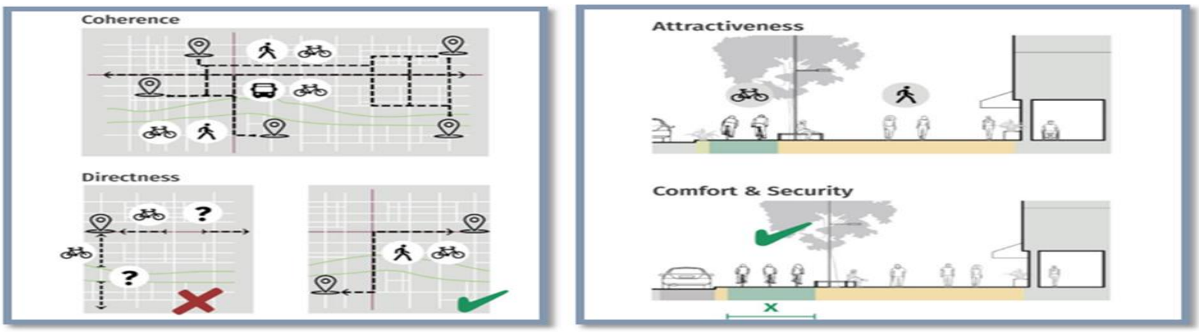

Figure 6 Network planning principles

2.6 Cycle Facility Design

The cycling route's capacity to draw users of all ages and abilities depends on the physical state of the cycle infrastructure. To increase the usability of cycle paths, factors such as pavement quality, junction treatments, lighting, and drainage must be taken into account. With an equitable distribution of roadways, all streets should be planned using a full streets approach to meet the demands of all users and activities. While smaller streets need sufficient traffic calming measures to lower vehicle speeds, larger routes require continuous cycle tracks and secure intersections.

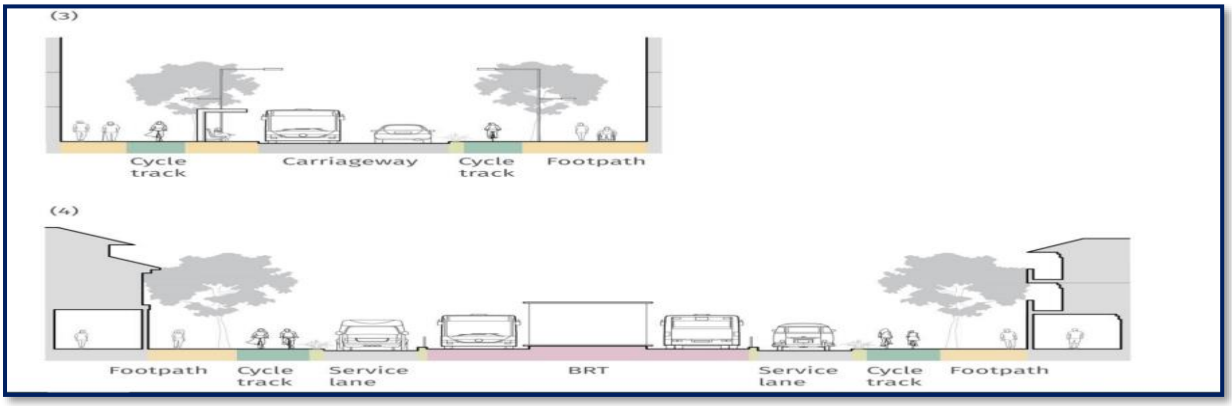

Figure 7 Cycle facility typologies: (1) local street functioning as a shared space for pedestrians, cycles, and vehicles, (2) cycles in a low-speed carriageway, (3) and (4) dedicated cycle tracks protect cyclists. (Source: Ministry of Transport and Logistics, forthcoming.)

2.6.1 Cycle Tracks

To physically separate cycle facilities from mixed traffic, Principal Arterial Streets (PAS), Sub-Arterial Streets (SAS), and Collector Streets (CS) must be used. According to the Ministry of Transport and Logistics' design standards for cycle lanes are as follow:

- Minimum widths for one-way and two-way traffic are 2 and 3.0 meters, respectively.
- Height: 150 mm higher than the highway.
- Occupying the space between the sidewalk and the highway
- Separation from the highway in terms of space. Sharrows and painted network are unacceptable because they pose a safety risk to cyclers. The distance between the cycle track and the carriageway should be at least 0.5 m. When the buffer is next to a parking lane, it should be paved.
- Surface material: Smooth asphalt, or concrete. Paver blocks are to be avoided
- Cycles can pass between central bollards along the cycle path on either side
  The following are acceptable bike facility designs:
- Raised cycle network should be built into new streets at the same level as the sidewalk.
- Create protected cycle network on existing streets that are physically separated from mixed traffic and have the same unidirectional design on both sides of the road.
- The proposed design for the cycle infrastructure features two separated, unidirectional cycle lanes on either side of the road. It is permitted to install a bidirectional-cycling track on one side of the street when there are space restrictions.

Table 1 Cycle facilities by street category (source Ethiopia harmonized street design manual ,ministry of logistic and transport)

Street category	ROW (m)	Cycle track typologies
Principal Arterial Streets (PAS)	31-60	• Unidirectional lanes on both sides of the street: 2.0 m per direction
Sub-Arterial Streets (SAS)	21-30	• Unidirectional lanes on both sides of the street (30 m ROW): 2.0 m per direction • Bidirectional lane on one side of the street (ROW below 30 m): 3.0 m for two directions
Collector Streets (CS)	15-20	• Bidirectional lane on one side of the street: 3.0 m for two directions • Cycles in mixed traffic, with traffic calming measures
Local Streets (LS)	6-14	• Shared space with cycles, pedestrians, and mixed traffic
Source: Ethiopia Harmonised Street Design Manual (MoTL, forthcoming).		

2.7 cycling in Addis Ababa, Ethiopia

The use of cycles as a form of transportation has not received much attention lately. The city recently developed a non-motorized transportation policy and action plan that supports the creation of cycle infrastructure and encourages cycle use. There are various opportunities and new problems for cyclists in Addis Ababa, some of which are listed here.

2.7.1 Strategy for Non-Motorized Transportation

The UN Environment and UN Habitat funds were used to design the NMT plan. The Institute for Transportation & Development Policy (ITDP) and city institutions (Transport Programs Management Office and the City's Road and Transport Bureau) worked together to develop the strategy. In the Addis Ababa road network, walking and bicycling have been given top attention under the policy (Bureau, Addis Ababa City Administration Road and Transport, 2018). Similarly, to this, the master plan for the new city acknowledged the value of non-motorized transportation and allotted, on average, 50% of the road's right of way (comission, Addis Ababa city plan, 2017). To help the city and clear the way for the promotion of active transportation (cycling and walking), all these strategy documents have been created.

2.7.2 Determine the present and future state of the cycle network

The Bloomberg Initiative for Global Road Safety and its partners are striving to identify a bicycle network through the strategy plan for non-motorized transportation. National Associate City Transport Authorities (NACTO), who located the potential location in the road network (Bureau, Addis Ababa City Administration Road and Transport, 2018), specifically took on the assignment. This concept design is already prepared for capital investment, which can entail locating financing for the development of bicycle infrastructure from the local city budget as well as from donors and international lenders. According to the NMT policy, 200 km of bicycle and truck lanes will be built during the next ten years (Bureau, Addis Ababa City Administration Road and Transport, 2018). Cycling facilities are aligned between the master plan and NMT plans, which is significant.

2.7.3 Guide for Bicycle Design

The city lacks a design manual for cycle infrastructure. Attempts have been made to build cycle network in three specific locations throughout the city based on information that is publicly available worldwide. Even though the design was examined by the international partners (National Associate City Transport authorities and World Resource Institute (NACTO)), implementation and construction were not done entirely by the design. The intersections, for instance, are not designed adequately. Large concerns with drainage exist, and during the wet season, water overflows onto the bicycle path. Furthermore, ISSN 2520-2979 Journal of Sustainable Development of Transport and Logistics, 4(2), states that the pavement structures at the intersection were not built using the conventional axle load.

The World Bank's Transport System Improvement Program has already allocated funding for the consultancy service for creating the road transport design guide, demonstrating how well the city and international partners working on the city's road safety under the Bloomberg Initiative for Global Road Safety recognize the significance of the design guide for bicycle infrastructure (United nations economic commission for africa, 2020).

2.7.4 Benefits to local businesses' Economies

The majority of city people use walking as a form of transportation, which can result in longer journey times and unsafe walking on the Addis Ababa road (Tulu G. S., 2013)because of the exposure to the risk of crashes associated with poor road safety.

Additionally, many individuals in Addis Ababa prefer to walk since they cannot afford the high cost of public transportation (Tulu G. S., 2013)or there is a serious lack of it in the city (Fenta, 2014). While walking saves time and money on transportation, cycling has significant economic advantages over walking.

According to evidence from numerous nations, using a cycle as a form of transportation provides wider economic advantages (Rajé, F., & Saffrey, A., 2016).

Retail activity near cycle facilities and the places it affects has increased employment effects and improved public spending effectiveness. Similar to this, a South African study found that people who frequently use cycles for all types of excursions could save up to 45 percent of their monthly household income compared to those who utilize public transportation and mass transit (Volker ,Jamey M. B., 2021)

2.7.5 Creating Livable Cities

The least developed nations' new idea of a "livable city" calls for them to enhance their neighborhoods and streets so that more people may use mass transit, cycles, and foot traffic. There are advantages to the fact that many Addis Ababa residents commute by foot (Geller, Alyson L, 2003).The city has the potential to employ cycles if the infrastructure, cycles of good quality, and their replacement components are affordable. Another is that cycling should be made safer, more enjoyable, and more fascinating by the city. As a result, many residents can be drawn not only to their main travels but also to school trips, side trips, and leisure pursuits.

Cyclists are 'happier' than those who utilize other forms of transportation, according to (Simon Kingham, Paul Tranter, 2015). In general, compared to driving a car, cycling fosters a closer bond and a greater sense of community between individuals and their environment (Bielak, Zach, 2015). If the city provides safe, cozy, and engaging riding facilities, the city has a big potential for bicycle utilization. In turn, this will strengthen the local economy, develop responsible streets and neighborhoods, and ultimately improve the quality of life for inhabitants.

2.7.6 Increase traffic safety

The use of non-motorized transportation can be a useful strategy for lowering accident risk exposure. For example, the safety advantages of bicycling have reduced the number of citywide traffic fatalities currently occurring (consortium, mobile 2020 project, 2013). Examples include Seweden's zero-vision road safety approach and the sustainable safety policy of the Netherlands. The British have also adopted risk reduction tactics that prioritized promoting non-motorized transportation in the city. The exposure to crash risk can be significantly decreased by doing this (Abebe, 2022). Even though their interactions are non-linear, the country's exposure to the risk of crashes is directly correlated with the number of vehicles in use (R. Elvik, P. Christensen, A. Amundsen, 2004).

2.7.7 Addis Ababa Cycle Network Plan

The cycle network in Addis Ababa is one component of the city's overall mobility policy, which intends to facilitate daily cycling for a variety of users. The network was established by planning principles after the mapping of the current conditions and consultations with user groups in Addis Ababa. (Addis ababa transport bureau ,Institute for transportation and development policy , United nations human settlements programme, 2023). Planning for a cycle network should connect different stores, hospitals, schools, and markets to facilitate excursions with many purposes. The implementation plan gives priority to cycle corridors that connect key locations with concentrated employment, leisure, and educational possibilities with residential areas based on different criteria.

The implementation plan includes short-term projects that can be completed in two years, medium-term projects that can be completed in three to five years, and long-term corridors that will be completed in three parts over a period of six to ten years. (As shown in figure 8) From this, we can deduce that the planning for the Addis Ababa Cycle Network is related to the consideration for this case study.

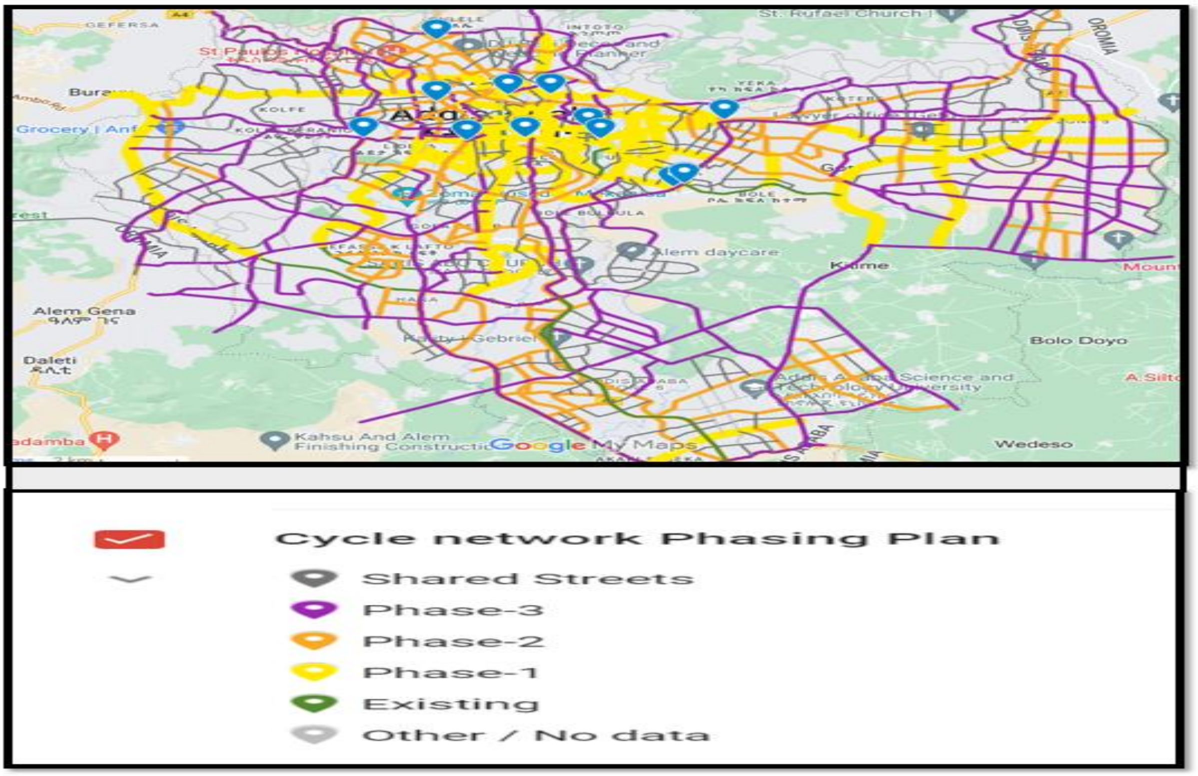

Figure 8 Addis Ababa Cycle Network Plan

2.8 Slopes and Gradients

Cycle highways should be usable by cyclists with different levels of fitness and skill and on different types of cycles. Not all cyclists are sporty, not all cycles have a wide range of gears, and therefore not everyone can climb steep hills.

Way downhill might seem easier, but with steep gradients, it can be risky, due to higher speeds and much longer braking distance, (gravity is counteracting the braking power).

Overall elevation changes increase the energy expense of cyclists, therefore reducing the comfort of using and competitiveness of cycle highways.

2.8.1 How can it be measured?

The simplest measure of the gradient is a percentage – rise/run. E.g. a gradient of 3% means that the cyclist ascends or descends 3 m in 100 m. G=H/L.

However, steepness is not everything – short steep slopes can be acceptable, provided that the cyclists have space to speed up before climbing it (and – going in the opposite direction – naturally slow down without braking after descending). Several manuals vary the threshold for steepness depending on slope length or height difference. CROW's "Design manual for bicycle traffic" introduced a measure of slope severity S=H2/L.

A somewhat related parameter is the vertical curve radius. The higher the radius, the smoother the transition between sections of the cycle path with different gradients.

Gradient for cyclists should not generally exceed 6%, although very short sections with up to 10% might be acceptable. For longer ascends gradients should be reduced to 2-3% (but see also the discussion further).

Guidelines/ standard	Maximum gradients
Design Manual for Bicycle Traffic (CROW, NL)	2-10% depending on slope height - see slope severity
Qualitätsstandards für Radschnellverbindungen (Baden-Württemberg, D)	6%
Réseau cyclable à haut niveau de service. Objectifs et principes d'aménagement (CEREMA, F)	6%
Manual for the design of cyclepaths in Catalonia (E)	2% (no length limit); 4% (max 4 km); 5% (2 km); 6% (240 m); 10% (30 m); 25% (15 m)

Figure 9 shows gradients and recommended slope (source: Design manual for cycle traffic .crow NL)

2.8.2 How is it related to other criteria?

Design speed and parameters related to it should be increased on slopes, both because of higher speed and reduced braking capabilities for cyclists going downhill.

Gradients can be a critical risk factor for crossings on slopes and shortly after the bottom of them. Cyclists going downhill have less time to react and require significantly longer distances to stop.

Width should be increased on slopes – cyclists going downhill appreciate a wider safety margin because of higher speed, and those going uphill need more space for balancing the cycle because of lower speed.

If you need to overcome a significant elevation difference, achieving low gradients can compromise directness.

2.9 ArcGIS network analysis

Among other things, ArcGIS Network study enables performing a geographic study of the network, including routing between nodes, facility placement and service area design. The tools' ability to use the actual state of the road network, including directions, speed restrictions, and blockages of any kind, is one of its most significant advancements. ArcGIS network analysis allows users to dynamically model realistic network conditions, such as turn restrictions, speed limits, height restrictions, and traffic situations, during various times of the day. (Kumar and Kumar, 2016)

According to (Suo, M.Liang, Y., 2011) authors, one of the primary tasks of GIS is network analysis, which is significant for transportation planning, traffic tourism, urban planning, electric power, and communication.

2.9.1 Four step transport (FSM) planning

Transport planning, as we all know, involves four crucial steps: Trip generation, Trip distribution, and mode choice and trip assignment in route or path optimization for this study closest facility analysis.

Trip generation, or choosing to go there for a specific reason, trip distribution -- the selection of a location, mode choice -- the choice of travel mode and traffic assignment in route or path optimization from this closest facility analysis for study.

The most time-consuming and data-intensive activity is transportation planning, which necessitates significant coordination between several planning sectors and substantial resource allocation. These factors make it unwise for a single agent or person to handle transportation planning.

In this regard, models, equations, parameters, and data have been incorporated from survey at the case study area in simple linear regression.

2.9.1.1 Trip generation

It is the initial stage of the modeling activity, which consists of the trip production and the trip attraction portions. the phrase "trip production" refers to the number of trips produced in each traffic zone that is connected to a residential locations.

2.9.1.2 Trip distribution

The amount of trips travelling from each origin to each destination is let us created in the four-step transportation-forecasting model by focusing on the sources and destinations of trip makers. distribution of trips The analysis is done using the gravity model, in which the number of trips between two zones is inversely proportional to the distance between the two zones and directly proportional to the number of trips created in zone i and the number of trips attracted to zone j.

2.9.1.3 Mode choice

The third phase of the FSM model is mode selection. The modeler is given the percentage of each mode of transportation from the total trips made between two zones in this step, whereas trip distribution results in a set of numbers of OD pairs in a matrix.

Logit models are divided into three categories based on their utility function for mode choice probability. These are Binomial (if there are two alternative mode options) and multinomial logit , which enables a correlation between the utility of the alternatives in shared groups for this study's unspecified other alternatives and A statistical analysis technique called ordinal logistic regression can be used to model the connection between one or more explanatory variables and an ordinal response variable. A categorical variable with a distinct ordering of the category levels is called an ordinal variable.

2.9.1.4 Trip Assignment

The precise roads or routes that will be used for each journey can be identified once the number of trips that will enter and exit each zone, as well as the forms of transportation that the travelers will use, have been defined. The trip assignment entails allocating traffic to a network of streets and highways or a network of transit. The route for these studies analyzed by Arc GIS.

2.10 **Summary of Literature reviews**

As described in the literature above the practice of designing interconnected routes and amenities for cycle users in order to enhance community mobility is known as "cycle network planning." Specifically, no published material about cycle network planning in Addis Ababa relevant to this research topic has been located. Nonetheless, there exist further written materials about implementation frame work for cycle network planning. Cycling has benefits in terms of preserving space, lowering pollution, reducing crashes , consuming less energy, reducing traffic, improving mobility, saving money, etc. (UNEP, 2010).

The aim of this study is to enhance mobility, a great deal of time and labor goes into creating a GIS-based cycle network planning tool that can be compared to the projected condition of the network. This study focuses on adopting a novel, highly reliable cycle network design and analysis for home-to-school activities using Addis Ababa as an example.
An analysis of the road network using the best route, service area, and closest facility criteria for residents (incidents) and schools (facilities), taking into consideration some attributes for this study, will be combined with the study's methods using ArcGIS Software, which is spatially compatible for network planning activities.

CHAPTER 3 MATERIAL AND METHODOLOGY

3.1 Study Area

Addis Ababa is the capital city of Ethiopia and the African Union and is often called the "African Capital" due to its historical, diplomatic, and political significance for the continent. Located in the foothills of the Entoto Mountains and standing 7,726 feet (2,355 meters) above sea level, it is the third-highest capital in the world. It is located in the geographic center of the country.

The city is situated on 527 km2 in Ethiopia. An approximate estimate of the population density is 5,165 people per square kilometer. There are 11 subcities in Addis Ababa. In order to gather data for this study planning a cycle network for home-to-school trip analysis is taken into account when defining the study area from visual site observations and ground truth analysis using representative residential densities and facilities were performed using Google Earth Pro.

There are four primary justifications for the center sites chosen in this case study. First off, because the city is tiny, cycling is a viable alternative mode of transportation for urban trips under five kilometers (Fernando Fonsica, 2023). Second, it is difficult to design a cycle network in this city due to the diversity of urban features present, particularly with regard to topography, urban tissue, and street layout. Since the Addis Ababa NMT strategy was implemented recently, cycling has been prioritized as a mode of transportation in an effort to counteract the city's rapid growth, motorization, congestion, air pollution, and rising rate of traffic fatalities (Global Designing Cities Initiative, world resource institute, 2020)

Third, the city is a prime illustration of a beginning-cycling city, with a high automobile-based reliance on mobility. Fourth, since cycling is encouraged as a daily means of transportation as part of the municipality's commitment to making mobility more sustainable. By offering preliminary direction in the creation of integrated strategies that go beyond putting isolated measures, like building a connected cycle network, the planning practice method outlined in this study could assist the urban planners of Addis Ababa City and other comparable starter cities.

Due to the above reason, cycle network plans in the example of Addis Ababa city, which has been selected as a center for the study for Destination location of schools (facilities), commuters who utilize buses and public taxis to get to Mexico, Megenagna are the focus of this case study using convenience selecting method also to select the location of the representative residence and representative school (facilities) for the study . Using Arc GIS software, the radius of the residential locations (incidents) from the main centers used for network analysis extension is a set amount.

Figure 10 showing study area boundary (Source: Prepared by Author, 2023)

Table 2 description of some sample of selected representative schools location for the study area (source: from google earth pro, 2023)

Id No	School Id	School name	Easting	Northing	Elevation	subcity
1	SCL1	DandiiBoruSchool	474959.6	994106.7	2331	KIRKOS
2	SCL2	Cistercian Monastery acadamy	480598.7	996255.2	2372	Bole
3	SCL3	Ethio-Parents' School	478716.0	995137.7	2354	Bole
4	SCL4	Joy Academy	473202.1	994828.1	2308	yeka

5	SCL5	Hillside SchooL	481611.6	997943.4	2416	Yeka
6	SCL6	International Community School of Addis Ababa (formerly American Community School	470052.4	994494.2	2323	Addis Ketema
7	SCL7	Lideta Catholic Cathedral School	472439.2	998312.4	2430	Lideta
8	SCL8	Lycée Guebre-Mariam	472784.9	997522.4	2385	Arada
9	SCL9	Nativity Girls School	472337.5	998200.0	2420	Bole

Table 3 description of some sample of selected representative residence location for the study area (source: from google earth pro, 2023)

Id No	**Residence Id**	**Residence name**	**Easting**	**Northing**	**Elevation**	**subcity**
1	**RDLocation1**	**Sengatera condominium**	**472183.6**	**996508.6**	**2374**	**Lideta**
2	**RDLocation2**	**Legehar condominium (Legehar tsebel)**	**472438.2**	**995723.7**	**2354**	**Kirkos**
3	**RDLocation3**	**24-condominium**	**477502.1**	**995405.2**	**2341**	**Bole**

4	RDLocation4	Signal condominium	476285.7	997231.1	2387	yeka
5	RDLocation5	Balsha wolde-chilotsite condominium	473526.0	998564.0	2430	Arada
6	RDLocation6	Lideta condominium	470967.7	996223.9	2359	lideta
7	RDLocation7	Shola Condominium	476971.0	997288.0	2376	Yeka
8	RDLocation8	yeka michael condominium block2	477424.9	997808.0	2416	yeka
9	RDLocation9	Handmade Luxury Real Estate	477032.6	997226.2	2374	yeka

The locations for carrying out cycle network planning for home to school activities for this study are decided based on the combination of suitability of gradient, speed and time impedance, traffic condition and the function of road .

The study locations chosen for the present study, satisfies the following criteria:

- The selected school location and residence location are representative for the case study.
- The traffic condition is continuous.
- The width of the road is considered

Table 4 Data/information and its source

Set of data	Source of the Data	Format	Data Objective

Road Network of Addis Ababa	Addis Ababa city government plan and development commission	.shp	Input data for network analysis
Land Use map of Addis Ababa	Addis Ababa city government plan and development commission	.pdf	Consider land use classification
DEM	Ethio_elevation	.tif	Generate elevation

Table 5 Software and instrument used for the study

Type	Source	Purpose
Arc GIS v. 10.8	Self	Network Analysis, Propose Optimum sites& others
Google Earth Pro	Self	To show the ground truth of the selected optimum sites, to obtain the location of origin-destination
MS-Office	Self	To prepare the study text and to perform statistical analysis.
Computer 8 GB Ram (Hp)	Self	Processing of raw data
External Hard Disc	Self	Data backup

3.2 Research Design

This study used a network analysis and descriptive technique. In the case of Addis Ababa, Ethiopia, the data were used for cycle network planning and evaluation of home-to-school trips. Both quantitative and qualitative data are being collected. The quantitative data will include the shape, length, and width of the street type, as well as the collection of representative schools and homes. On the other hand, the coordinates of sample incidents and facilities, names, and the like, will make up the qualitative data. Next, utilizing Arc Gis software and the network analysis extension, the network analysis will be completed.

3.3 Sampling Strategy and data collection

There are various approaches to gathering data. They are listed as follows:

1. Direct collection methods

2. Secondary source methods.

Data from direct collection is used to assign representative location for this case study network analysis.

The primary data was collected from visual observation the ground truth using

- Google earth pro in Collecting representative facility and residence location

The secondary data obtained from

- Road network of Addis Ababa city from Addis Ababa city plan and development commission

- Different research papers made on related title from internet source.

3.4 Flow of the methodology

The study's methodological flow is shown in the figure below, and additional details and an interpretation of the approach are provided Figure 11 below.

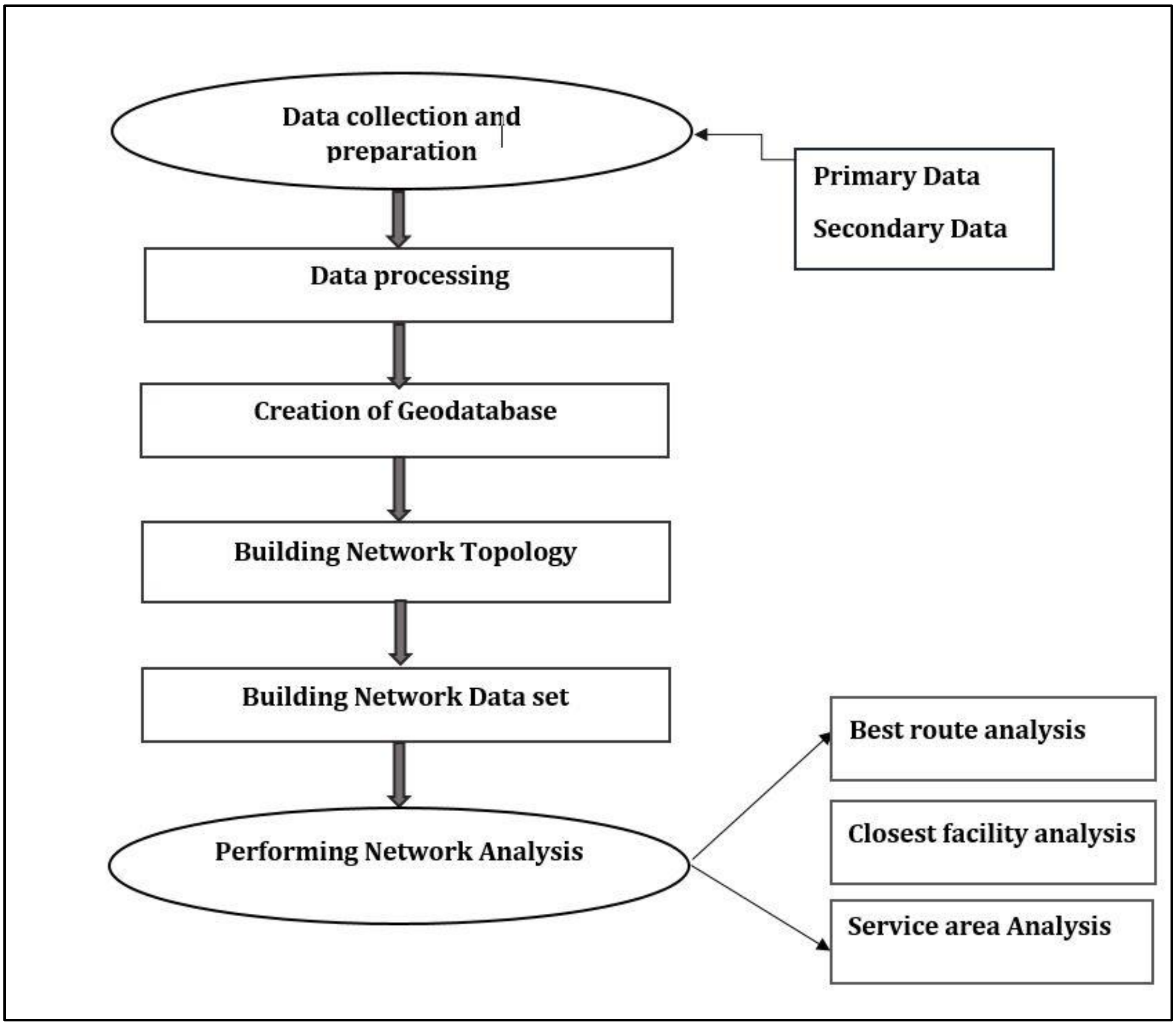

Figure 11 Flow of the methodology

3.4.1 Data Collection and Preparation

This stage involves gathering the map of the study region and getting the information on the road network ready for future investigation. The road network information for Addis Ababa city was first collected from Addis Ababa city government plan and development commission (.shp). The length, trip time, and speed of each road segment were entered in ArcGIS along with other parameters used to build the road network data, such as functional class.

3.4.2 Data processing

After gathering and preparing the data, the data processing stage is crucial because it involves converting the raw data into a format that can be more easily analyzed and understood by users. The primary and secondary data for this study were gathered and stored in Excel format (.xlsx), which was then imported into an Esri shape file format (.shp).

3.4.3 Creation of geodatabase

The Geo-database is the native data structure used in ArcGIS and is the fundamental data format used for both editing and management of the data. It provides the fundamental data structure for managing and editing the data. A Geodatabase can be personal, file, or enterprise. In this proposed method, a personal Geo-database has been created using ArcGIS. A personal Geodatabase is a database that can store, query, and manage both spatial and non-spatial data. It is used to handle road networks, selected residential locations, and school locations for the study area.

3.4.4 Building network topology

Building a topology of the road network is required to find any data inaccuracies to achieve good analysis and findings. Using a topology-editing tool, these mistakes were confirmed, and the proper corrections were made. As a result, an error-free digital road shapefile that could be used to create a road network dataset was produced. The following topology criteria were used to achieve this: Must Not Overlap, Must Not Have a Dangle, Must Not Intersect, and Must Be a Single Part. Each of these rules also has its error-correcting technique.

3.4.5 Building Network Dataset

A network dataset must be constructed to conduct a network analysis within ArcGIS. It is now ready to be used in creating the network dataset that will be used in the network analysis after the road network defects have been fixed.

The produced network dataset with properties for geodatabases Network Analysis Using GIS for A case study of Addis Ababa City, Ethiopia's bicycle network station location using metrics including hierarchy, meters, minutes, one-way, road class, journey duration, and more. Addis Ababa Road was selected to construct a network dataset for this study since it is ideal for modeling transportation networks.

It consists of a collection of edges, which stand in for the routes that agents will take, a set of junctions, which enable movement from one edge to another, and a set of turns, which stand in for the information that can be stored to influence movement between two or more edges.

3.5 Method of Data Analysis

Using GIS software, the study's approach included analyzing the road network to find the best cycling route from the study area's homes to School Activities. The steps are as follows

Step 1: Launching the Arc Gis program and Arc Map Including the shape files for the Addis Ababa city road network, typical school locations (in Csv format), and residence locations (in Csv format).

Step 2: Added Csv format files are transformed into the projected coordinate system Adindan UTM Zone 37N. Additionally, DEM.Tif (Ethio-elevation) raster data is added and used for the case study area's slope/gradient analysis.

Step 3: Connect the folder where the study data sets are located in the arc catalog, construct the feature data set, and create the feature data set class to import the shape files into the feature data set for the case study in this step.

Step 4: you will utilize network topology criteria to check for defects in the road network shape file in ArcMap, and the result will be an error-free digital road shapefile that can be used to construct a road network dataset for this study.

Step 5. Select the network analysis extension tool from the customize tool bar, then proceed to the road network shape file in the arc catalog to construct new network data from feature classes that serve as network sources and have connection policies and characteristics attached to them. provides the name of the study's network data set, connectivity settings, and a window for specifying the network data set's attributes when building it.

Step 6: Using the network analysis extension tool, execute network analyses such as the best route, closest facility, and service area analyses on the created network data set by loading and assigning study area locations, such as study area schools and residence sites, for this study.

The network analysis process has been summarized in six stages, starting with gathering and preparing the primary and secondary data that were utilized in the study, followed by processing the data that were used in further analysis. A geodatabase was then created and used to hold the prepared data. Then create the network dataset and network topology. After applying the network analysis procedure, it then searches for the best path for residence and school trips.

This was performed by representative candidates' sites (School locations i.e. facilities) and residential locations (incidents i.e. the beginning or ending) point features.

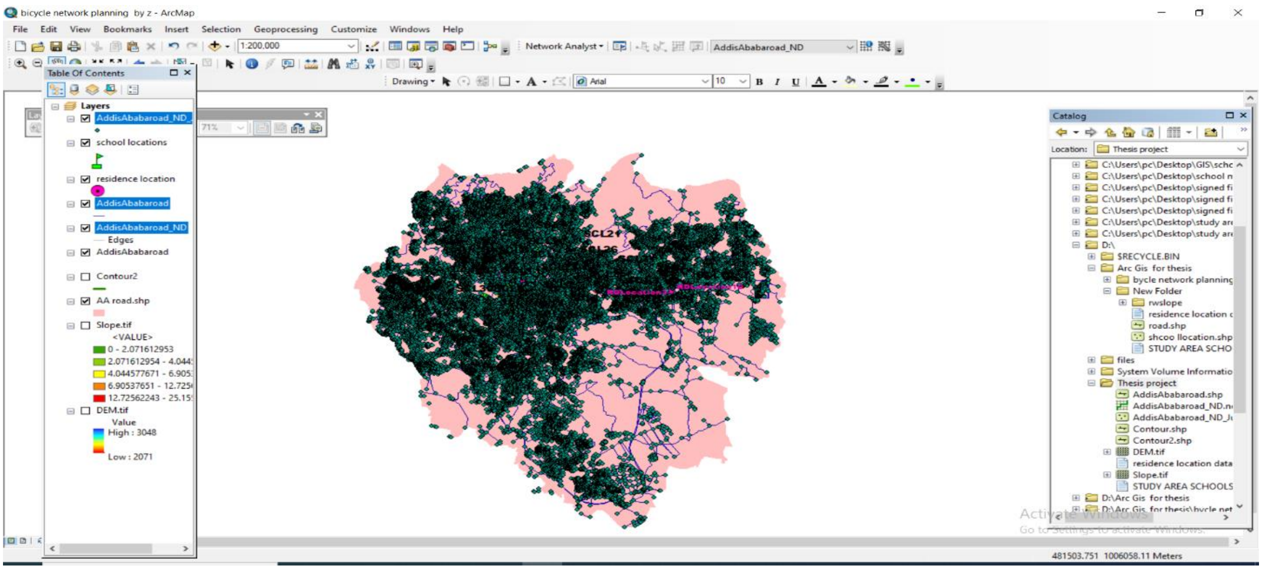

Figure 12 Building Network data set for the study area

3.6 Network attributes (factors)

Network attributes are characteristics of the network components that regulate network traversability. The amount of time it takes to drive a certain distance on the road, which streets Network Analysis Using GIS for finding the optimal path for a cycle network : Addis Ababa City case study, including information on the types of cars, the maximum speed limit, and which streets have one-way traffic.

The basic characteristics of these network features are name, usage kind, and use by default. The utilization type, which determines how the attributes will be employed during analysis, is also taken into account in this study.

3.6.1 Connectivity

Selecting the edge and junction elements from the source of the features to generate a network dataset. For appropriate network analysis results, it is crucial to make sure those edges and junctions are built properly.

Geometric coincidences of line endpoints, line vertices, and points, as well as the application of connectivity rules established as attributes of the network dataset, provide the foundation for connection in a network dataset. Any vertex connectivity policy technique was used in this investigation.

3.6.2 Cost

Impedance is measured and planned using specific characteristics, such as transit time. These characteristics are scattered along an edge. Network analysis typically involves the minimizing of cost (also known as impedance) during the calculation of a path (also known as finding the optimum route).

Finding the quickest route can reduce travel time while finding the shortest route can reduce distance. The network dataset's cost attributes additionally include travel time and distance.

The data in the shapefile was measured in minutes and meters, respectively, and the one-way constraint was disregarded. The Cost attribute reported in this study is based on data connected to the shapefile that includes journey time and distance by car.

3.7 Performing Network Analysis

The road network analysis has been implemented using ArcGIS Network Analyst Extension. A powerful extension of ArcGIS provides network-based spatial analysis, including route analysis, closest facility analysis, and service area analysis (Dabhade et al, 2015).

It allows users to dynamically model realistic road network factors, such as turn restrictions, speed limits, and traffic conditions at different times of the day. The ArcGIS Network Analyst Extension is used to calculate the least accumulated cost between the destination node and every other node in the network.

Based on GIs-based network Analysis for locating cycle networks for home-to-school trips: In the case of Addis Ababa City, there are three types of network analysis: best route analysis ,closet facilities analysis and service area analysis.

3.7.1 Best route analysis

This study determines the street's fastest and shortest paths based on the impedance, so that if the fastest and shortest routes are the best options, the impedance factors are time and distance, respectively.

The optimum route may therefore be defined as the one with the lowest impedance or the one with the lowest cost, where the impedance is chosen depending on the city putted standard. Any cost element can be used as an impedance while determining the best course of action. The optimal route analysis in this study was determined using the temporal impedance factor.

3.7.2 Closest facilities analysis

The closest facility solver figures out which facility is closest to the incident location by calculating the driving time and distance between the facilities and the location of the incidents, or vice versa.

3.7.3 Service Area Coverage Analysis

Service area is a function of accessibility. It is a region that encloses all accessible streets within a given time and restriction. Service Area is used to evaluate the service coverage extent of a facility within specified impedance and it is established by a Network Analyst to examine accessibility by exposing any gap in facility service coverage within a given time.

In ArcGIS Network Analysis, accessibility is measured in terms of travel time, distance, or any other impedance on the network. Drive time polygons are ring-like polygons that display all accessible streets within a particular travel- time from that point of origin.

CHAPTER 4 RESULT AND DISCUSSION

General

To make the paper easier to read, the research's findings are presented in analytical and tabular versions. This chapter is organized into six sections to help with the action: gradient suitability analysis, best route analysis, closest facility analysis, service area analysis, cycle network analysis plan for this study with cycle network plan and logical network analysis results with normal network conditions of road network.

4.1 Gradient suitability analysis

The Slope/gradient tool measures the degree of steepness at each raster surface cell. The slope value determines how steep the terrain is; the slope value indicates flatter terrain. The Slope tool should be substituted with the Surface Parameters tool because it offers a more recent implementation of slope. The Slope tool fits a plane to the nine local cells, although a plane might not accurately describe the landscape and might hide or exaggerate interesting natural changes. The Surface Parameters tool adapts a surface to the vicinity of cells rather than a plane, giving the landscape a more realistic fit.

Here, we may measure the topography or gradient of the cycle network in the research area, which has an impact on its attractiveness and comfort. The slope percentage of the bicycle network serves as an indicator for planning the topography of the network. Because it requires more effort, cyclists will not use areas with steep slopes. Degrees or percent (percent rise) can be used to calculate the output slope raster. If you think of the percent rise as the rise multiplied by the run and divided by 100, it will be easier to understand. The fraction of cycle networks with low slopes is used to plan this variable.

The ratio is calculated by dividing the vertical height difference of the bicycle route in the transit-oriented development region by the route's overall length. NACTOS suggests that the best slope percentage for a network of bicycle routes be less than 6%; gradient analysis supports this recommendation. (Figure 13) by Arc GIS depicts the slope percentage for the area where the cycle network plan is within the acceptable range and is low compared to the suggested percentage, making the network suitable for cycling in the study area.

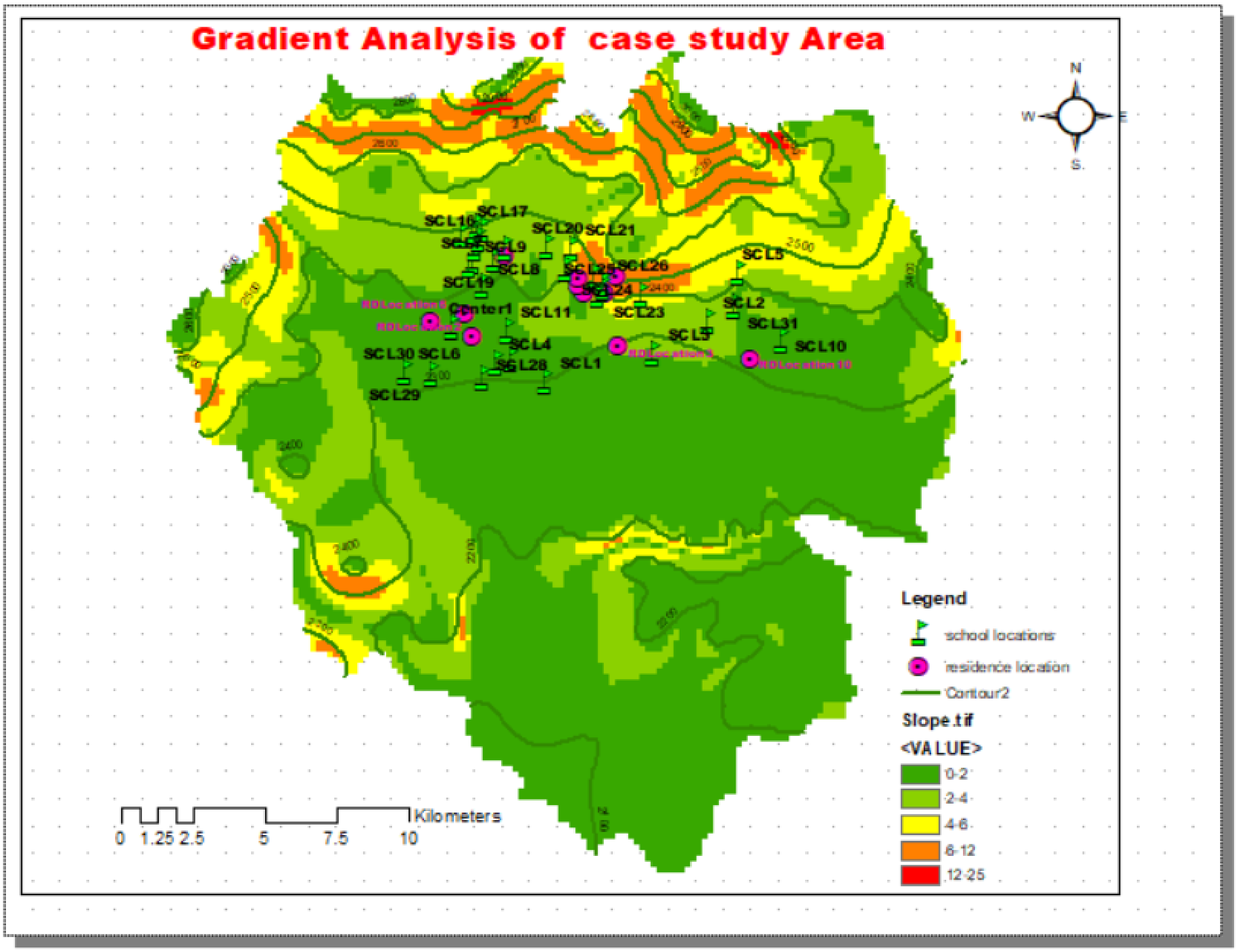

Figure 13 Gradient analysis for the study area

4.2 best route analysis

According to the impedance used in this study to identify the network's fastest and shortest paths, the impedance factors are time and distance and also considering traffic condition Making cycling irresistible. Cycles can be used in conjunction with other forms of transportation, such as public transportation, over longer distances. Because of the numerous advantages of cycling, several nations have been implementing a wide range of cycle-friendly policies to entice tourists to pedal frequently.

If the fastest and shortest routes are the best possibilities. In cases when the impedance has been chosen, the lowest impedance or the least expensive path may be considered the optimal route. If you are trying to decide what the optimal course of action is, you can utilize any cost component as an impedance.

In this investigation, Within a hierarchical network, the functionality of roads can be divided into three categories: through roads, distributor roads, and access roads. Through roads (arterials) are ideally suited for through traffic as well as for planning the cycle network because they are made to convey cars from point home to point school efficiently.

The majority of access routes are residential streets, which prioritize safe, leisurely paths for people. Distributor roads (collector) link access and through roads, promoting traffic flow and offering secure interchanges, particularly when they cross a road serving a different purpose.

For the purposes of this study, the researcher has taken into account the function of the road (see Table1) for optimal route analysis resulted in (see appendix B).according to the study's findings, choosing the shortest network or the network with the shortest travel distance constitutes choosing the best network. GIS seeks to identify the shortest distance and shortest travel time optimal network between the specified origin and destination.

Therefore in networking the facilities best network for this study is one that has a total length of 13028.36 m and total minutes of 202.46 after the best network analysis settings have been resulted for the facilities, or schools.

4.2 Closet Facility Analysis

4.2.1 Trip generation

For this research, Home-based education /school trip production =1.686X-10.638 where ’X’ Number of students, where R^2 is 0.99 has computed and selected The term "trip attraction" refers to trips that are drawn to non-residential end schools. Total education trip attraction = 1.61X+0.063 where 'X' number of Student Enrolment, where R^2 is 0.99. and from the selected number of students representative schools Six representative zones of SCL8 (lychee Gebremariam school), SCL1 (Dandiboru school),SCL3(Ethio parents school), SCL21 (Kokebe tsibah secondary and preparatory school), SCL22 (School of tomorrow) and SCL 18(Minilik high school) students Enrollment for this study the total trip production is 38784 and total trip attraction is 37098.

4.2.2 Trip distribution

The "trip table," a matrix that shows the amount of trips travelling from each origin to each destination, is created in the four-step transportation forecasting model by focusing on the sources and destinations of trip makers. distribution of trips.

Analysis is done using the gravity model, in which the number of trips between two zones is inversely proportional to the distance between the two zones and directly proportional to the number of trips created in zone i and the number of trips attracted to zone j.

Table 6 showing school trips for this study

	SCL 8	SCL 1	SCL 3	SCL 21	SCL 22	SCL 18	O_i	
SCL 8							3024	
SCL 1							4036	
SCL 3							5047	
SCL 21							6467	
SCL 22							8419	Σ
SCL 18							11791	37098
Dj	2898	3864	4830	6186	8050	11270		
						Σ	38784		

Table 7 showing cost matrix for the study

Cost matrix (generalized cost matrix) for this study						
	SCL 8	SCL 1	SCL 3	SCL 21	SCL 22	SCL 18
SCL 8	7	12	14	22	23	27
SCL 1	12	5	13	15	17	23
SCL 3	14	13	5	20	17	13
SCL 21	22	15	20	8	13	15
SCL 22	23	17	17	13	8	14
SCL 18	27	23	13	15	14	10

For the service / Educational trips you shall use a single constrined gravity model with a deterrence function like a exponential function; F = exp ($-\alpha$ cij) & α=0.07 to determine basic single constrained matrix as shown in the (Table 7) then Making the model double constrained by adjusting the attractions proportionally for iteration process.

Table 8 Deterence function computation table

Deterrence function computation							
	SCL 8	SCL 1	SCL 3	SCL 21	SCL 22	SCL 18	Sum
SCL8	1,775.4	1,668.1	1,812.8	1,326.2	1,609.1	1,702.6	9,894.1
SCL 1	1,251.1	2,722.9	1,944.2	2,164.7	2,449.0	2,252.7	12,784.6
SCL 3	1,087.7	1,555.4	3,403.6	1,525.4	2,449.0	4,536.4	14,557.5
SCL 21	621.3	1,352.2	1,191.1	3,533.5	3,240.3	3,943.8	13,882.1
SCL 22	579.3	1,175.5	1,469.4	2,490.0	4,598.2	4,229.8	14,542.2

SCL 18	437.8	772.4	1,944.2	2,164.7	3,021.3	5,596.5	13,936.8

The basic constraint matrix is computed as shown below by Dj*Oi* exp (-αcij)/ αexp (-αcij). Also Making the model double constrained by adjusting the attractions proportionally or corrected attractions for preparations by doubly constraint gravity model basic constraint matrix & iterations Dj*Σ Dj /ΣOi by as shown in the table 8.

Table 9 showing correction of attractions

Corrected attractions:						
SCL 8	SCL 1	SCL 3	SCL 21	SCL 22	SCL 18	SUM
3030	4040	5050	6467	8416	11782	38784

Table 10 showing Basic single constraint matrix after correction of attractions

Basic single constraint matrix							
	1	2	3	4	5	6	Sum
1	543	510	554	405	492	520	3,024
2	395	860	614	683	773	711	4,036
3	377	539	1,180	529	849	1,573	5,047
4	289	630	555	1,646	1,510	1,837	6,467
5	335	681	851	1,442	2,662	2,449	8,419
6	376	663	1,670	1,859	2,595	4,807	11,971
	2,316	3,883	5,423	6,565	8,881	11,897	38,964
Dj	3,030	4,040	5,050	6,467	8,416	11,782	38,784
	1.31	1.04	0.93	0.99	0.95	0.99	

Table 11 Iteration 0ne of trip distribution

1. iteration									
	1	2	3	4	5	6	Sum	Oi	ai
1	710	530	516	399	466	515	3,137	3,024	0.96
2	517	894	571	673	733	704	4,093	4,036	0.99
3	493	561	1,099	521	805	1,558	5,036	5,047	1.00
4	379	655	517	1,622	1,431	1,819	6,422	6,467	1.01
5	439	708	792	1,420	2,523	2,425	8,307	8,419	1.01
6	492	690	1,555	1,832	2,459	4,761	11,789	11,971	1.02
Sum	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
D_j	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
bj	1.00	1.00	1.00	1.00	1.00	1.00			

Table 12 Iteration Two of trip distribution

2. iteration									
	1	2	3	4	5	6	Sum	Oi	ai
1	684	511	497	385	449	497	3,024	3,024	1.00
2	510	882	564	664	722	695	4,036	4,036	1.00
3	494	562	1,101	522	806	1,561	5,047	5,047	1.00
4	381	660	520	1,633	1,440	1,832	6,467	6,467	1.00
5	445	718	803	1,439	2,557	2,458	8,419	8,419	1.00
6	500	701	1,579	1,860	2,497	4,834	11,971	11,971	1.00
Sum	3,014	4,034	5,064	6,503	8,473	11,876	38,964		
D_j	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
bj	1.01	1.00	1.00	0.99	0.99	0.99			

Table 13 Iteration Three of trip distribution

3. iteration									
	1	2	3	4	5	6	Sum	Oi	ai
1	688	512	496	383	446	493	3,018	3,024	1.00
2	512	883	562	660	718	689	4,024	4,036	1.00
3	497	563	1,098	519	801	1,548	5,027	5,047	1.00
4	383	661	519	1,624	1,431	1,818	6,435	6,467	1.00
5	447	719	800	1,431	2,540	2,438	8,375	8,419	1.01
6	502	702	1,574	1,850	2,481	4,796	11,905	11,971	1.01
Sum	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
D_j	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
bj	1.00	1.00	1.00	1.00	1.00	1.00			

Table 14 Iteration four of trip distribution

4. iteration									
	1	2	3	4	5	6	Sum	Oi	ai
1	689	513	497	384	447	494	3,024	3,024	1.00
2	514	886	564	662	720	691	4,036	4,036	1.00
3	499	565	1,102	521	804	1,555	5,047	5,047	1.00
4	385	664	521	1,632	1,438	1,827	6,467	6,467	1.00
5	449	722	805	1,439	2,553	2,451	8,419	8,419	1.00
6	505	706	1,583	1,860	2,494	4,823	11,971	11,971	1.00
Sum	3,042	4,056	5,072	6,498	8,456	11,840	38,964		
D_j	3,030	4,040	5,050	6,467	8,416	11,782	38,784		
bj	1.00	1.00	1.00	1.00	1.00	1.00			

The final trip distribution matrix for the study area is presented as indicated in the table above while dealing with how the Origin and destination matrix for the chosen zone of this research study area is developed and how the trip distribution model is thus carried out.

4.2.3 Mode choice

Logit models are divided into three categories based on their utility function for mode choice probability. These are Binomial (if there are two alternative mode options) and multinomial logit , which enables a correlation between the utility of the alternatives in shared groups for this study's unspecified other alternatives.

4.2.4 Trip Assignment

The precise roads or routes that will be used for each journey can be identified once the number of trips that will enter and exit each zone, as well as the forms of transportation that the travelers will use, have been defined. The trip assignment entails allocating traffic to a network of streets and highways or a network of transit. The route for these studies analyzed by GIS are as shown and discussed below (see appendex E1 & table 14).

Having (Figure 14) by Arc GIS depicts the slope percentage for the area where the cycle network plan is within the acceptable range and is low compared to the suggested percentage, making the network suitable for cycling in the study area.

Finding the closest facilities (schools) for dwellings was the study's analytical solution. It generates a total of 48 routes using the facility class labels color ramps in (appendix F) and from sorted results in (Table 14) Based on available travel time and traffic conditions, the closet facilities analysis determines the closest facilities that can be reached in a certain amount of time from an incident location.

It is necessary to create a closet facility analysis layer and its analysis attributes to apply this analysis. The characteristics that must be considered when analyzing closet facilities are the impedance factor, journey time (in minutes and meters) accumulated over the distance traveled, the number of facilities to be located, and the direction of travel.

The closest facility or facilities to an incident based on a given network can be identified using this layer. This analysis determines the closest facilities that can be reached in a predetermined amount of time from an incident (a residence) to facilities (a school).

Facilities with facility class label rank1 have maximum travel times of 2.549 minutes, minimum travel times of 0.309 minutes, maximum lengths of 1699.963 meters, and minimum lengths of 205.749 meters, facilities with facility class label rank 2 have maximum travel times of 4.427 minutes, minimum travel times of 0.828 minutes, maximum lengths of 2952.356 meters, and minimum lengths of 551.949 meters.

The facility class label rank 3 has a maximum travel time of 4.520 minutes, a minimum travel time of 1.339 minutes, a maximum length of 3014.426 meters, and a minimum length of 892.792 meters. Lastly, the facility class label rank 4 has a maximum travel time of 6.081 minutes, a minimum travel time of 1.614 minutes, a maximum length of 4055.767 meters, and a minimum length of 1076.169 meters. The facilities (schools) and incidents (residence) for this study are chosen as indicated in the table below.

Table 15 Arranged & and summarized closest facility analysis results

FacilityID	IncidentID	FacilityRank	Name	Total_Length	Total_Minutes	Rank
27	7	1	Location 7 - Location 27	205.749	0.309	1
27	9	1	Location 9 - Location 27	322.220	0.483	2
20	5	1	Location 5 - Location 20	377.044	0.565	3
25	4	1	Location 4 - Location 25	738.782	1.108	4
25	11	1	Location 11 - Location 25	748.147	1.122	5
24	12	1	Location 12 - Location 24	827.460	1.241	6
12	6	1	Location 6 - Location 12	933.455	1.400	7
12	1	1	Location 1 - Location 12	982.525	1.473	8
12	2	1	Location 2 - Location 12	1043.264	1.564	9
24	8	1	Location 8 - Location 24	1092.911	1.639	10
3	3	1	Location 3 - Location 3	1557.998	2.336	11
10	10	1	Location 10 - Location 10	1699.963	2.549	12
28	7	2	Location 7 - Location 28	551.949	0.828	1
28	9	2	Location 9 - Location 28	598.537	0.897	2
24	11	2	Location 11 - Location 24	866.407	1.299	3
24	4	2	Location 4 - Location 24	974.270	1.461	4
28	8	2	Location 8 - Location 28	1198.749	1.797	5
28	12	2	Location 12 - Location 28	1304.639	1.956	6
21	5	2	Location 5 - Location 21	1358.715	2.037	7
4	2	2	Location 2 - Location 4	1429.147	2.143	8
8	1	2	Location 1 - Location 8	1528.933	2.293	9
6	6	2	Location 6 - Location 6	2412.562	3.617	10
13	3	2	Location 3 - Location 13	2493.281	3.738	11
2	10	2	Location 10 - Location 2	2952.356	4.427	12
25	7	3	Location 7 - Location 25	892.792	1.339	1
25	9	3	Location 9 - Location 25	896.667	1.344	2
27	11	3	Location 11 - Location 27	1121.272	1.681	3
27	4	3	Location 4 - Location 27	1131.307	1.696	4
27	8	3	Location 8 - Location 27	1222.881	1.834	5
25	12	3	Location 12 - Location 25	1447.324	2.170	6
18	5	3	Location 5 - Location 18	1458.683	2.187	7
30	2	3	Location 2 - Location 30	1814.244	2.720	8
11	1	3	Location 1 - Location 11	2144.407	3.215	9
32	6	3	Location 6 - Location 32	2412.562	3.617	10
25	3	3	Location 3 - Location 25	2646.931	3.969	11
33	10	3	Location 10 - Location 33	3014.426	4.520	12
24	7	4	Location 7 - Location 24	1076.169	1.614	1
24	9	4	Location 9 - Location 24	1080.043	1.619	2
28	11	4	Location 11 - Location 28	1147.856	1.721	3
28	4	4	Location 4 - Location 28	1157.891	1.736	4
13	8	4	Location 8 - Location 13	1270.893	1.906	5
27	12	4	Location 12 - Location 27	1529.911	2.294	6
15	5	4	Location 5 - Location 15	1825.422	2.737	7
11	2	4	Location 2 - Location 11	1836.981	2.754	8
9	1	4	Location 1 - Location 9	2347.027	3.519	9
31	6	4	Location 6 - Location 31	2596.392	3.893	10
27	3	4	Location 3 - Location 27	2760.004	4.138	11
5	10	4	Location 10 - Location 5	4055.767	6.081	12

Table 16 The closest facility chosen after analysis for all label class

FacilityID	IncidentID	FacilityRank	Name by ID	Total_Length	Total_Minutes	Rank	Remark
27	7	1	RDLocation7 -SCL 27	205.749	0.309	1	Chosen
27	9	1	RDLocation9 - SCL27	322.220	0.483	2	Chosen
20	5	1	RDLocation5 - SCL 20	377.044	0.565	3	Chosen
28	7	2	RDLocation7 - SCL28	551.949	0.828	4	Chosen
28	9	2	RDLocation 9 - SCL 28	598.537	0.897	5	Chosen
25	4	1	RDLocation4 - SCL 25	738.782	1.108	6	Chosen
25	11	1	RDLocation11 - SCL 25	748.147	1.122	7	Chosen
24	12	1	RDLocation12 - SCL 24	827.460	1.241	8	Chosen
24	11	2	RDLocation11 - SCL 24	866.407	1.299	9	Chosen
25	7	3	RDLocation 7 - SCL25	892.792	1.339	10	Chosen
25	9	3	RDLocation 9 - SCL 25	896.667	1.344	11	Chosen
12	6	1	RDLocation 6 -SCL 12	933.455	1.400	12	Chosen
24	4	2	RDLocation 4 - SCL 24	974.270	1.461	13	Chosen
12	1	1	RDLocation 1 - SCL 12	982.525	1.473	14	Chosen
12	2	1	RDLocation 2 - SCL 12	1043.264	1.564	15	Chosen
24	7	4	RDLocation 7 - SCL 24	1076.169	1.614	16	Chosen
24	9	4	RDLocation 9 - SCL 24	1080.043	1.619	17	Chosen
24	8	1	RDLocation 8 - SCL 24	1092.911	1.639	18	Chosen
27	11	3	RDLocation 11 - SCL 27	1121.272	1.681	19	Chosen
27	4	3	RDLocation 4 - SCL27	1131.307	1.696	20	Chosen

The output of table for the 20 best label classes selected shows that the location with the shortest total travel time was RDLocation 7(shola condominium) -SCL 27(new grand school), where the travel time was 0.309 minutes, and the location with the longest total travel time was RDLocation 4 (Signal condominium)-SCL27 (new grand school) where the travel time was 1.696 minutes.

4.3 Service Area Coverage Result & Discussion

For this study, you can locate service zones around any facilities (i.e. schools) on a network using the ArcGIS Network Analyst extension. All accessible streets (i.e, streets that are within a given impedance) are included in a network service area. For instance, all of the facilities that are contained within the interval breaks for this study are included in the breaks with interval service areas for a facility on a network (as shown in appendix H and table 16).

Table 17 service area analysis result for the study area

ObjectID	FacilityID	Name	FromBreak	ToBreak	Remark
1	33	SCL33 : 500 - 1000	500	1000	SC
2	21	SCL 21 : 500 - 1000	500	1000	SC
3	1	RDLocation 1 : 500 - 1000	500	1000	RD
4	23	SCL 23 : 500 - 1000	500	1000	SC
5	20	SCL 20 : 500 - 1000	500	1000	SC
6	2	RDLocation 2 : 500 - 1000	500	1000	RD
7	32	SCL 32 : 500 - 1000	500	1000	SC
8	19	SCL 19 : 500 - 1000	500	1000	SC
9	3	RDLocation 3 : 500 - 1000	500	1000	RD
10	24	SCL 24 : 500 - 1000	500	1000	SC
11	18	SCL 18 : 500 - 1000	500	1000	SC
12	4	RDLocation 4 : 500 - 1000	500	1000	RD
13	31	SCL 31 : 500 - 1000	500	1000	SC
14	17	SCL 17 : 500 - 1000	500	1000	SC
15	5	RDLocation 5 : 500 - 1000	500	1000	RD
16	25	SCL25 : 500 - 1000	500	1000	SC
17	16	SCL 16 : 500 - 1000	500	1000	SC
18	6	RDLocation 6 : 500 - 1000	500	1000	RD
19	30	SCL30 : 500 - 1000	500	1000	SC
20	15	SCL15 : 500 - 1000	500	1000	SC
21	7	RDLocation7 : 500 - 1000	500	1000	RD
22	26	SCL 26 : 500 - 1000	500	1000	SC
23	14	SCL14 : 500 - 1000	500	1000	SC
24	8	RDLocation 8 : 500 - 1000	500	1000	RD
25	29	SCL 29 : 500 - 1000	500	1000	SC
26	13	SCL13 : 500 - 1000	500	1000	SC
27	9	RDLocation 9 : 500 - 1000	500	1000	RD
28	27	SCL 27 : 500 - 1000	500	1000	SC
29	12	RDLocation12 : 500 - 1000	500	1000	RD
30	10	RDLocation 10 : 500 - 1000	500	1000	RD
31	28	SCL 28 : 500 - 1000	500	1000	SC
32	22	SCL 22 : 500 - 1000	500	1000	SC
33	11	RDLocation 11 : 500 - 1000	500	1000	RD
34	11	RDLocation11 : 200 - 500	200	500	RD
35	12	RDLocation 12 : 200 - 500	200	500	RD
36	10	RDLocation 10 : 200 - 500	200	500	RD
37	29	SCL29 : 200 - 500	200	500	SC
38	13	SCL13 : 200 - 500	200	500	SC
39	9	RDLocation9 : 200 - 500	200	500	RD
40	27	SCL27 : 200 - 500	200	500	SC
41	14	SCL 14 : 200 - 500	200	500	SC
42	8	RDLocation 8 : 200 - 500	200	500	RD
43	30	SCL 30 : 200 - 500	200	500	SC
44	15	SCL 15 : 200 - 500	200	500	SC
45	7	RDLocation 7 : 200 - 500	200	500	RD
46	26	SCL 26 : 200 - 500	200	500	SC
47	16	SCL 16 : 200 - 500	200	500	SC

48	6	RDLocation 6 : 200 - 500	200	500	RD
49	31	SCL 31 : 200 - 500	200	500	SC
50	17	SCL 17 : 200 - 500	200	500	SC
51	5	RDLocation5 : 200 - 500	200	500	RD
52	25	SCL 25 : 200 - 500	200	500	SC
53	18	SCL 18 : 200 - 500	200	500	SC
54	4	RDLocation 4 : 200 - 500	200	500	RD
55	32	SCL 32 : 200 - 500	200	500	SC
56	19	SCL19 : 200 - 500	200	500	SC
57	3	RDLocation3 : 200 - 500	200	500	RD
58	24	SCL 24 : 200 - 500	200	500	SC
59	20	SCL20 : 200 - 500	200	500	SC
60	2	RDLocation 2 : 200 - 500	200	500	RD
61	33	SCL 33 : 200 - 500	200	500	SC
62	21	SCL21 : 200 - 500	200	500	SC
63	1	RDLocation 1 : 200 - 500	200	500	RD
64	23	SCL 23 : 200 - 500	200	500	SC
65	22	SCL22 : 200 - 500	200	500	SC
66	28	SCL 28 : 200 - 500	200	500	SC
67	23	SCL 23 : 0 - 200	0	200	SC
68	22	SCL 22 : 0 - 200	0	200	SC
69	21	SCL21 : 0 - 200	0	200	SC
70	24	SCL 24 : 0 - 200	0	200	SC
71	20	SCL 20 : 0 - 200	0	200	SC
72	19	SCL 19 : 0 - 200	0	200	SC
73	25	SCL 25 : 0 - 200	0	200	SC
74	18	SCL 18 : 0 - 200	0	200	SC
75	17	SCL 17 : 0 - 200	0	200	SC
76	26	SCL 26 : 0 - 200	0	200	SC
77	16	SCL 16 : 0 - 200	0	200	SC
78	15	SCL15 : 0 - 200	0	200	SC
79	27	SCL27 : 0 - 200	0	200	SC
80	14	SCL 14 : 0 - 200	0	200	SC
81	13	SCL 13 : 0 - 200	0	200	SC
82	28	SCL28 : 0 - 200	0	200	SC
83	12	RDLocation 12 : 0 - 200	0	200	RD
84	11	RDLocation 11 : 0 - 200	0	200	RD
85	29	SCL29 : 0 - 200	0	200	SC
86	10	RDLocation 10 : 0 - 200	0	200	RD
87	9	RDLocation 9 : 0 - 200	0	200	RD
88	30	SCL 30 : 0 - 200	0	200	SC
89	8	RDLocation 8 : 0 - 200	0	200	RD
90	7	RDLocation 7 : 0 - 200	0	200	RD
91	31	SCL 31 : 0 - 200	0	200	SC
92	6	RDLocation 6 : 0 - 200	0	200	RD
93	5	RDLocation : 0 - 200	0	200	RD
94	32	SCL 32 : 0 - 200	0	200	SC
95	4	RDLocation 4 : 0 - 200	0	200	RD
96	3	RDLocation 3 : 0 - 200	0	200	RD
97	33	SCL 33 : 0 - 200	0	200	SC
98	2	RDLocation 2 : 0 - 200	0	200	RD
99	1	RDLocation 1 : 0 - 200	0	200	RD

Table 16 illustrates that the service area analysis demonstrates that the facilities of the study area that are provided during breaks are enclosed within break intervals with incidents (residence location), and will be appropriately served for this study's activities. Thus, it demonstrates that the case study area is satisfied by the network service area analysis extension tool in this study.

4.4 cycle network analysis plan for this study Vs cycle network plan

In this section, after the findings of the network analysis In order to verify if the planned cycle network is connected and whether streets have logical cycle network planning that is consistent with the intended scenarios, the logical network analysis of this study is compared with the phase plan of the planned cycle network.

Table 18 Comparison of logical network analysis with planned network phase

Network Name	utilizing the street for network analysis	Row (m)	Connected to phase plan
RD location 1 – SCL 11	Ras mekonn Avenue/PAS	40	Phase 1
RD location1 - SCL 8	Churchill Avenue PAS	40	Existing
RD Location4 - SCL 24	Kenenisa Street/SAS	25	Phase 2
RDLocation4 - SCL 25	Kenenisa street/SAS	25	Phase 2
RDLocation4 - SCL 27	Kenenisa street/SAS	25	Phase 2
RDLocation4 - SCL 28	Kenenisa street/SAS	25	Phase 2
RDLocation 7 – SCL 25	Kenenisa street/SAS	25	Phase 2
RD Location 9 - SCL 25	Kenenisa street/SAS	25	Phase 2
RD Location 11 - SCL 25	Kenenisa street/SAS	25	Phase 2
RDLocation 11 - SCL 27	Kenenisa street/SAS	25	Phase 2
RDLocation 11 - SCL 28	Kenenisa street/SAS	25	Phase 2
RD Location 12 - SCL 25	Kenenisa street/SAS	25	Phase 2
RD location 3- SCL 3	BL-03 -785 Av/ Bole PAS	60	Existing
RD Location 8 - SCL 24	Fikre Mariam Aba techan street /ring road/PAS	40	Phase1
RDLocation 2 - SCL 12	Mozambique Street/SAS	30	Phase 1
RD Location 1 - SCL 12	Chad Street/PAS	40	Phase2
RD Location 6 - SCL 12	Chad street/PAS	40	Phase2
RD Location 2 - SCL 4	SAS	30	Phase 1
RD Location 10 - SCL 2	SAS	30	Phase 1
RD Location 3 - SCL 13	SAS	30	Phase 1
RD Location 1 - SCL 8	Churchill Avenue/PAS	40	existed
RD Location 5 - SCL 21	General winget street/SAS	25	Phase 2
RD Location 6- SCL 32	South Africa street/SAS	30	Phase 1
RD Location 6 - SCL 6	South Africa street/SAS	30	Phase 1

RD location3- SCL 27	Kebele 24 to Megenagnam/SAS	30	Phase 3
RD Location 3 - SCL 13	Fikremariam aba techan street/Ring road/PAS	40	Phase 1
RD location8- SCL 13	Fikremariam aba techan street/Ring road/PAS	40	Phase 1
RD location8- SCL 28	Fikremariam aba techan street/Ring road/PAS	40	Phase 1
RD location8- SCL 27	Fikremariam aba techan street/Ring road/PAS	40	Phase 1
RD location1- SCL 9	Tesema aba kemaw street/PAS	40	Phase 3

The logical network analysis of this study is contrasted with the phase plan in the table 17. According to the data, 10.35% of the study area's networks are connected to the existing phase, 37.93% are connected to Phase 1 under the short-term implementation plan, 44.83% are connected to Phase 2 under the medium-term implementation plan, and the remaining 6.90% are connected to phase 3 under the long-term implementation plan.

After analysis, results regrading with street types about 60% of analysis for this study is compatible with secondary arterial streets (SAS) with ROW 30 m network to be implement unidirectional network on both sides of street 2m width per direction. In addition, for ROW less than 30m network to be implement is bidirectional on one side of the street 3m for two directions.

40% of Analysis result for this study is compatible with principal Arterial streets (PAS) network to implement is unidirectional network on both side of the street 2m per direction. From these comparisons, it is clear that the proposed network was taken into account in the network analysis for this study.

Table 19 Comparison of network analysis results with normal network conditions of road network

		Result from cycle netwok analysis							Due normal network condition on the road network		
ObjectID	FacilityID	FacilityRank	Name	IncidentID	Total_Length	otal_Minute	Rank	T.length	T. minutes	% of length reduction	% of minutes reduction
25	27	1	Location 7 - Location 27	7	205.749	0.309	1	6900	10.35	97.02	97.02
33	27	1	Location 9 - Location 27	9	322.220	0.483	2	6900	10.35	95.33	95.33
17	20	1	Location 5 - Location 20	5	377.044	0.565	3	4200	6.30	91.02	91.03
13	25	1	Location 4 - Location 25	4	738.782	1.108	4	1100	1.65	32.84	32.86
41	25	1	Location 11 - Location 25	11	748.147	1.122	5	2700	4.05	72.29	72.30
45	24	1	Location 12 - Location 24	12	827.460	1.241	6	1000	1.50	17.25	17.29
21	12	1	Location 6 - Location 12	6	933.455	1.400	7	4700	7.05	80.14	80.15
1	12	1	Location 1 - Location 12	1	982.525	1.473	8	3700	5.50	73.45	73.21
5	12	1	Location 2 - Location 12	2	1043.264	1.564	9	5200	7.80	79.94	79.95
29	24	1	Location 8 - Location 24	8	1092.911	1.639	10	2400	3.60	54.46	54.48
9	3	1	Location 3 - Location 3	3	1557.998	2.336	11	1800	2.70	13.44	13.48
37	10	1	Location 10 - Location 10	10	1699.963	2.549	12	4400	6.60	61.36	61.38
26	28	2	Location 7 - Location 28	7	551.949	0.828	1	7800	11.70	92.92	92.93
34	28	2	Location 9 - Location 28	9	598.537	0.897	2	8200	12.30	92.70	92.70
42	24	2	Location 11 - Location 24	11	866.407	1.299	3	1700	2.55	49.03	49.05
14	24	2	Location 4 - Location 24	4	974.270	1.461	4	1500	23.00	35.05	93.65
30	28	2	Location 8 - Location 28	8	1198.749	1.797	5	8800	26.00	86.38	93.09
46	28	2	Location 12 - Location 28	12	1304.639	1.956	6	7600	24.00	82.83	91.85
18	21	2	Location 5 - Location 21	5	1358.715	2.037	7	5000	14.00	72.83	85.45
6	4	2	Location 2 - Location 4	2	1429.147	2.143	8	4200	15.00	65.97	85.71
2	8	2	Location 1 - Location 8	1	1528.933	2.293	9	1700	9.00	10.06	74.53
22	6	2	Location 6 - Location 6	6	2412.562	3.617	10	2600	3.90	7.21	7.25
10	13	2	Location 3 - Location 13	3	2493.281	3.738	11	8700	13.05	71.34	71.35
38	2	2	Location 10 - Location 2	10	2952.356	4.427	12	4900	7.35	39.75	39.77
43	27	3	Location 11 - Location 27	11	1121.272	1.681	3	6000	9.00	81.31	81.32
15	27	3	Location 4 - Location 27	4	1131.307	1.696	4	6100	9.15	81.45	81.46
31	27	3	Location 8 - Location 27	8	1222.881	1.834	5	7900	11.85	84.52	84.53
47	25	3	Location 12 - Location 25	12	1447.324	2.170	6	2700	4.05	46.40	46.42
19	18	3	Location 5 - Location 18	5	1458.683	2.187	7	3900	11.00	62.60	80.12
7	30	3	Location 2 - Location 30	2	1814.244	2.720	8	3900	5.85	53.48	53.50
3	11	3	Location 1 - Location 11	1	2144.407	3.215	9	2500	3.75	14.22	14.26
23	32	3	Location 6 - Location 32	6	2412.562	3.617	10	2800	4.20	13.84	13.87
11	25	3	Location 3 - Location 25	3	2646.931	3.969	11	2900	4.35	8.73	8.76
28	24	4	Location 7 - Location 24	7	1076.169	1.614	1	2600	3.90	58.61	58.63
36	24	4	Location 9 - Location 24	9	1080.043	1.619	2	2600	3.90	58.46	58.48
44	28	4	Location 11 - Location 28	11	1147.856	1.721	3	6900	10.35	83.36	83.37
16	28	4	Location 4 - Location 28	4	1157.891	1.736	4	7000	10.50	83.46	83.47
32	13	4	Location 8 - Location 13	8	1270.893	1.906	5	6900	10.35	81.58	81.59
48	27	4	Location 12 - Location 27	12	1529.911	2.294	6	7400	11.10	79.33	79.33
20	15	4	Location 5 - Location 15	5	1825.422	2.737	7	2900	4.35	37.05	37.08
8	11	4	Location 2 - Location 11	2	1836.981	2.754	8	2000	3.00	8.15	8.19
4	9	4	Location 1 - Location 9	1	2347.027	3.519	9	2600	3.90	9.73	9.76
24	31	4	Location 6 - Location 31	6	2596.392	3.893	10	12600	18.90	79.39	79.40
12	27	4	Location 3 - Location 27	3	2760.004	4.138	11	6500	9.75	57.54	57.56
40	5	4	Location 10 - Location 5	10	4055.767	6.081	12	5100	7.65	20.48	20.51

In the table 18, network analysis findings are contrasted with scenarios for proposed networks. It illustrates that network utilization in this study area demonstrates a maximum network utilization of 97.02%, a minimum network utilization of 7.25% and 7.21%, and an average network utilization of 61.50% and 57.30% in terms of travel length and minutes, respectively.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this study, the Addis Ababa road network was subjected to GIS-based network analysis. It focuses on determining the best cycle network for home-to-school sites on the road network, as well as determining the best network for facilities and analysis on the nearest facilities to incidents and service area analysis.

The best method for network analysis, especially in a crowded city like Addis Ababa, is to use the functions of ArcGIS software's Network Analyst extension, which integrates the data gathered to be used in the analysis and, as is the case in Addis Ababa, produces more accurate results that are suitable for realistic road networks in this study.

In addition, the researcher finally compared the existing network situation of the study area. In light of this, it can be deduced from the outcome of the analysis of the best network (route) that it emphasizes choosing the best network between facilities (such as schools) located along the road network data.

The total distance is 13028.36 meters, and the travel time is 202.46 minutes in networking facilities using best route analysis tool in Arc GIS. The finest facilities for dwelling are RDLocation 7(shola condominium) -SCL 27(new grand school), with a length of 205.749 m and a trip duration of 0.309 minutes, according to the results of the analysis of the closest facilities using facility labels .

Those network analysis results up to 300m is proposed to walking after network analysis for this study. In addition, the research area's service coverage was evaluated using ArcGIS network analyzer tools.

The outcome led to the conclusion that the facilities in the study region are adequately able to meet the expectations of the residence site. For this activity in the study, it has been shown in the tables above that the planned circumstances are compatible with the logical network planning condition by comparing the logical network with the analysis of the planned cycle network scenario.

To improve connectivity to those sites, reduce travel time, and further integrate non-motorized transportation systems, network utilization for specific activities must also be developed.

Finally, it is determined that additional research and multi-criteria analysis should be carried out, especially from a cost feasibility point of view in the study region, to implement those outcomes from this study. The Google Earth Pro search engine was used to determine the actual location of those points.

5.2 RECOMMENDATIONS

By the study's findings. The recommendations given for the study area are listed below.

- This study strongly recommended that gathering and storing the physical position of various activities is crucial for future expansion and interpretation, as well as allowing researchers to carry out their study without difficulty.
- To satisfy the majority of groups who do not use motorized transportation in their daily activities, the Addis Ababa city administration should increase the number of cycle lanes in the city as much as possible, including the proposed networks. This will show that the city road administration is meeting the essential needs of citizens in the transportation system.
- This study made the recommendation that when developing cycle networks, the city's future development and population expansion must be taken into account. Since it is evident that the lack of a well-planned network of cycle network combined with the growing population presents problems for the city administration.

5.2.1 Suggestion for further research

For potential future research. The following recommendations for further research are provided by this study.

- Investigating the creation of a Web GIS-based database to locate various network-planning activities dynamically will allow for rapid and simple access.
- It will be easier to implement and encourage consumers to be flexible when suggesting a new cycle network if the site of the cycle share program is properly thought out.
- Further investigation of on this study considering FSM (four-step modeling in transport planning) with other modes of transport for application of mode choice.

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APPENDIXES

Appendix A: some samples of the Addis Ababa road network

SNO	osm_id	geomtype	aggtype	type	Name	label	oneway	Shape_Leng	Length
1	4677317	W	minor_road	residential			no	315.788	315.788
2	4677323	W	minor_road	residential			no	928.406	928.406
3	4677325	W	minor_road	residential			no	495.114	495.114
4	4677326	W	minor_road	residential			no	244.625	244.625
5	4677359	W	transnational_road	trunk	Equatorial Guinea Street	Equatorial Guinea Street	yes	1399.755	1399.755
6	4677416	W	major_road	primary	Ras Abebe Aregay Street	Ras Abebe Aregay Street	yes	603.510	603.510
7	4677442	W	major_road	primary	Mozambique Street	Mozambique Street	yes	1161.145	1161.145
8	4677450	W	major_road	primary			no	203.134	203.134
9	4677458	W	transnational_road	trunk	Chad Street	Chad Street	yes	383.737	383.737
10	4677463	W	major_road	primary	Uganda Street	Uganda Street	yes	1382.834	1382.834
11	4677506	W	major_road	primary	Tesema Aba Kemaw Street	Tesema Aba Kemaw Street	yes	293.289	293.289
12	5921435	W	major_road	primary	Roosevelt Street	Roosevelt Street	yes	1215.397	1215.397
13	5921436	W	major_road	primary			no	54.789	54.789
14	5921439	W	minor_road	residential			no	470.303	470.303
15	5921440	W	minor_road	residential			no	395.084	395.084
16	5921443	W	minor_road	residential			no	793.659	793.659
17	5921444	W	minor_road	residential			no	1346.917	1346.917
18	5921445	W	minor_road	residential			no	376.594	376.594
19	8104263	W	transnational_road	trunk	Ring Road	Ring Road	yes	2560.887	2560.887
20	8104280	W	major_road	primary	Jimma Road	Jimma Road	no	5730.444	3525.061
21	8104345	W	minor_road	residential			no	109.236	109.236
22	8104346	W	minor_road	residential			no	76.311	76.311
23	8104347	W	minor_road	residential			no	71.068	71.068
24	8104350	W	minor_road	residential			no	563.837	563.837
25	8104351	W	minor_road	residential			no	1152.867	1152.867
26	8104352	W	minor_road	residential			no	548.196	548.196
27	8104353	W	minor_road	residential			no	1183.008	1183.008
28	8104354	W	minor_road	residential			no	542.149	542.149
29	8104580	W	minor_road	residential			no	145.702	145.702
30	8104355	W	minor_road	residential			no	673.881	673.881
31	8104356	W	minor_road	residential			no	509.441	509.441
32	8104357	W	minor_road	residential			no	364.637	364.637
33	8104358	W	minor_road	residential			no	97.409	97.409
34	8104359	W	minor_road	residential			no	1114.615	1114.615
35	8104360	W	minor_road	residential			no	345.043	345.043
36	8104361	W	major_road	primary	entral Africa Republic Stree	Central Africa Republic Street	no	538.279	538.279
37	8104362	W	minor_road	residential			no	1192.119	1192.119
38	8104363	W	minor_road	residential			no	999.965	999.965
39	8104364	W	minor_road	residential			no	539.723	539.723
40	8104365	W	minor_road	residential			no	443.375	443.375
41	8104366	W	minor_road	residential			no	733.734	733.734
42	8104367	W	minor_road	residential			no	194.995	194.995
43	8104368	W	major_road	secondary	Congo Street	Congo Street	no	1097.686	1097.686
44	8104425	W	minor_road	residential			no	331.172	331.172
45	8104582	W	minor_road	residential			no	509.754	509.754
47	8104514	W	major_road	secondary	Somalia Street	Somalia Street	no	1361.299	1361.299
48	8104522	W	major_road	secondary	Bekele Weya Street	Bekele Weya Street	yes	486.206	486.206
49	8104523	W	major_road	secondary	Sao Tome & Principe Street	Sao Tome & Principe Street	no	629.079	629.079
50	8104525	W	major_road	secondary	Liberia Street	Liberia Street	no	359.220	359.220
51	8104538	W	minor_road	residential	Dej Wolde Michael Street	Dej Wolde Michael Street	no	479.557	479.557
52	8104558	W	major_road	primary	Mauritania Street	Mauritania Street	no	1403.331	1403.331
53	8104561	W	minor_road	residential			no	432.476	432.476
54	8104563	W	minor_road	residential			no	689.097	689.097
55	8104569	W	minor_road	residential			no	234.929	234.929
56	8104570	W	minor_road	residential			no	234.988	234.988
57	8104573	W	minor_road	residential			no	321.481	321.481
58	8104575	W	minor_road	residential			no	592.698	592.698
59	8104576	W	minor_road	residential			no	320.314	320.314
60	8104577	W	minor_road	residential			no	238.234	238.234
61	8104578	W	minor_road	residential			no	129.423	129.423
62	8104579	W	minor_road	residential			no	222.598	222.598
63	8104583	W	minor_road	residential			no	464.455	464.455
64	8104585	W	minor_road	residential			no	598.060	598.060
65	8104586	W	minor_road	residential			no	116.936	116.936
66	8104587	W	minor_road	residential			no	115.687	115.687
67	8104588	W	minor_road	residential			no	301.280	301.280
68	8109791	W	major_road	primary	Alexander Pushkin Avenue	Alexander Pushkin Avenue	yes	1134.210	1134.210
69	8110238	W	major_road	primary	Mike Leyland Street	Mike Leyland Street	yes	1226.810	1226.810
70	8111456	W	major_road	primary	Libya Street	Libya Street	yes	768.829	768.829
71	8111457	W	minor_road	residential			no	532.513	532.513
72	8111459	W	minor_road	residential			no	377.495	377.495
73	8111460	W	minor_road	residential			no	956.501	956.501
74	8111461	W	minor_road	residential			no	283.505	283.505
75	8111462	W	minor_road	residential			no	419.297	419.297
76	8111463	W	minor_road	residential			no	182.231	182.231
77	8111464	W	minor_road	residential			no	131.944	131.944
78	8111465	W	minor_road	residential			no	128.782	128.782
79	8111466	W	minor_road	residential			no	158.549	158.549
80	8111467	W	minor_road	residential			no	184.667	184.667
81	8111468	W	minor_road	residential			no	1281.305	1281.305
82	8111469	W	minor_road	residential			no	311.755	311.755
83	8111470	W	minor_road	residential			no	232.374	232.374
84	8111471	W	minor_road	residential			no	346.068	346.068
85	8111862	W	minor_road	residential			no	605.048	605.048
86	8111863	W	minor_road	residential			no	250.279	250.279
87	8111864	W	minor_road	residential			no	781.010	781.010
88	8111865	W	minor_road	residential			no	656.753	656.753
89	8111866	W	minor_road	residential			no	251.979	251.979
90	8111867	W	minor_road	residential			no	295.686	295.686
91	8111868	W	minor_road	residential			no	196.886	196.886
92	8111869	W	minor_road	residential			no	194.434	194.434
93	8111870	W	minor_road	residential			no	78.392	78.392
94	8111871	W	minor_road	residential			no	83.272	83.272
95	8111872	W	minor_road	residential			no	145.489	145.489
96	9713688	W	major_road	primary	kre Mariam Aba Techan Stre	Fikre Mariam Aba Techan Street	no	5929.437	5929.437
97	22337891	W	minor_road	residential	Mahtama Gandhi Street	Mahtama Gandhi Street	no	310.721	310.721
98	9713691	W	transnational_road	trunk	Comoros Street	Comoros Street	yes	1233.793	1233.793
107	25010525	W	major_road	primary			no	13.421	13.421
108	9717648	W	transnational_road	trunk			no	3140.858	3140.858
109	21897238	W	major_road	primary	Gobena Aba Tigu Street	Gobena Aba Tigu Street	no	288.883	288.883

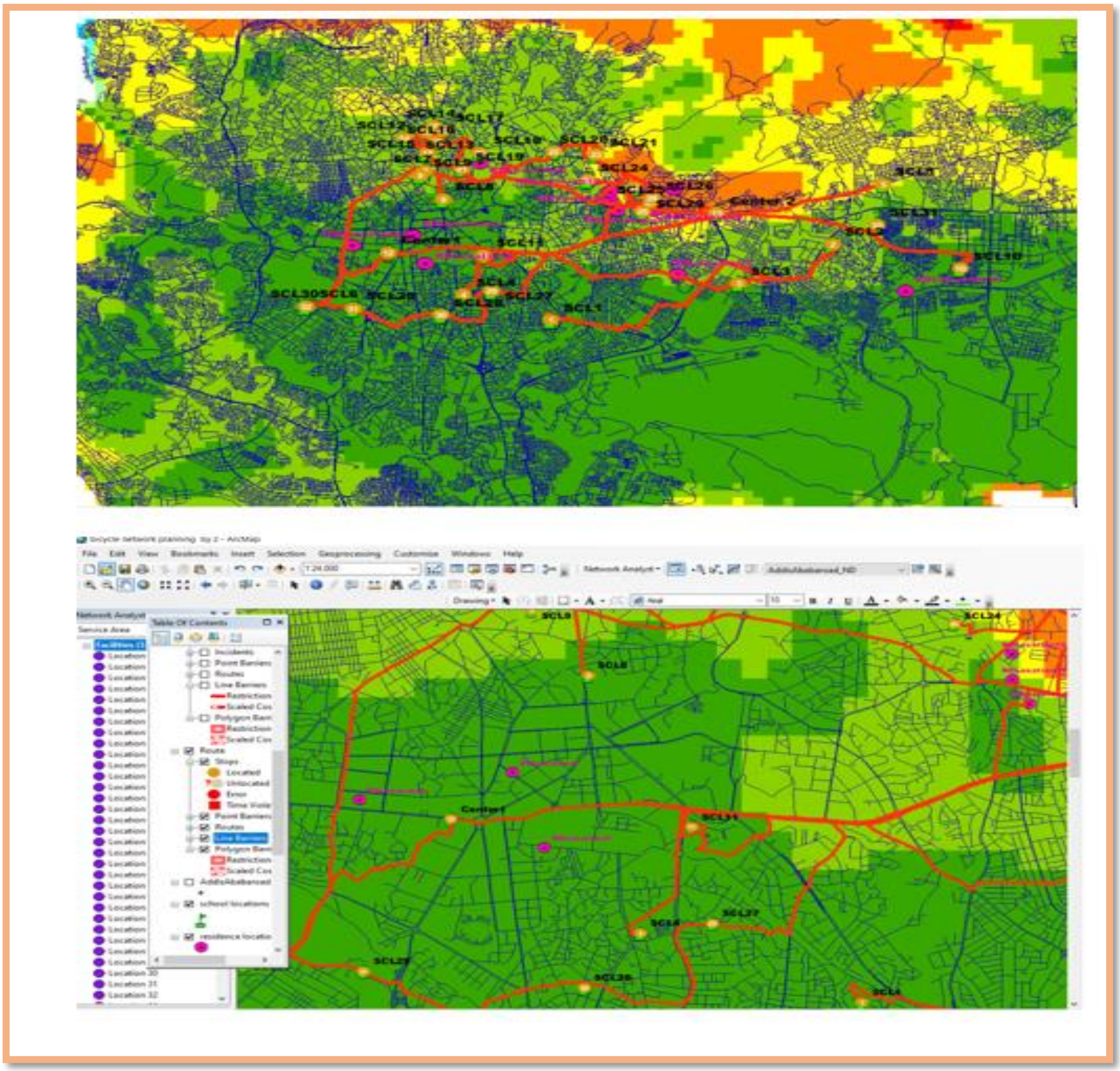
Appendix B: some samples of residence (incidents) location

ID	Residence name	EASTING	NORTHING	ELEVATION
RDLocation1	Sengatera condominium(mexico)	472183.57	996508.63	2374
RDLocation2	Legehar condominium (Legehar tsebel)	472438.18	995723.69	2354
RDLocation3	24-condominium (to megenagna)	477502.06	995405.16	2341
RDLocation4	Signal condominium (megenagna)	476285.71	997231.05	2387
RDLocation5	Balsha wolde-chilot site condominium	473526.01	998563.99	2430
RDLocation6	Lideta condominium(to mexico)	470967.74	996223.85	2359
RDLocation7	Shola Condominium	476970.95	997287.95	2376
RDLocation8	yeka michael condominium block2	477424.85	997808.04	2416
RDLocation9	Handmade Luxury Real Estate	477032.62	997226.16	2374
RDLocation10	flintstone home shola appartment	482070.55	994944.08	2296
RDLocation11	Signal residence	476152.29	997481.45	2387
RDLocation12	Balderas Condominium	476144.52	997747.65	2398

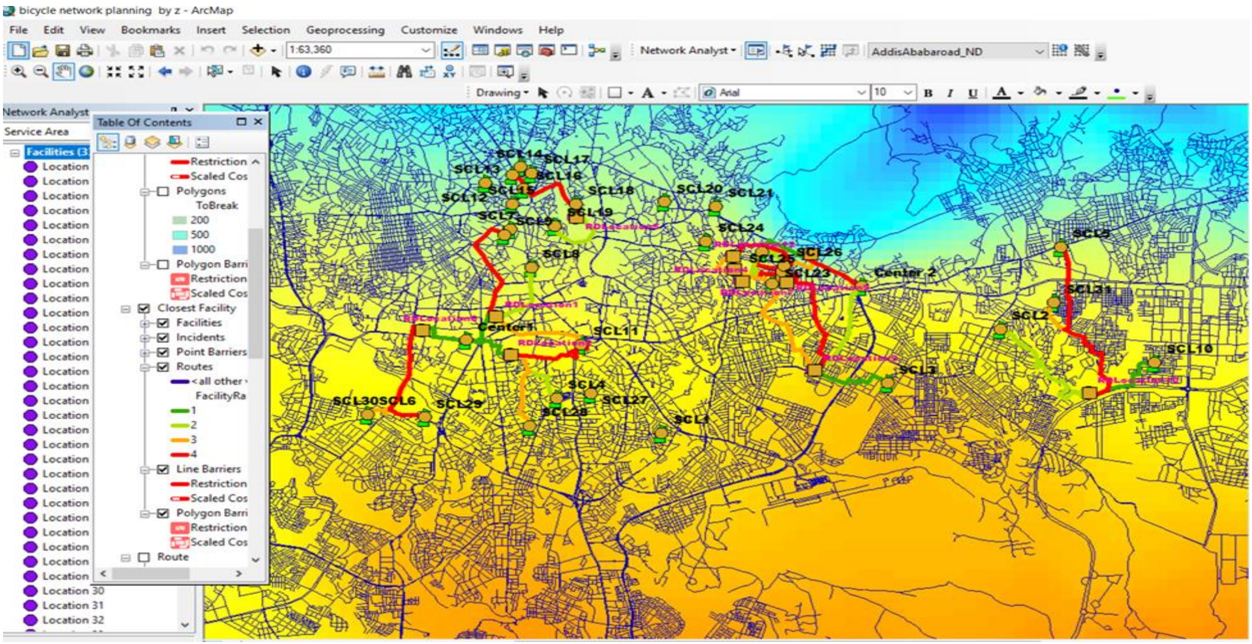
Appendix C: some sample of Schools (facilities) location

School ID	School name	EASTING	NORTHING	ELEVATION	Near by street
SCL1	Dandii Boru School	474959.58	994106.73	2331	ras mekonn Avenue/A5
SCL2	Cistercian Monastery acadamy	480598.72	996255.22	2372	A2
SCL3	Ethio-Parents' School	478716	995137.69	2354	A2
SCL4	Joy Academy	473202.07	994828.05	2308	ras mekonn Avenue/A5
SCL5	Hillside SchooL	481611.62	997943.4	2416	A2
SCL6	International Community School of Addis Ababa (formerly American Community School	470052.35	994494.16	2323	via Roosevelt St
SCL7	Lideta Catholic Cathedral School	472439.2	998312.37	2430	Via churchil avenue
SCL8	Lycée Guebre-Mariam	472784.88	997522.43	2385	via Ras Mekonen Ave/A5 and Churchill Ave
SCL9	Nativity Girls School	472337.54	998200	2420	Via churchil avenue
SCL10	One Planet International School[2]	483171.27	995567.3	2367	via unnamed roads
SCL11	St. Joseph School (mexico)	473608.85	995936.12	2343	ras mekonn Avenue/A5
SCL12	Nejashi Acadami	472021.61	999260.96	2458	Via churchil avenue
SCL13	Bethlehem Secondary School	472462.74	999426.43	2493	Via churchil avenue
SCL14	Laura Academy	472602.53	999594.83	2498	Via churchil avenue
SCL15	Awelia Primary School/Piazza	472475.13	998831.26	2463	Via churchil avenue
SCL16	New Era Primary And Secondary Public School	472650.49	999140.41	2484	Via churchil avenue
SCL17	Jiva School	472784.21	999467.85	2491	Via churchil avenue
SCL18	Minilik I High School	473532.17	998837.01	2452	Via churchil avenue
SCL19	INDIAN NATIONAL SCHOOL	473171.62	998384.54	2441	Via churchil avenue
SCL20	Sandford International School | Kebena |	475007.96	998871.47	2457	via Fikremariam Aba Techan St and Comoros St
SCL21	Kokebe Tsibah Secondary & Preparatory School	475857.59	998779.03	2419	via Fikremariam Aba Techan St and Comoros St
SCL22	School Of Tomorrow, Misrak Branch, 2QGP+RW7, Addis Ababa	476623.95	997847.26	2411	via Fikremariam Aba Techan St and Comoros St
SCL23	Fidel school, 2QCQ+9G3, Addis Ababa	476800.68	997183.83	2420	via Equatorial Guinea St/A2
SCL24	Abune Gorgorios School, Addis Ababa	475686.41	998061.89	2402	via Fikremariam Aba Techan St
SCL25	Magic Carpet Schools, 2QFR+75P, Addis Ababa	476967.97	997436.1	2458	via Kenenisa Ave
SCL26	Yeha Science And Technology Acadamy, Addis Ababa	476994.58	997558.04	2527	via Kenenisa Ave
SCL27	New Grand School, Addis Ababa	473769.8	994930.06	2343	ras mekonn Avenue/A5
SCL28	Chabod School, Addis Ababa	472754.73	994257.6	2319	ras mekonn Avenue/A5
SCL29	Intellectual Schools | Sarbet KG Branch | ??????? ?/ ?? | ?? ??, XPWP+CFP, Seychelles St, Addis Ababa	471003.98	994430.69	2323	via Roosevelt St
SCL30	International Community School of Addis Ababa | Karl	470052.35	994494.16	2323	via Roosevelt St
SCL31	NATIONS NEW HOPE ACADEMY, addis ababa ethiopia, 1000	481490	996799.64	2376	A2

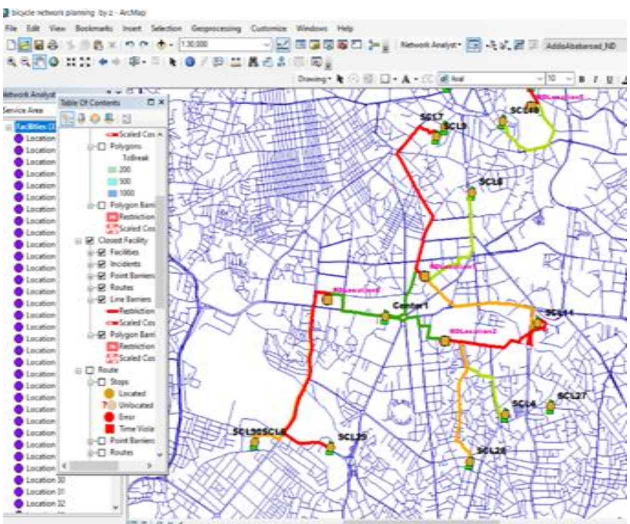
Appendix D: Best network map for the school facilities

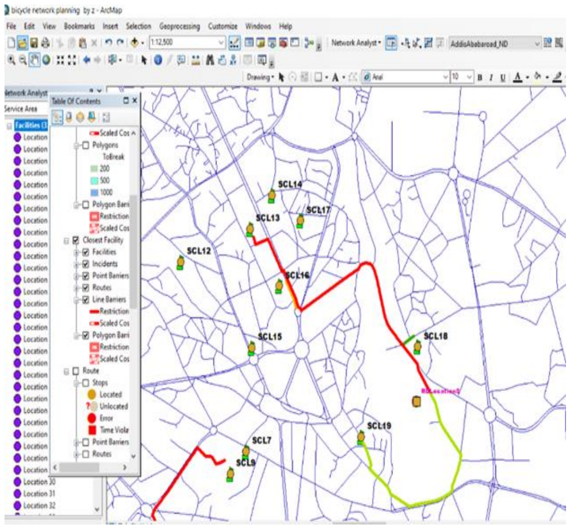


Appendix E. Closest facility results of the study area



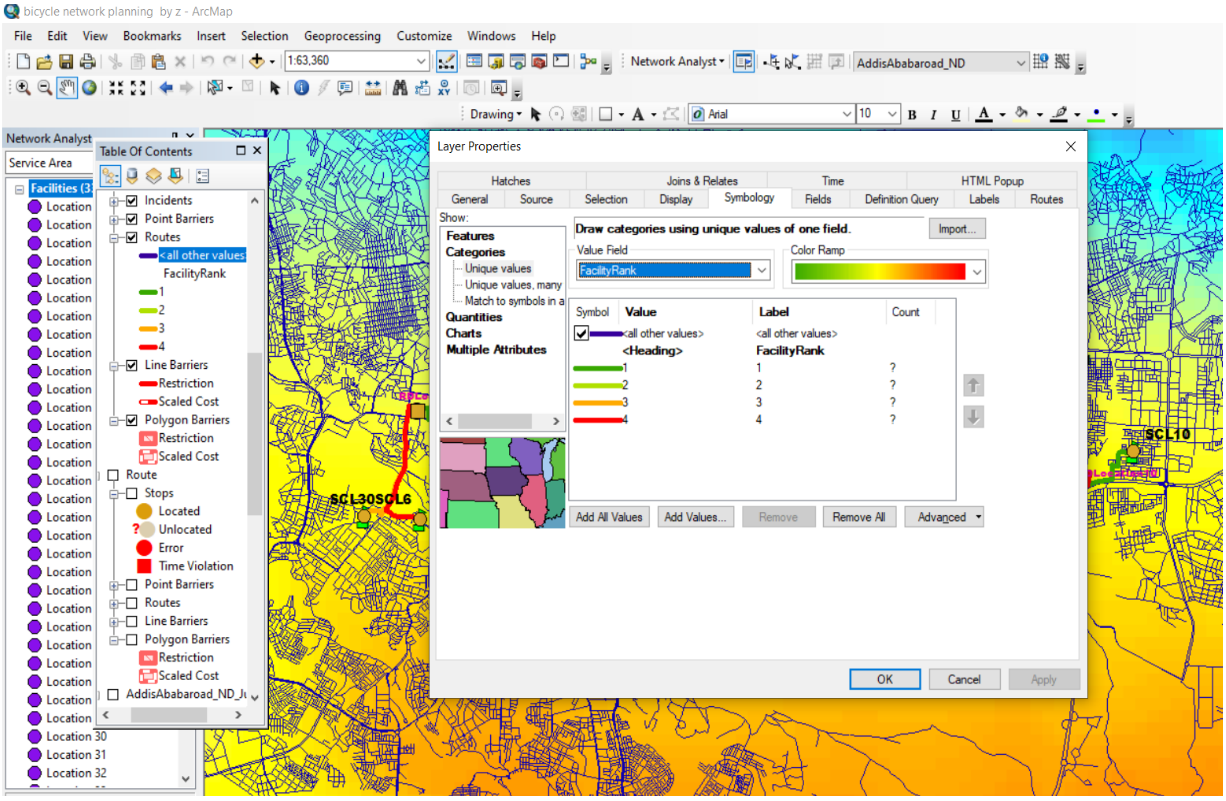
Appendex E1 figure showing closest facility general results of the study area





Appendex E2 sample figure showing closest facility zoom out results of the study area

Appendix F Closest facility for the study area by label rank



Appendix G .Closest facility analysis result from attributes table

bicycle network planning by z - ArcMap

File Table

Routes

FacilityID	FacilityRank	Name	IncidentCurbApproach	FacilityCurbApproach	IncidentID	Total_Length	Total_Minutes
12	1	Location 1 - Location 12	Right side of vehicle	Left side of vehicle	1	982.524879	1.473212
8	2	Location 1 - Location 8	Left side of vehicle	Right side of vehicle	1	1528.933196	2.292504
11	3	Location 1 - Location 11	Left side of vehicle	Left side of vehicle	1	2144.406682	3.215352
9	4	Location 1 - Location 9	Right side of vehicle	Right side of vehicle	1	2347.027072	3.519166
12	1	Location 2 - Location 12	Left side of vehicle	Left side of vehicle	2	1043.264464	1.564286
4	2	Location 2 - Location 4	Right side of vehicle	Left side of vehicle	2	1429.146688	2.142882
30	3	Location 2 - Location 30	Right side of vehicle	Left side of vehicle	2	1814.244497	2.720303
11	4	Location 2 - Location 11	Right side of vehicle	Left side of vehicle	2	1836.98118	2.754394
3	1	Location 3 - Location 3	Right side of vehicle	Right side of vehicle	3	1557.997961	2.336076
13	2	Location 3 - Location 13	Left side of vehicle	Right side of vehicle	3	2493.280689	3.738447
25	3	Location 3 - Location 25	Left side of vehicle	Right side of vehicle	3	2646.931392	3.968835
27	4	Location 3 - Location 27	Left side of vehicle	Left side of vehicle	3	2760.0045	4.138377
25	1	Location 4 - Location 25	Right side of vehicle	Left side of vehicle	4	738.782274	1.107737
24	2	Location 4 - Location 24	Right side of vehicle	Right side of vehicle	4	974.269761	1.46083
27	3	Location 4 - Location 27	Right side of vehicle	Left side of vehicle	4	1131.307036	1.696293
28	4	Location 4 - Location 28	Right side of vehicle	Right side of vehicle	4	1157.891351	1.736154
20	1	Location 5 - Location 20	Left side of vehicle	Right side of vehicle	5	377.044249	0.565345
21	2	Location 5 - Location 21	Right side of vehicle	Right side of vehicle	5	1358.714996	2.037275
18	3	Location 5 - Location 18	Left side of vehicle	Left side of vehicle	5	1458.682762	2.187168
15	4	Location 5 - Location 15	Left side of vehicle	Left side of vehicle	5	1825.421644	2.737062
12	1	Location 6 - Location 12	Right side of vehicle	Right side of vehicle	6	933.45502	1.399637
6	2	Location 6 - Location 6	Left side of vehicle	Left side of vehicle	6	2412.562151	3.617434
32	3	Location 6 - Location 32	Left side of vehicle	Left side of vehicle	6	2412.562151	3.617434
31	4	Location 6 - Location 31	Left side of vehicle	Left side of vehicle	6	2596.392214	3.893072
27	1	Location 7 - Location 27	Left side of vehicle	Left side of vehicle	7	205.749221	0.308502
28	2	Location 7 - Location 28	Left side of vehicle	Right side of vehicle	7	551.948733	0.827597
25	3	Location 7 - Location 25	Right side of vehicle	Left side of vehicle	7	892.792417	1.338662
24	4	Location 7 - Location 24	Right side of vehicle	Right side of vehicle	7	1076.169033	1.613619
24	1	Location 8 - Location 24	Right side of vehicle	Right side of vehicle	8	1092.910796	1.638721
28	2	Location 8 - Location 28	Right side of vehicle	Right side of vehicle	8	1198.748977	1.797416
27	3	Location 8 - Location 27	Right side of vehicle	Right side of vehicle	8	1222.880939	1.833599
13	4	Location 8 - Location 13	Right side of vehicle	Right side of vehicle	8	1270.893275	1.905589
27	1	Location 9 - Location 27	Left side of vehicle	Left side of vehicle	9	322.219994	0.48314
28	2	Location 9 - Location 28	Left side of vehicle	Right side of vehicle	9	598.537423	0.897453
25	3	Location 9 - Location 25	Left side of vehicle	Left side of vehicle	9	896.666562	1.344471
24	4	Location 9 - Location 24	Left side of vehicle	Right side of vehicle	9	1080.043178	1.619428
10	1	Location 10 - Location 10	Left side of vehicle	Right side of vehicle	10	1699.962684	2.548933
2	2	Location 10 - Location 2	Right side of vehicle	Left side of vehicle	10	2952.356292	4.426782
33	3	Location 10 - Location 33	Left side of vehicle	Right side of vehicle	10	3014.426219	4.519849
25	1	Location 11 - Location 25	Left side of vehicle	Left side of vehicle	11	748.146515	1.121778
24	2	Location 11 - Location 24	Left side of vehicle	Right side of vehicle	11	866.40678	1.299099
27	3	Location 11 - Location 27	Left side of vehicle	Left side of vehicle	11	1121.271539	1.681246
28	4	Location 11 - Location 28	Left side of vehicle	Right side of vehicle	11	1147.855855	1.721106
24	1	Location 12 - Location 24	Left side of vehicle	Right side of vehicle	12	827.459972	1.240702
28	2	Location 12 - Location 28	Left side of vehicle	Right side of vehicle	12	1304.638647	1.956188
25	3	Location 12 - Location 25	Right side of vehicle	Left side of vehicle	12	1447.323868	2.170132

Appendix H . Service area coverage result for the study area