Identification of Accessible Shortest Route from Accident Incident to Health Facilities Using Geospatial Technologies: The Case of Arada Sub City, Addis Ababa

Yonas Tefera Gecho

A Thesis Submitted to the Department of Geomatics Engineering, School of Civil Engineering and Architecture, Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Geo-informatics

Office of Graduate Studies
Adama Science and Technology University

June, 2023
Adama, Ethiopia

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ADVISOR: TILAHUN ERDUNO (PHD)

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APPROVAL SHEET

I, the Major advisor of the thesis entitled as "Identification of Accessible Shortest Route from Accident Incident to Health Facilities Using Geospatial Technologies: The Case of Arada Sub City, Addis Ababa". In addition, developed by Yonas Tefera Gecho. Here by certify that the recommendation and suggestions made by the board of examiners are appropriately in corporate into the final version of the thesis.

Tilahun Erduno (PHD	___________________	_________________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Yonas Tefera Gecho have read and evaluated the thesis entitled "Identification of Accessible Shortest Route from Accident Incident to Health Facilities Using Geospatial Technologies: The Case of Arada Sub City, Addis Ababa". In addition, examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Geo- Informatics Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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DECLARATION

I declare that this thesis proposal entitled "Identification of Accessible Shortest Route from Accident Incident to Health Facilities Using Geospatial Technologies: The Case of Arada Sub City, Addis Ababa".is my own work and has not been submitted to any university for similar purpose. The references used in this proposal are duly recognize by proper citations.

Yonas tefera	____________________	________________
Name of student	Signature	Date

RECOMMENDATION

We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled "Identification of Accessible Shortest Route from Accident Incident to Health Facilities Using Geospatial Technologies: The Case of Arada Sub City, Addis Ababa". Prepared under my guidance by Yonas Tefera Gecho. Submitted in partial fulfilment of the requirements for the degree of Mater's of Science in Geo-informatics. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tilahun Erduno (PHD	________________	________________
Major Advisor/Supervisor	Signature	Date

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LIST OF ACRONYMS

AMS	Ambulance Management System
ART	Ambulance Response Time
CAD	Computer-Aided-Dispatch
EMS	Emergency Medical Services
GIS	Geographic Information Systems
GIS-T	Geographic Information Systems for Transporation
GNFS	Ghana National Fire Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
Ha	Hectare
ID	Identity Number
MCH	Maternal Child Health
UDOT	Utah Department of Transportation
WHO	World Health Organization

ABSTRACT

Access to health facilities in many low - income and middle-income countries remains low, with a strong association between individuals' distance to facilities and health outcomes. Arada sub-city is the oldest of all sub-cities located in the central part of the capital city of Addis Ababa. Emergency medical services (EMS) is a system that provides emergency medical care. Once a serious illness or injury-causing incident activates it. According to observations in Arada Sub City, the problem of sudden mortality is primarily caused by traffic accidents. The arrival of the ambulance in time is very low due to this; people with different accidents are at high risk of sudden death. The objective of this study is using GIS in the shortest routes of path for ambulance services systems by using network analysis technique in Arada sub city: In this study, a detail GIS database of the road network, ambulance locations, accident site and hospitals were prepared using ArcGIS Pro software with the extension of network analyst. The main technical implementation was conducted based on Esri's ArcGIS Network Analysis tool; after building network topology and network dataset. The network analysis was performed to identify the closest healthcare facility and the fastest route depending on the accident location. In order to determine the closest facility and best route analysis during the study, seventeen ambulance stations, nine accident locations, and twenty-four hospitals were used. As a result, three closest facility the ambulances reach the accident site, fastest path from ambulance to accident site and then to health center and ambulances allow to use both major & local roads during peak hours since the routes are congested respectively. The results mainly focus on the analysis of the results and discussion of simulation results as well as the shortest routes. Implementing the network dataset by calculating the closest emergency ambulance service facility for emergency incidents and finding shortest possible path for ambulance vehicles will accomplishes the study effectively. In the future, it will be necessary to verify the road data, including traffic speed mode, pavement quality, and one-way streets, by driving through the research area. This study recommend that emergency dispatch system must build by modernizing the existing technology. And also developed network datasets are important entities for further analysis in fire and police dispatch in the network analysis environment.

Key words: - *Ambulance, Geographic Information Systems, Global Positioning System & Network analysis*

CHAPTER I: INTRODUCTION

The provision of emergency medical services is a crucial aspect of health care. Transporting patients quickly and immediately to the hospital and health center is necessary. This can be done by managing ambulances effectively and speeding up ambulance response times. In times of emergency, Emergency Medical Services (EMS) are crucial to everyone's life. The key objective of many successful EMS systems can be operationally defined by the effective and consistent provisions of immediate medical care to the patients in case of any medical emergency Ambulance Response Time (ART) is the time between the call for the ambulance and ambulance reached at the scene, in emergency situations. ART is the Key Performance Indicator (KPI) to evaluate performance of Emergency Medical Services (EMS) because it is directly related to people’s life. (Wei Lam, *et al.*, (2015).

A system that provides emergency medical care is called emergency medical services (EMS). When an occurrence that results in serious illness or injury activates it, EMS focuses on the patients and emergency medical care. Technological advances such as geographic information systems (GIS), can allow emergency vehicles to reach patients more quickly (Wilde 2009), and efficiency in routing emergency fire and medical vehicles to a traffic incident is critical for saving lives (Cova 1999).

1.1. Background of the Study

A GIS can be e utilized for many roles in emergency management. It is an effective tool for determining emergency vehicle response routing and solving the emergency vehicle shortest path routing problem (Alivand *et al*. 2008, Cova 1999, Panahi and Delavar 2008).

The least expensive or most impassable route between two points can be determined by applying the shortest path algorithm to a routing problem in a transportation network. The shortest way may also be referred to as the fastest, most direct, or least expensive path or route, depending on the type of cost. There are several impedance facts that can affect emergency services and vehicle response times. They include distance, travel time, and traffic congestion because of variations in traffic flow related to the time of the day. Traffic congestion is a major problem in urban areas and can disrupt emergency response (Panahi and Delavar 2008; 2009, Naqi *et al*. 2010).

Most applications solve the shortest path problem based on the distance as a weight. This paper mainly focused on time parameter instead of the distance, which calculated the path between two points that takes minimum time based on one or more parameters other than the distance. Examples of these parameters are road width, average speed, waiting time. In emergencies, the best path is preferred, that it takes the minimum time to reach a destination, which helps to save people life. The main objective of this research is to find the best path and representing this valuable spatial information to end-users in an efficient way using GIS software. Most of shortest path algorithms (Dijkstra's shortest path algorithm, Euler's algorithm, etc.) are finding the shortest path that has only the least distance between a source node and a destination node. Applying one of these algorithms on GIS software that resolve emergency situations is not suitable for real road network because it considers only the length of the path to find the shortest one and does not consider other real-time traffic information (i.e., Road width, speed limit, surface condition, turn restrictions, etc.) which should be defined to identify more realistic routes. The road network of the Greater Cairo region was use as a case study to apply the proposed enhanced methods. (Alazab *et al.* 2011)

1.2. Statement of the Problem

The location of EMS facilities has attracted the most attention from local governments and academia of all the issues that can arise during EMS development. It has received a lot of attention in the city development plan in order to satisfy resident safety concerns and make it easier to achieve health objectives.

The time between dispatch and the arrival of an emergency vehicle at the scene is known as the ambulance response time. The amount of time between the dispatch of the ambulance and the patient's arrival at the hospital is known as the ambulance service time. In addition, transportation of a patient to emergency hospital seems quite simple but in actual it is quite difficult and gets more difficult during peak hours. Because of congestion on ambulance response and service, time is so difficult and makes unable to reach the incident site properly. Because it is an explicit assumption of geographical allocation models that short response times are desirable, a reasonable expectation is that the probability of a patient surviving an emergency should be a decreasing function of response time. Longer response times should thus have fewer patient survivals than shorter response times (Baker, Clayton & Taylor, 1989). Rational location of emergency medical service (EMS) facilities could improve access to EMS, and thus assist in saving patients' lives and improving their health outcomes. A considerable amount of spatial optimization research has been devoted to the development of models to support location planning in the context of EMS, with extensive applications in policy making around the world. In Addis Ababa, access to emergency services is challenging during peak hours from 7 am to 10 am and from 4 pm to 7 pm. Additionally, during the winter months when schools are open. However, in Addis Ababa, studies on the location of EMS facilities have not been paid enough attention to, let alone their practical applications. Regardless of details of specific conditions and issues, typical location problems of Addis Ababa EMS could fall into the maximum coverage location problem. This paper conducted location optimization for EMS facilities in Addis Ababa.

1.3 Objectives

1.3.1 General Objective:

The general objectives of this study is to assess the shortest route access from incidents location to emergency medical facilities; A case of Arada Sub City.

1.3.2 Specific Objectives:

The specific objectives of the study are to:

1) identify the accident, ambulance and emergency hospital location by using GPS.
2) analyze EMS facilities using GIS
3) develop closest facility map for ambulance, accidental sites and emergency service hospital.

1.4. Research Questions

1) How to identify the accident sites, ambulance and emergency hospital location?
2) How can the GIS techniques be involved the process of optimum route selection?
3) How to project EMS map to show ambulance location, accidental sites and emergency service hospital location?

1.5 Significance of the Research

If the research's findings are put into practice as suggested, then interested health officials (decision makers), patients and their families, medical staff, ambulance drivers, the general public, the academia etc. will all greatly benefit from its findings in order for patients to receive the necessary assistance at the appropriate time and location during an emergency situation. When the study's findings are properly put into practice, a reduction in patients' suffering during accidents will be noticeable. Additionally, government offices and both public and private emergency response providers will be equipped to properly assist the community.

1.6 Scope and Structure of the Study

The study area which is Arada sub-city is located roughly in the northern part of the capital city of Ethiopia, Addis Ababa. The total area of Arada sub-city is 950 hectares with the total area of road network accounts about 186.81 hectare including all asphalt, coble, gravel, paved and unpaved road. The study area contains different types of land uses i.e., road network, business districts, administrative area, several educational institutions, residential area and the like.

GIS is a spatial technique which is particularly used in this research. The parameters used by this research to identifying the shortest route for emergency vehicles by performing network analysis.

1.7 Limitations of the Study

Limited access to updated data regarding Ethiopia cities was among the challenges faced during this study.

CHAPTER II: LITERATURE REVIEW

2.1 Optimal path for emergencies

Several studies have been reported in the research domain using a range of techniques and methods, but there are still areas that need further attention especially in health security, recommendation and management. The author in (O.A. Edward 2017) proposed shortest route optimization for road accident emergencies in order to reduce the average loss of lives. They dealt with the problem of finding shortest paths in traversing some locations within the Kumasi Metropolis in the Ashanti Region of Ghana. Constructing the minimum spanning tree considering the dual carriage ways in the road network of Kumasi Metropolis within the shortest possible time for emergency services. The authors analyzed the distance needed to be covered but necessity may arise to consider suitable hospital to treat patients. The comparative analysis and implementation of shortest path algorithm for emergency response and logistic planning is introduced. The author was motivated to solve the transportation problem by determining the optimal path for emergencies, get to facility location and ensure effective vehicle routing from source to destination at minimum cost.

2.2 Identify accident spots using GPS

In (S. Chaklader, J. Alom, M. Islam, and A.S. Sabbir 2014), an emergency rescue dispatch system for road vehicles for instant notification of road accident and post-crash analysis is proposed. The objective was to enhance the reporting of vehicle crashes and provide post-crash analysis. The approach used involves pinpointing the exact location of the crash using GPS and sending the data to an emergency rescue authority using GSM text service. Also motion sensors and record of event in images were used to carry out post-crash analysis which reduced the time it takes for emergency rescue to arrive at the crash location. The approach is good for the detection and mitigation of frequent points of accidents but failed to sample available parametric facilities in the hospitals for efficient medical services. Traffic accident analysis to identify accident spots on road network by analyzing collected police record data. GIS was used to plan and manipulate the transportation system and equally analyze nearby hospital. Optimal route to the nearest hospital was achieved but only the usual accident locations were accepted for analysis. An accident detection and reporting system is developed as a life-saving system by sending timely accident information to emergency service. GPS receiver was used to monitor the speed of a vehicle and detect occurrence of accident as well as notification of the location and time of the accident from the GPS data processed by microcontroller via the GSM network to alert emergency service center. A device-oriented information system using GSM was achieved but monitoring events used speed as the only parameter without any algorithmic computation. (Khan *et al.* 2019) also developed accident detection and smart rescue system using android smartphone with real-time location tracking. The aim was to reduce the response time of emergency services in traffic accidents. On board sensors of a smartphone was used to detect vehicular accidents and report it to the nearest emergency responder available. A complete tracking system was developed for accident emergency victims without providing the platform for ensuring patient medical treatment by recommending nearest and suitable hospitals. Shortest path from source to destination was provided by the proposed technique but no relationship to medical attention. Ojekudo and Akpan also applied Dijkstra algorithm to shortest route problem for businesses and industries so as enhance quick delivery of goods and service by selecting the optimal path. Their method provided alternative paths for selecting shortest route to transport goods from source to destination. A vehicle accident detection and messaging system is developed using GPS and GSM. The objective was to provide an optimum solution to traffic hazard. An alarm application that uses accelerator and force sensor was developed to achieve their objective. The system detects was able to crash signal using existing hardware platforms but failed lacks real computation scheme for accident treatment.

2.3 Geographic Information Systems for EMS

Furthermore, (Bagchi *et al.*) introduced an ambulance service using modified Dijkstra algorithm with the aim of ensuring quicker reach to the emergency destination upon the request for an ambulance service. A predefined set of data about the ambulance services were collected analyzed to determine the shortest route to reach emergency location. The authors in applied GIS in determining road emergency medical service location for identifying the best emergency system location to accident black spots and response time. However, suitable medical service to an emergency was not implemented in their scheme. A GIS-based news route approach was used to determine the shortest path from logging site to destination using ArcGIS software. As a result, a path with minimum links and length as well as maximum vehicle speed was established. In addition to the use of GIS, the authors in (N. Paul-Silviu, and H. Ionel 2014) worked on GIS based network analysis for the identification of shortest route access to emergency medical facilities. Modeling the shortest path in order for an ambulance to travel through a road network was established using GIS technology. Close proximity of hospitals to the accident location is achieved but did not consider the facility criteria. (Ni *et al*.) introduced shortest path analysis using Dijkstra algorithm in emergency response system. The objective was to ensure routing and re-routing of vehicles from various key locations including hospitals, fire and police department to the event scene and from the event scene to hospitals or other locations. Dijkstra Algorithm along with GIS were used on-site while a web application was used off-site to manage emergency information. However, the method suffers cases of traffic congestion.

Geographic Information Systems for Transportation (GIS-T) represents one of the most important application areas of GIS technology (Goodchild 2000). Shaw (2010) referred to GIS-T as the application of information technology to the transportation problem. (Abkowitz *et al*. 1990) stated over two decades ago that the field of transportation was inherently geographic and GIS was a technology with considerable potential for achieving gains in efficiency and productivity for many transportation applications**.**

The use of GIS for network analysis is essential for improving emergency response routing based on travel time information (Alivand *et al*. 2008, Panahi and Delavar 2008). (Curtin 2007) thought network analysis was one of the most significant research and application areas in GIS science while (Sadeghi- Niarki *et al.* 2011) mentioned network analysis is a powerful tool in the GIS environment for solving the optimal path in a network.

A GIS stores these edge and junction features with their attributes. Spatiotemporal networks are networking whose topology and parameters change with time. These networks are important to applications such as emergency traffic planning and route finding (George *et al*. 2007).

2.4 Factors affect emergency services and vehicle response times

Several factors can affect emergency services and vehicle response times. Variations in traffic flow or volume related to time of day is one of them. This is referrers to as traffic congestion. Traffic congestion can have several causes. Some are predictable such as traffic during daily peak hours and some less predictable such as weather or accidents. The majority of traffic congestion delays are cause by delays during peak hour traffic. (Kok *et al.* 2012). Delays affecting response times in emergency services caused by traffic congestion are consider dynamic because they spread through a network and vary over time (Panahi and Delavar 2009, Riad *et al.* 2012).

Road traffic accidents worldwide have become a major threat to public safety and health because it is responsible for disabling and injuring about 50 million people across all age groups and gender per year (Khorasani-Zavareh *et al*., 2012; McIlroy *et al*., 2019, WHO, 2018 and Naboureh *et al*., 2019). About 1.35 million people died worldwide due to road traffic accidents in 2016, which is equivalent to about 3, 700 persons every day in addition to the injured ones. (WHO, 2015 and 2018; ITF 2017; Khanh *et al*., 2019).

A more recent study (Kamga *et al*. 2011) showed dynamic traffic models are particularly appropriate for modeling highway incidents because the timing of incident occurrence, management, recovery, and the use of alternate routes is critical to roadway performance and driver behaviors. (Haghani *et al*. 2003) argued the purpose of vehicle dispatching is to minimize the total travel time in the system and that time-dependent shortest path analysis is useful for the calculation of travel times Dynamic shortest path routing should improve emergency response times (Panahi and Delavar 2008; 2009).

The increasing concentration and growth of motor vehicles have been attributed to be because of rapid and unplanned urbanization globally. This increasing automobile use and growth across the globe have greatly contributed to the increasing incidences of road traffic-related morbidity and mortality (Afukaar, Antwi & Ofosu-Amaah 2003; Bhagyaiah & Shrinagesh 2014; Centers for Disease Control 1988).

In developing countries, (Pardo *et al*. 2012) identified that the existing reality of transportation in the cities is not ideal. (Akogun 2015, Moss, and O'Neill 2012) state that the transport sector has been test to be the problem of African cities, owing to challenges such as pollution and road accidents.

Presently, injuries because of road traffic crashes are considered as one of the main reasons for death (eight leading cause of death across all age groups) and the leading cause for death of younger generation within the age of 5–29 years old (WHO, 2015 and WHO, 2018).

The economic costs attributed with road crashes range from 2% to 5% of each country's Gross Domestic Product (WHO, 2018). Countries of the Global South especially the less developed countries of South-Asia, Africa and Latin America often bears the greatest burden. Although these countries have only 50% of the world's vehicles, 90% of the world's fatalities due to roads crashes occur in these countries (WHO, 2015). In south Asia, riders of two and three wheelers represent the majority of the fatalities 43% recoded in the region In Thailand and Myanmar for example, the rate of fatalities related to motorcycles accounted for about 24.3 per 100, 000 and 12.9 per 100, 000 respectively. Unfortunately, in south Asia, Africa and Nigeria, these major categories of road users remain neglected when road systems are design. (ESCAP, 2010, WHO, 2018).

2.5 Global EMS

As reported, with over 3500 deaths on global roads, tens of millions of people are injured or disabled every year. Out of this, 90% occurs in low and middle-income countries in Africa (Nantulya & Reich 2002; WHO 2011) with a projected 65% increase by 2020. This explains the health burden because of road accidents occurring in most developing nations of the world. (WHO 2011).

In India, the authors developed a desktop-based emergency response system for emergency readiness and management through GIS in Delhi, India. The main objective of this application was to provide immediate response to any incident or accident. A detailed transportation network used maintained and integrate with real time traffic data provided by Navteq in India. The near real-time traffic information was used to analyze suitable routes to the incident location by avoiding highly congested routes and therefore reducing the response time. Using GIS capabilities, various analyses we performed such as finding the shortest route using Origin–Destination (Anshul Bhagat, Nikhil Sharma 2013).

In Aurangabad city, Maharashtra State, India the authors tried to solve the problem of finding a specialized hospital and its shortest path to reach. They used the ArcGIS software and Dijkstra's algorithm that provide the shortest path from one location to another for finding the nearest location of the hospitals from user's location. The calculations of the shortest path we based on road distances; traffic congestion. (*AmrapaliDabhade, Dr. K.V.Kale, Yogesh Gedam, July 2015).*

In Cairo, the authors developed a GIS based application for healthcare emergency response system services to manage healthcare in the Almokatam zone in the south of Cairo, Egypt. The optimal route was mode based on the distance to the closest healthcare service providers. The system integrated data acquisition from databases and plotted the location-based features of satellite image through a web base interface which gives access to all different tasks by different end users to be a decision maker or policy makers in system management. (A. Gubara, A. Amasha, Z. Ahmed and S. El Ghazali, *2014*).

In Ghana, the authors established a GIS based fire emergency response service in Kumasi Metropolis, Ghana where the Ghana National Fire Service (GNFS) can identify the optimal route from its location of any fire incident. The optimal route was mode based on the travel distance, travel time, the slope of the roads and the delays in travel times. (Eric K. Forkuo and Jonathan A. Quaye-Ballard 2013).

There are multiple ways to calculate the shortest path from point A to point B. The one used by ArcGIS software is Dijkstra algorithm the algorithm searches for the distance from the starting point to every other vertex until it reaches the destination point and gives the shortest path possible. This makes possible for the rapid calculation of the most appropriate route as well as other functions like closest facility. Vector data provide the basis of the model. Vector lines are use to describe spatially distributed streets and points to represent locations along the network (hospitals, accidents, junctions). The object of the study is to model shortest paths along the street network as well as closest facility for ambulances to reach with the injured person. The coordinate system used in the analysis is Stereo 70, the national coordinate system of Romania. (ESRI, 2014; Magyari-Sáska, 2013; Kai *et al,* 2014).

2.6 Shortest path problem

(A. Sahar, and E. Sadoullah 2011) considered the dynamic shortest path problem, motivated by its applications in dynamic minimum cost flows in transformation problem. In their work, the shortest path problem is seen to be equal to time-expanded network through the application of Label Correcting Algorithm for solving this problem and the time complexity of the algorithm is $O(|nT||mT|)$. They applied conventional method on the time-expanded network but the huge network size proves difficult for realistic problems without any benefit during network expansion. The authors in (B. Ganeshkumar, and D. Ramesh 2010) developed an emergency response management and information system to improve emergency recovery through solving the routing problem when a critical situation occur using GIS technology. Their work provided efficient route for speedy transportation of a patient when an emergency occurs. GIS technology was also used by (J.K. Deepthi, and B. Ganeshkuma 2010) to identify accident hot spots so as to investigate high-rate accident locations and safety deficient areas. Their idea facilitates spatial data sharing with transportation agencies. Sommer (C. Sommer 2010) investigated shortest path query processing in networks both from a theoretical and a practical point of view. A simple and general method based on Voronoi duals to efficiently support the shortest path queries in undirected graphs with very low pre-processing overheads and competitive query times, at the cost of exactness was used. This method is a good alternative to existing exact methods designed for transportation networks.

The shortest path can be computed either for a given start time or to find the start time and the path that leads to least travel time journeys. The classic shortest path problem and finding the best route for vehicle routing in static road networks based on Dijkstra's algorithm was been examined extensively in the literature over the years (Alazab et al. 2011, Alivand *et al.* 2008, Kim *et al*. 2005). In addition (George *et al.* 2007).

In, Dijkstra's algorithm the authors provided a study that depicted the preliminary results for a decision support tool to model network congestion routing and provide an alternative route during rush hours in emergency cases. The system predicts traffic flow and barriers during rush hours and suggests the alternative route to reach hospitals at the time of emergency. The authors used ArcGIS 9.3 network analyst tool and Dijkstra's algorithm for performing shortest path analysis. The main objective of this study was to find the best route from the nearest hospital ambulance to the incident location and from the incident location to the nearest hospital with alternate routes. (Suneet Naithani, Abhishek Choudhry, Sandeep Chauhan, 2013).

A shortest path problem is to find a path with minimum travel cost from one or more origins to one or more destinations through a network (Lim and Kim 2005, Panahi and Delavar 2008). Shortest path analysis is important because of its wide range of applications in transportation (Lim and Kim 2005). The shortest path helps calculate the most optimal route, and optimal routing is the process of defining the best route to get from one location to another. The best route could be the shortest or fastest depending on how it is defined (Naqi *et al.* 2010).

Currently, integration of GIS in primary care research has been encouraging due to the Improvement of GIS technology, making it suitable and understandable by healthcare researchers. Many studies have described the results of access barriers to health care and its effects on health outcomes. This study is important to better understand and to modify how the planning of health care is carried out (Luther S. L., Studnicki J., Kromery J., Lomando-Frakes K. 2003).

Recent GIS data models related to GIS-T are static in nature. Static information is not sufficient to estimate travel time, since it does not reflect dynamically changing traffic conditions. Static information could lead to incorrect shortest paths; however, if there is a way to obtain the cost in real-time and then apply a time-dependent shortest path algorithm, it would result in a better solution for the shortest path (Panahi and Delavar 2009).

2.7 Methods of EMS spatial analysis

According to (Nadi and Delavar 2003), most conventional GIS data models are based on a static representation of reality and constrain GIS capabilities for representation of dynamic information. GIS data models that can represent the dynamic aspects of transportation challenges are need to represent and analyze space-time information (Shaw 2010). Static variables that could be assigned to a road edge or junction might include distance, speed limits, free-flow travel time, number of lanes, turn penalties, slope of the road, hierarchical classifications, etc. (Li and Lin 2003, SadeghiNiaraki *et al*. 2011, Thirumalaivasan and Guruswamy 1997).

In recent years, traffic congestion in Davis County, Utah has become more problematic and widespread, thus affecting emergency response performance. Traffic congestion will continue to be a concern as the region grows in population and congestion increases (Utah Department of Transportation (UDOT) 2008, United States Census Bureau 2012). East-west transportation is restricted by a narrow urban corridor and many of the resident's commute south to Salt Lake County. From (2000 to 2010,) Davis County experienced a population growth rate of 28.2% and an increase in housing units by 31.6%, and the average population density per square mile increased by 30.7% (United States Census Bureau 2012). With no signs of slowing population growth or opportunities for employment, Davis County must plan for a variety of transportation facilities such as roads and mass transit systems to accommodate the anticipated growth (UDOT 2008).

This study selected Davis County, Utah as the case study area because of its constricted, north/south orientated road system and traffic congestion. Using commercial ready-to-use GIS software, a dynamic road network was created and a real-world emergency response routing analysis was performed to determine the shortest, fastest, and most optimal path or routes for emergency response vehicles by applying different cost attributes or impedances. An analysis and comparison of the resulting emergency vehicle routing scenarios was mad to demonstrate how routes and travel times are affect when these cost attributes are applied. (Davis County Emergency Management Services, 2009).

In contrast, travel time is considered dynamic due to traffic volume, and historical traffic data applied to a network can approximate traffic congestion. Dynamic variables known as costs or weights are time-dependent or time-varying travel times derived from historical traffic data. Dynamic variables that could be assign to a road edge or junction might include weather variables or time-varying travel time derived from traffic count data (Sadeghi-Niaraki *et al.* 2011, Thirumalaivasan and Guruswamy 1997).

The network analysis will better reflect actual traffic conditions occurring at various times 12 hours during the day when time-dependent variables are incorporated (Kok *et al.* 2012, Panahi and Delavar 2009).

There are several ways to apply historical traffic data to a road network. One approach is to compute travel times for each road segment, which are then stored as attributes for each feature. Depending on the sampling rate, storage and duplication issues can be a concern (Demiryurek *et al*. 2009, Esri 2012, George *et al*. 2007). Another method is the use of historical traffic profiles often referred to as speed profile that are used to produce travel time estimates (Nannicini 2009, Park *et al.* 2005, TomTom 2012). Historical traffic profiles can represent the value of travel time observed at the time intervals of each link for a specific period in the past (Kim *et al.* 2007). The use of traffic profiles can be useful because it is not realistic to have a road network completely covered by traffic recorders, and they can reduce computation time and database storage and improve data quality (Chien and Kuchipudi 2003, Shaw 2000).

A historical profile can be considered summary statistics such as mean/median travel time for each time slice (e.g., 60 minutes) of a road segment which are observed for certain past time periods (e.g., 30 days). For instance, if mean travel time is used as a historical profile, it represents the average value of the observed edge travel times over certain past times (Park et al. 2005).

(Kim *et al*. 2005) examined the value of real-time traffic information such as accidents, bad weather, traffic congestion, etc., to optimize vehicle routing in a dynamic network. Real-time traffic information combined with historical traffic data can used to develop routing strategies that tend to improve both cost and service productivity measures. Historical traffic data can realistically represent peak-hour traffic congestion and help emergency vehicles avoid these congested areas and improve travel time. (Kok *et al.* 2012and Panahi and Delavar 2009).

Various literatures have talked about measuring spatial and the outcome of spatial measurement of accessibility as well as methods and theories of measuring spatial accessibility to health care. (Toran-Pour & Yue 2012, Word Health Organization (WHO) 2011).

In the literature, the terms "spatial accessibility" and "spatial patterns of accessibility" are occasionally use interchangeably; most researchers define "spatial accessibility" as the ability to physically travel from a potential health care user's location to a health care facility's location using a transportation network, and "spatial patterns of accessibility" as the spatial distribution of certain spatial characteristics (Ikporukpo C.O.1987).

Methods of spatial analysis offers tools, which enables the description and the understanding of the spatial arrangement of health care and examines the relationship that exist between health outcomes and access to improve health care delivery. GIS as a computer-based system aids the integration and analysis of geographically referenced data. It has the ability to process data collected, store and retrieve data when needed, analyze and display data as maps. This enables the visualization of patterns and generating of new ideas (A Case of Atwima Mponua District of Ghana Cromley E. K. 2003).

CHAPTER III: MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Ethiopia

Ethiopia is a Federal Democratic Republic composed of 11 National Regional states: namely Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Gambella, Sidama, Tigray, Southern Nations Nationalities and People Region (SNNPR), South West Ethiopia Peoples' Region (SWEPR), and Harari; and two chartered administrative cities (Addis Ababa City administration and Dire Dawa city council). The national regional states as well as the two cities administrative councils are further dividing in to eight hundred woredas and around 15,000 kebeles.

Ethiopia, located in the horn of Africa, is a land locked country since the independence of Eritrea in 1993. It is border to the north by Eritrea, to the North-West by Sudan, to the South-West by West Sudan, to the South by Kenya, to the East by Somalia, and to the Northeast by Djibouti. There are more than eighty ethnic groups. Ethiopia is the second populated nation in Africa with a total population of 82,101,998 of which 41,431,989 were males and 40,670,009 were females (Central statistics Agency of Ethiopia, 2011).

3.1.2 Addis Ababa

Addis Ababa, the political capital and the most important commercial and cultural center of Ethiopia, is geographically located at the heart of the nation, $9^{o}2'$ N latitude and $38^{o}45'$E longitude. Its average altitude is 2,400 meter above sea level, with the highest elevations at Entoto Hill to the north reaching 3,200 meters. This makes Addis Ababa one of the high-altitude capital cities. Based on this figure, the population of Addis Ababa accounts for 3.6% of the national population and 18% of the urban population in Ethiopia. It has shown an annual rate of population growth of 2.1%. Addis Ababa is a true primal city in Ethiopia in terms of population. The high population growth rate observed in the past years is thus due to high migration to the city seeking jobs and better education. The working age population is by contrast quite robust; the population between the ages of 15 to 65 is 72% for Addis Ababa. The average family size is 3.9 according to a 2013 estimate. (CSA, 2013).

Addis Ababa is one of the two self-governing chartered cities in Ethiopia with the status of a special autonomous region within the national federal government system. Its Council is accountable both to the city voters and to the federal government. The city is divided in to

11 sub-cities and 120 weredas, which are the lowest administrative units. (This Study preparation is for the combination of sub cities and weredas in Addis Ababa city administration and approved by government cabinet (on October 2013E.C).

3.1.3 Arada Sub City

Arada is one of the sub cities from the 11 sub cites in Addis Ababa. It has a 992.7-hectare surface area. Its coordinates are 9^o 2' 6'' N and 38^o 45' 28'' E. The sub-city is basically located in the northern section of Addis Ababa, close to the center, located from the south (Kirkos and Lideta) to the west (Addis Ketema) to the east (Yeka) from the north (Gulele Sub-Cities), each sub-city divided into 8 werdas this has approved by Addis Ababa city administration government cabinet (October 2013 E.C).

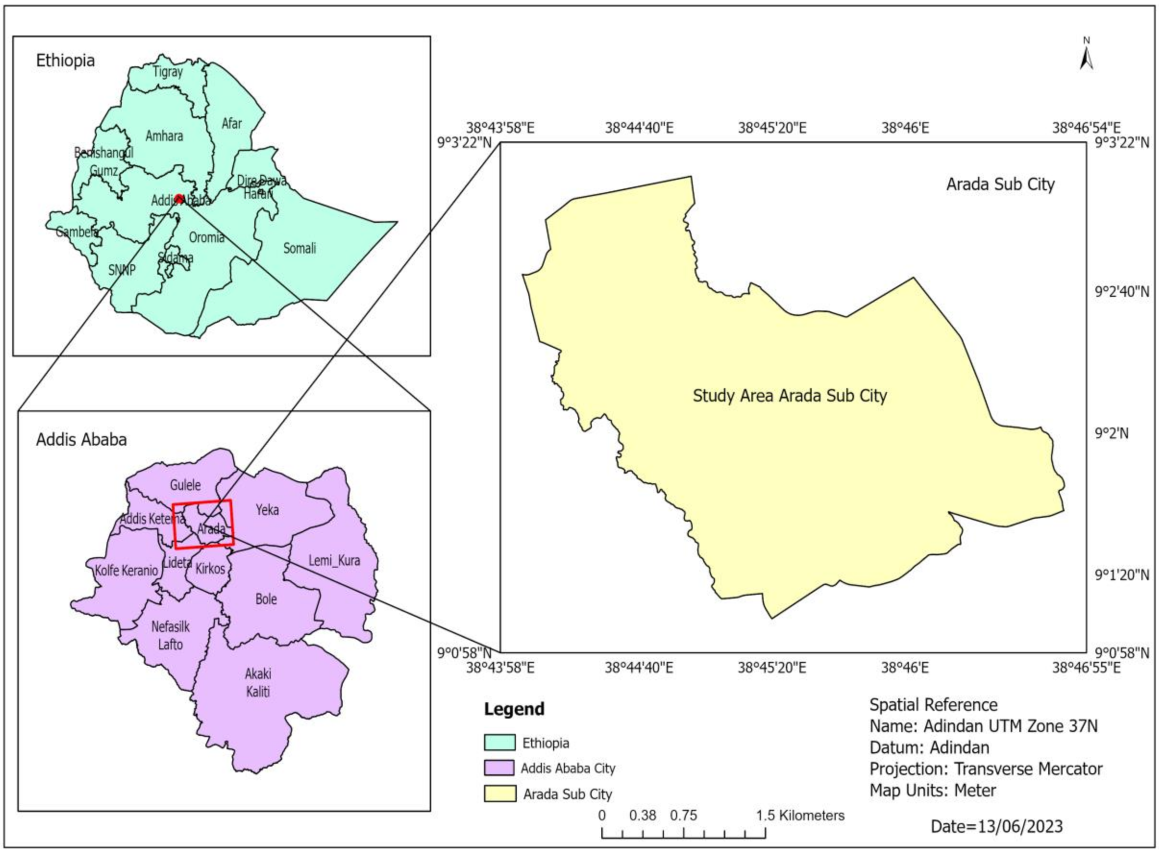

Figure 3.1 Location Map of the Study Area

According to the 2007 census result, the population of Arada sub city was 211,501 out of the entire city population of 2.7 million. From the total population 99,165 were males and 112,336 were females.

Table 3.1 Population Density of Arada Sub City (2007)

Arada	Male	Female	Both sex	Area/Ha	Population density/Ha
Arada sub city	99,165	112,501	211,501	949.86	222.67
Woreda 01	10,289	11,147	21,436	150.04	142.87
Woreda 02	10,709	11,301	22,010	58.02	379.35
Woreda 03	6,373	7,296	13,669	65.59	208.40
Woreda 04	11,534	13,779	25,305	110.84	228.30
Woreda 05	11,571	13,779	24,725	95.15	259.85
Woreda 06	9,238	10,623	19,861	90.59	219.24
Woreda 07	12,852	15,305	28,157	131.98	213.34
Woreda 08	11,601	13,026	24,627	107.97	228.10
Woreda 09	8,335	9,059	17,394	99.60	174.53
Woreda 10	6,337	7,184	13,521	39.54	341.96

Source: CSA, 2007

3.1.4 Transport and Existing Road Network

The main components of Addis Ababa transport system in general and Arada sub-city in particular are the road network, city buses, minibuses, taxis, small number of private vehicles and large pedestrian. The road network provides the means for travel through the city. Recently, the light railways supplement the intra-city transportation service.

The road network of Addis Ababa City has a radial form which is shaped by five regional roads radiating out of Central Business District. There is no well-defined hierarchical system. However, SMEC International (during the development of a pavement management system) divided the road network into the following four categories. The distribution of road network length provided by AACRA is given in table 3.2 and 3.3.

Arterial Roads: As per the Master plan these roads have varying width ranging from 30m to 60m. These roads provide continuous traffic flow, including intra-urban and inter-urban public transport lines. The ring road is included in this category.

Sub-Arterial Roads: have a road width ranging from 20m to 25m. These roads include a lower level of intra-urban mobility than the main arterial streets and connect adjoining areas.

Collector Roads: The proposed width of these road categories is 15m and includes minor public streets used to collect and distribute the traffic to and from local streets and provides access to arterials streets.

Local Roads: The proposed width of these types of roads is 10m. Streets that provide access to residential, business areas are included in this category.

Table 3.2 shows the trend of the different hierarchical roads as described and given by Addis Ababa City Road Authority.

Table 3.2 Addis Ababa City Road Hierarchy

Road Hierarchy	Total Length (km)	Length in 7mWidth	No of Bridges	Pavement Status
Arterial Roads	364	1130	171	Very Good
Sub-Arterial Roads	152	425	80	Very Good
Collector Roads	225	342	34	Good
Local Roads	267	267	430	Good
Total	**1008**	**2164**	**715**	

Source: AACRA, 2015

The following table shows the road type classification in Addis Ababa. As indicated on the table below, the total length of roads in the city has increased to 591.91 km if which 66.66 km was asphalt road and the rest 13.15, 71.42, 1.32, 39.36 km was cobble, gravel, care stone and earth work road respectively.

Table 3.3 Addis Ababa City Road Type Classification

Road Type	Master Plan Road Length(km)	Local Road Length(km)
Asphalt	466.66	474.31
Cobble	13.15	514.08
Gravel	71.42	1,018.16
Care Stone	1.32	258.35
Earth work	39.36	291.35
Total	591.91	2556.25
Under Construction	101.36	-
Planned Asphalt	253.47	-

Source: AACRA, 2015

In Arada sub-city more than 25km of the existing road is covered by asphalt/concrete (table 3.4). However, most of the Asphalt roads need maintenance. Currently, the size and the type of road may change a lot, because of the construction of small-scale train rail way from Dejach Wubie to Merkato.

Table 3.4 Arada Sub-City Road Classification by Road Type

Road Type	Equivalent Road Length(km)	%	Road Area(km)	%
Asphalt	26.29	34.16	184.04	34.16
Gravel	2.69	3.49	18.85	3.49
Care Stone	27.95	36.21	195.62	36.21
Coble Stone	2.86	3.71	19.99	3.71
Earth work	17.17	22.31	120.17	22.31
Total	76.96	100	538.67	100

Source: AACRA, 2015

3.2 Materials

3.2.1 Addis Ababa City Aerial Photo

Addis Ababa aerial photo are a raster data. GIS provide that the imagery has been spatially rectify so that it will properly align with other data set. Addis Ababa city aerial photo gets from Addis Ababa city administration and in order to do network analysis it used digitization (Addis Ababa city administration 2010).

3.2.2 Shape File Data

A shape file is an ESRI Vector data storage format for storing the location, shape, and attributes of geographic features. It is stored as a set of related files and contains one feature class. Shape files often contain large features with many associated data and historically have been use in GIS desktop applications such as Arc Map For this study, we download Ethiopian Road line shape file *(https://data.humdata.org/dataset/hotosm_eth_roads).*

3.2.3 Global Positioning System

A global positioning system (GPS) is a network of satellites and receiving devices used to determine the location of something on Earth. Some GPS receivers are so accurate they can establish their location within one centimeter. The global positioning system (GPS) is a network of satellites and receiving devices used to determine the location of something on Earth. Some GPS receivers are so accurate they can establish their location within one centimeter (0.4 inches). GPS receivers provide location in latitude, longitude, and altitude.

They also provide the accurate time. GPS includes 24 satellites that circle Earth in precise orbits. Each satellite makes a full orbit of Earth every 12 hours. These satellites are constantly sending out radio signals. GPS receivers are programmer to receive information about where each satellite is at any given moment. A GPS receiver determines its own location by measuring the time it takes for a signal to arrive at its location from at least four satellites. Because radio waves travel at a constant speed, the receiver can use the time measurements to calculate its distance from each satellite (https/education. National geographic.org/resource/GPS 2022).

3.2.4 Software

The primary software programs used in this study were Microsoft Office products, ArcGIS Pro 3.0 from ESRI, and ArcGIS Mobile Apps (Microsoft Office and Excel).

Material Use

Table 3.5 Study Data and Software

No	**Type**	**Unit**	**Uses**
1	Addis Ababa aerial photo	1	Digitizing the road
2	GPS	1	To collect coordinate system
3	Personal computer (PC)	1	For all work
4	Road network dataset	1	For building network dataset
5	Microsoft office word	1	For report writing and flow chart work
6	ArcGIS Pro 3.0 and ArcGIS Mobile Apps	1	For analysis work

GIS :-A geographic information system (GIS) is a system that creates, manages, analyzes, and (create maps for all types of data). GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is use in science and almost every industry. GIS helps users to understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision-making.

Organizations use Geographical Information System (GIS) to obtain better information for better decision making. GIS presents the real-world objects on map and easy to use spatial tools for performing the most complicated task. In our real world, spatial objects are present in different ways. In Geographical Information System, spatial objects are represented as point, line and polygon. ArcGIS is GIS software, which belongs to ESRI software solutions (https://www.esri.com/en-us/what-is-gis/overview).

ArcGIS Pro: - ArcGIS Pro, the powerful single desktop GIS application, is a feature-packed software developed with enhancements and ideas from the ArcGIS Pro user community. ArcGIS Pro supports data visualization; advanced analysis; and authoritative data maintenance in 2D, 3D, and 4D. It supports data sharing across a suite of ArcGIS products such as ArcGIS Online and ArcGIS Enterprise, and enables users to work across the ArcGIS system through Web GIS (http://www.esri.com/en-us/arcgis-pro/overview).

ArcGIS Mobile**:** - Apps Smart phones and tablets are pervasive and many enterprises GIS deployments include a mobile component. ArcGIS Mobile apps support all of the Web GIS deployment models: SaaS, managed services, cloud environments, on-premises, or a hybrid variation. Two categories can be used to ArcGIS mobile apps. Mobile applications for fieldwork and field actions in support Mobile apps that support customized workflows are a solution.

GIS data and maps can easily be taken into the field to support mobile field worker. Field personnel can work with the same authoritative datasets on their mobile devices, helping collect new data (or edit attributes of existing data) that can be easy share with the office and monitored in real-time by dispatchers. Field operations tasks include planning, coordination, navigation, data capture, and monitoring personnel and assets.

With the pervasive use of smart phones and tablets, many enterprises GIS deployments now include a mobile field component. GIS data and maps can now be easily taken outside the office and into the field to support mobile field workers for field data collection. Field personnel can work with the same authoritative datasets on their mobile devices, helping collect new data that can be easily share with the office and monitored in real-time by dispatchers (ArcGIS Secure Mobile Implementation Patterns 2021).

3.3 Methodology

3.3.1 Building Geodatabase

One of the most important steps in creating an effective database is designing its schema. The same is true for any geo database. At the heart of any GIS system there is always a well-developed and organized database. Therefore, database development and organization has been given due attention in this study and involved entity and attribute identification and the database assembly.

Table 3.6 Content of Study Geodatabase

Theme	Fields	Description
Road network	Name, One-way	Name of the road
	Speed limits	Information of one-way road Speed limits on that road
	Length	Length of the road
	Category	key number
Health center	Name	Name of the health center
	Label	Label of the Health center
	Category	Category key number for private and gov't
Ambulance	ID	Identity number
	Employees	For including driver (locating using GPS)
Accident	Amb_ID	Ambulance Identity number
	Nearest_La	Nearest landmark

3.3.2 Geo-processing of Topo-sheet

In this phase, a Geo-referencing process for the downloaded roads network data is being perform. The Geo-referencing process allows the registration of the digitized topo-sheet on the earth's surface. It is considering a very critical stage as it affects the accuracy of the road network data.

3.3.3 Digitizing

Digitizing is the process of making features. We can see the satellite image editable and make them features to which additional spatial and non-spatial attributes can be assign. This means we are going to follow a process of making digital versions of objects that will have an attribute table with them. Once they are, digitize and have an associated attribute table these objects also be known as line features. By digitizing data to the attributed table. The digitizing process is start by creating new layers in Arc Catalog, and then adding features in Arc Map. The process of converting analog information in to digital information called digitization. Information on the map can be capture by digitizing each feature thus the process of digitization converts the spatial features on a map into digital format. Therefore, point, line, and area features that compose a map are convert into X & Y coordinates to represent a point and a string of coordinates represent a line. We digitized the Transportation network, (primary, secondary, and tertiary roads) and the features from a satellite image (Putter, Andhra Pradesh, 2010).

3.3.4 Building Network Topology

To get good analysis and results, it is necessary to build a topology of the road network to discover whatever errors in the data and correcting them. This was performed by applying some topology rules such as ensuring that there are no dangles in the road network and the roads do not intersect or overlap with themselves.

3.3.5 Building Network Datasets

Network datasets are well suited to model transportation networks. They are creating from source features, which can include simple features (lines and points) and turns, and store the connectivity of the source features. When we perform an analysis using the ArcGIS Network Analyst extension, the analysis always happens on a network dataset. A network dataset models the street network shown that one-way streets, turn restrictions, and overpasses/tunnels can be model. There are a few options available when creating a network dataset. The best option is to create a network dataset from feature classes in a feature dataset of a geo database. Since a feature dataset can store and easily communicate with multiple feature classes, the network dataset can support multiple sources and model a multimodal network. The shape file-based network dataset provides ArcView GIS users with the opportunity to rapid migrate their data. The shape-file network data set is created from a polyline shape file containing the network source (for instance, a street network) and, optionally, a shape-file turn feature class. Such a network dataset cannot support multiple edge sources and not be used to model multimodal networks.

***Network Analysis Layer*: -**A network analysis layer stores the inputs, properties, and results of a network analysis. It contains an in-memory workspace with network analysis classes for each type of input, as well as for the results. The features and records inside the network analysis classes are refer to as network analysis objects. Some properties of the network analysis layer allow you further define the problem you want to solve.

Network analyses are always performed on network datasets. Consequently, a network analysis layer must be bound to a network dataset. If you make a network analysis layer using a geo processing tool, you will set the network dataset as a tool parameter. In ArcMap, a network dataset must be added first so that when an analysis layer is created, Network Analyst can bind the analysis layer to the network dataset.

The proposed emergency dispatch system follows a systematic process. If accident occurs on the road network, information will be sent to the emergency dispatch operator, which is for warded to nearest ambulance location then to closest health center.

When a call come from accident site to emergency dispatch system informs this information nearest ambulance to accident site and allocate that ambulance to accident site. The emergency dispatch system tools were used to find the fastest path from nearest ambulance location to accident site, from accident site to nearest health center, route map and direction are sent to ambulance driver. In addition, some other information is also provided to ambulance driver such as:

- The fastest route between the closest ambulance station and the accident site, as well as the fastest route from the accident site to the closest medical facility, are provided if the accident happens during rush hour.
- Fastest routes on main roads, but this time the ambulance driver should choose the quickest route on both major and minor roads to prevent traffic and time delays and because if the ambulance is stuck in traffic, it takes longer to get to the accident scene. The major goal is to make it as easy as possible for the ambulance to get to the accident scene without being held up by traffic on the surrounding roads. The primary goal is to facilitate the ambulance's arrival at the accident scene as quickly as possible without experiencing delays due to traffic on the transportation system.

3.4 Analysis Work

The effective management of ambulance in order to achieve immediate transportation of patients from incident site to the nearest & appropriate emergency hospital plays a vital role in health services offered to citizens. An effective routing and districting of ambulances will minimize their response time and thus improve the way emergency incidents are being handled (Derekenaris. G 2000).

Emergency dispatch system is developing using ArcGIS Pro 3.0 software, GPS and ArcGIS Mobile Apps. In Each ambulance, a GPS receiver is installing to determine its real-time position (x, y coordinates).

3.4.1 During Peak Hours, Routing of Ambulance

In road safety research rapid response and treatment of road accident victims is of major concern. From the road safety studies it is recognized that time is a crucial factor in dealing with emergencies resulting from road traffic accidents, it is based on concept of Golden Hour. Time during victims may face death:

- Immediate death occurs within seconds after accident.
- Late death occurs within days or weeks of the accident.

AMS is a concept of Golden hour, during the peak hour most of the time roads are congested. AMS consider the congested roads and calculate the fastest route using both major and minor roads. (David Moore).

3.5 Esri's Solution for Emergency Call Taking

Emergency calls for service contain location information. Validated, dispatch able locations improve a tele communicator’s ability to appropriately assign first responders and ensure a timely response. Real-time, smart GIS maps improve computer-aided dispatch (CAD) and call routing so police, fire, and emergency medical services (EMS) professionals can get to those in need faster and with better situational awareness *(https://www.esri.com/en-us/industries/emergency-communications/strategies/call-taking-dispatch)***.**

3.6 Network Analysis

Agreeing with ESRI (2005) report on the advantage of ArcGIS® Network Analyst, ArcGIS Network Analyst tool is a powerful extension that provides network-based spatial analysis including routing, travel directions, closest facility, and service area analysis.

Moreover, Network analysis in GIS is often use to find solutions for problems occurred in transportation by using either vector or raster models to represent the real world. The vector-based model appears to be more suited to analysis of precisely defined paths such as roads and rivers. The raster-based model seems best suited for analysis of problems where paths are not pre-defined.

3.6.1 Closest Facility Analysis

The closest facility solver measures the cost of traveling between incidents and facilities and determines which are nearest to one another. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. The closest facility solver displays the best routes between incidents and facilities, reports their travel costs, and returns driving directions. Network Analyst allows performing multiple closest facility analyses simultaneously.

3.6.2 Shortest Path Analysis

The route solver can be used to find the best way to get from one location to another or to visit several locations. The best route can be the quickest route for a given time of day considering the traffic conditions applicable during that time, or it can be the shortest route that minimizes the travel distance. The route solver can also find the best route that visits each stop during permitted time windows you specify.

3.7 Flow chart

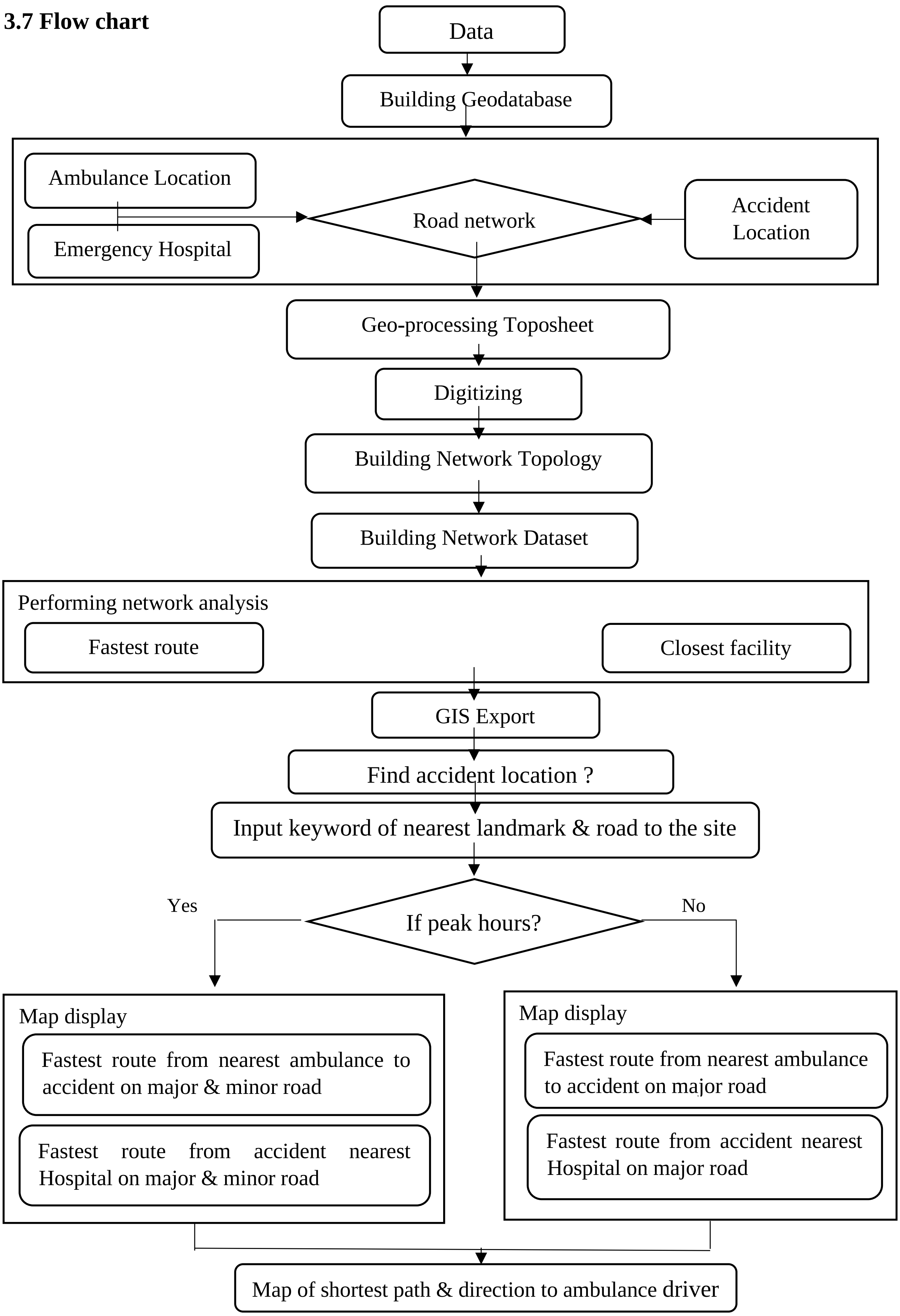

Figure 3.2 Flow chart of the study

CHAPTER IV: RESULT AND DISCUSSION

The objective of this study is to use GIS to identify the ambulance service systems' shortest routes using network analysis in the Arada Sub-City of Addis Ababa. These objectives were achieved with the Network Analyst extension's help. This chapter's key subjects are the analysis of the data, the justification of the simulation's findings, and the quickest routes. The limitations and potential solutions connected to continued development are also covered in this chapter.

4.1 Arada Sub City Road

Eleven different road types have been classified for the Arada Sub City based on the road data set. The Primary Road 42448.37m, Secondary Road 30367.17m, and Residential Road 81456.11m are essential for the network analysis study. The tables demonstrate that the information was acquired and organized in accordance with the health offices from Arada's Sub Cities. The following illustration displays various road types and maps:

Table 4.1Arada Sub City Road Attribute Table

No	**Highway**	**count highway**	**Sum Length in meter**
1	Path	16	385.24
2	Primary	553	42448.37
3	Primary link	51	1429.67
4	Residential	1110	81456.11
5	Secondary	392	30367.17
6	Secondary link	18	234.64
7	Service	187	11698.08
8	Steps	6	269.13
9	Tertiary	138	9739.54
10	Track	3	638.42
11	Unclassified	73	4902.73

Arada Sub City Road map study areas are shown below:

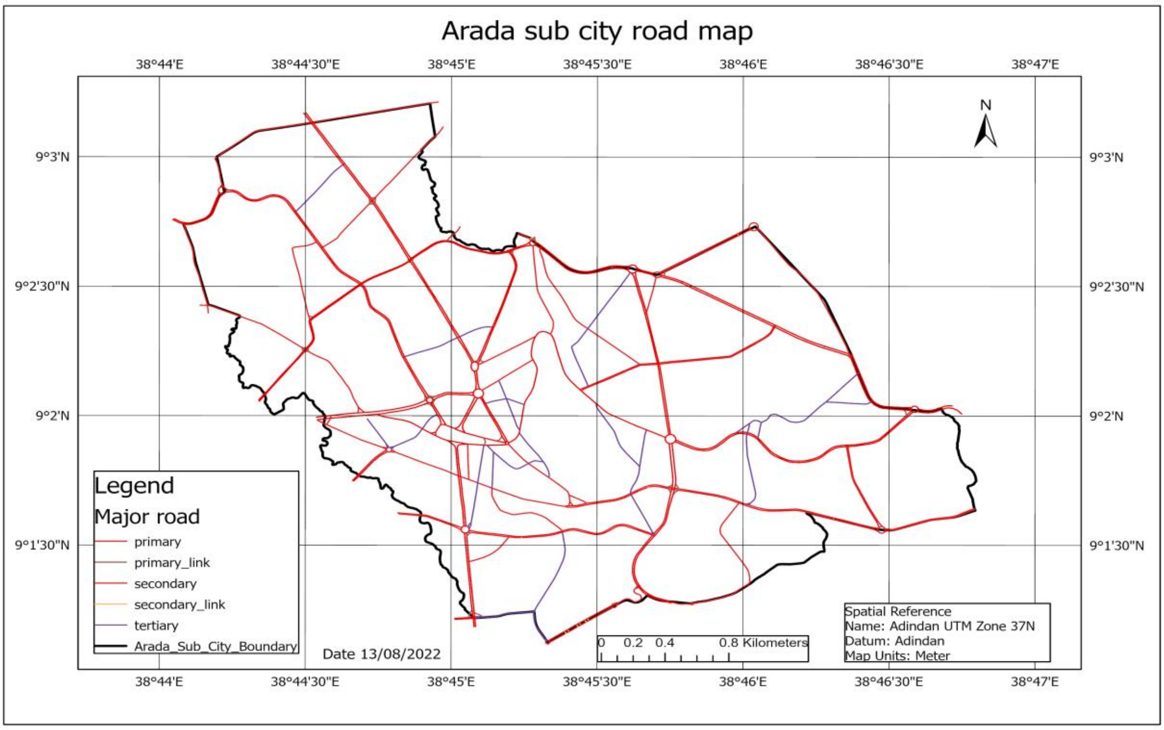

Figure 4 .1 Road map of Arada Sub City

4.2 Location of Health Center in Arada Sub City

According to information and coordinates acquired from the site and the Arada Sub City Health Office, there are currently 24 different health centers open for business, as can be seen in table 4.2 below. Figure 4.2 also includes a map of where health centers are located.

Table 4. 2 Arada Sub City Health Center name and X, Y Coordinate Attribute Table.

No	**Name**	**X (m)**	**Y (m)**
1	Tesfa_Medium_Clinic	472365.320	998148.150
2	Churchill_Health_Center	472828.750	997354.390
3	Teklehaimanot_General_Hospital	472063.970	998119.690
4	Afencho_Ber_Health_Center	472533.010	999664.690
5	ABET_Hospital	471732.410	999106.830
6	Addis_General_Hospital	471721.540	999176.460
7	Anania_MCH_Clinic	472185.440	999167.430
8	Arada_Giorgis_SMC	472657.740	999110.840
9	Ras_Emiru_Health_Center	471295.097	998800.090

10	Abune_Petros_Primary_Clinic	472755.788	998692.426
11	Abebech_Gobena _Specialized_Hospital	472065.849	998624.581
12	Semen_Health_Center	471539.197	1000442.764
13	Ras_Desita_Hospital	471788.866	999621.965
14	Police_Clinic	471388.471	1000245.818
15	Janmeda_Health_Center	474249.075	999206.668
16	Yikatit_12_Hospital	473548.304	999458.735
17	ChristMass_Internal_Brain&Spinal_Center	473840.903	998956.350
18	Kebena_HC	475316.931	998170.777
19	Life_Addis_Medium_Clinic	474412.985	998529.597
20	Berges Clinic	473497.906	997814.585
21	Addis MCH	474927.396	998656.913
22	Hemen MCH	473714.035	998185.721
23	Basha Woldie Hc	473670.324	998087.010
24	Arada HC	472883.535	998761.096

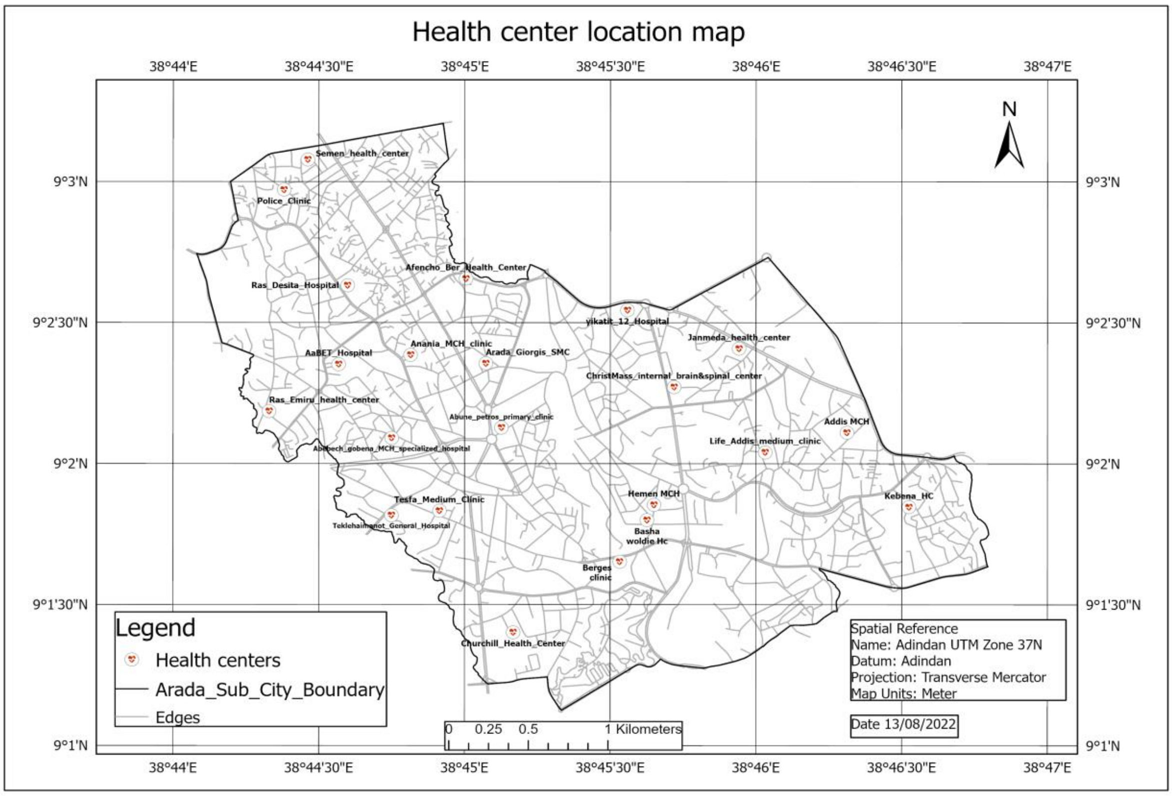

Figure 4.2 Location of Health Centers in Arada Sub City

4.3 Ambulance location in Arada Sub City

In the Arada Sub City, seventeen separate ambulance stations actively participate in emergency dispatch, as stated in table 4.3 below. Figure 4.3 displays the locations of ambulances.

Table 4.3 Arada Sub City Ambulances Name and X, Y Coordinate Attribute Table.

No	Name	X (m)	Y (m)
1	Ras Emiru Health Center	471789.223	999571.123
2	Police Clinic	471385.176	1000213.454
3	Abet Hospital	471664.497	999105.827
4	Ras Emiru Health Center	471336.175	998766.551
5	Teklehaymanot Hospital	472069.623	998148.098
6	Churchil Health Center	472828.304	997334.713
7	Meristopes	472925.657	997582.702
8	Basha Woldie Health Center	473694.584	998102.234
9	Hemen MCH	473709.976	998170.552
10	Kebena Health Center	475349.393	998164.360
11	Afinchober Health Center	472524.944	999680.273
12	Yikatit 12 Hospital	473625.646	999468.507
13	Janmeda Health Center	474262.422	999233.433
14	Addis MCH	474918.490	998622.416
15	Arada Health Center	472877.317	998782.927
16	Arada Giorgis Speciality Clinic	472665.248	999108.132
17	Ananiya MCH Clinic	472145.073	999141.592

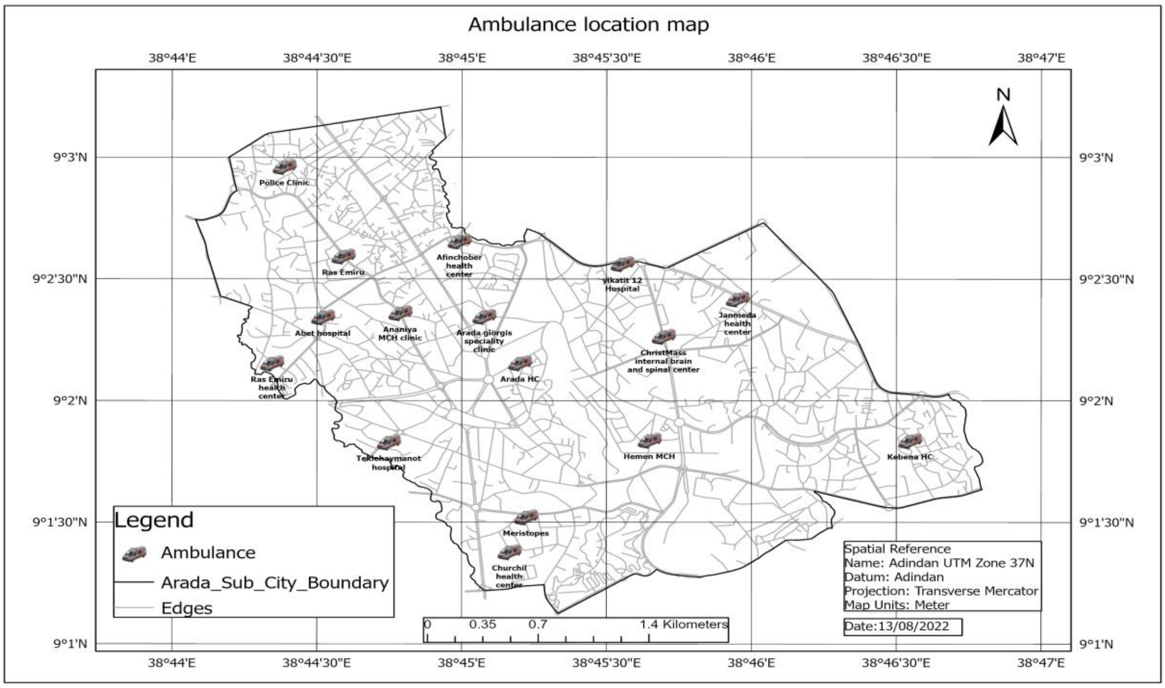

Figure 4.3 Location of Ambulances in Arada Sub City (X, Y coordinates)

4.4 Identifying the Accident site on the Road Network in Arada Sub City

The table below gives information on the accident's black spot coordinates despite the fact that there have been a number of incidents in various locations around Arada Sub City during the past two years. Additionally, see figure below.

Table 4.4 Arada Sub City Accidental Sites Name and X, Y Coordinate Attribute Table.

No	Name	X (m)	Y (m)
1	Accident at Atiklt Tera	472306.716	998700.387
2	Accident at Tewodros Adebabay	472673.219	997857.012
3	Accident at Somale Tera	472094.553	998288.557
4	Accident at Sebara Babur	472298.634	992444.510
5	Accident at Ras Amba	474891.440	998366.495
6	Accident at Kelifa Building	472076.974	998642.864
7	Accident at Banko Diroma	472670.640	998251.426
8	Accident at Abet Hospital	471838.507	999299.611
9	Accident at Addis Ababa Medical Collage	472627.629	999266.932

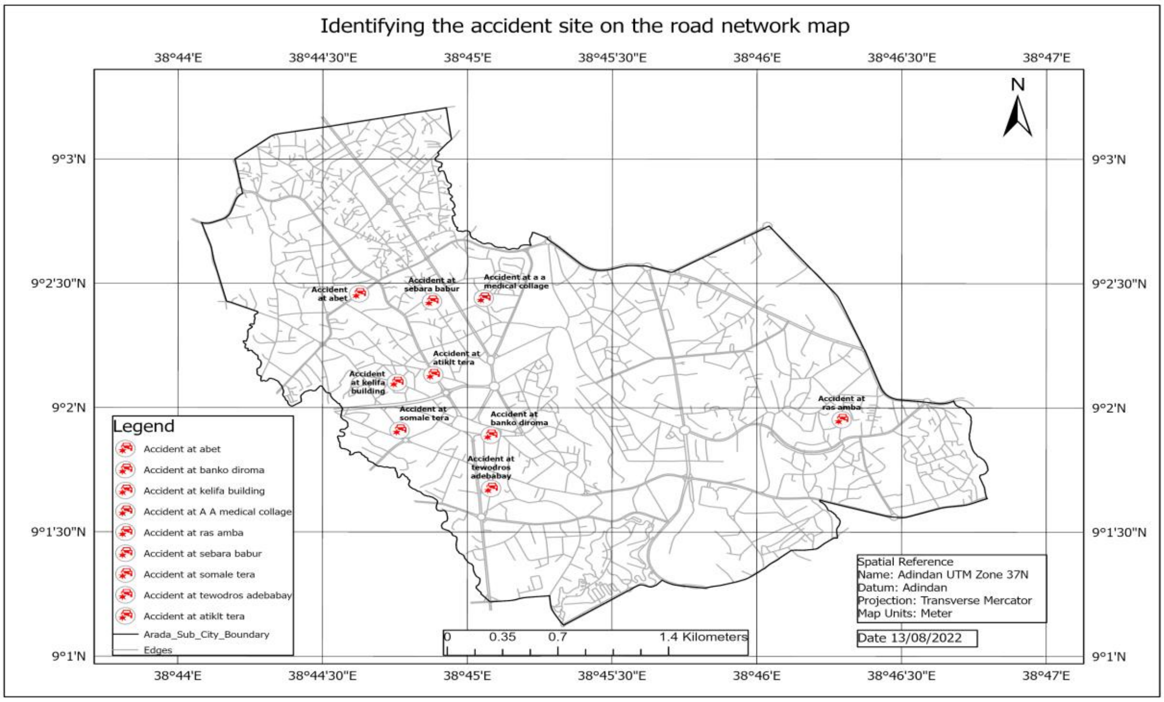

Figure 4.4 Accident Area Map of Arada Sub City

4.5 The Three Closest Ambulances can reach the Accident Site

It is necessary to specify how many facilities are sought after when locating the closest ones, as well as if the direction of travel is in or out of the facilities. Once the closest facilities have been identified, it is possible to display the best route to or from them, return the travel costs for each route, and display directions to each facility.

In this case, the hospitals and the ambulance are referred to as facilities, and the incident is the accident site. Network analyst allows performing multiple closest facility analyses simultaneously. This means you can have multiple incidents and find the closest facility (or facilities) to each incident

As a result, the network analysis closest facility solver will choose the three ambulances that are closest to the accident scene. The first ambulance attending the accident at Tewodros Adebabay travels from the Meristopes location shown in figure 4.5. The second closest ambulance will then depart from Churchill Health Center on the purple line route to the accident at Tewodros Adebabay show. The third closest ambulance, which is located in Teklehaymanot Hospital, follows a brown color route to the scene of the accident in Tewodros Adebabay.

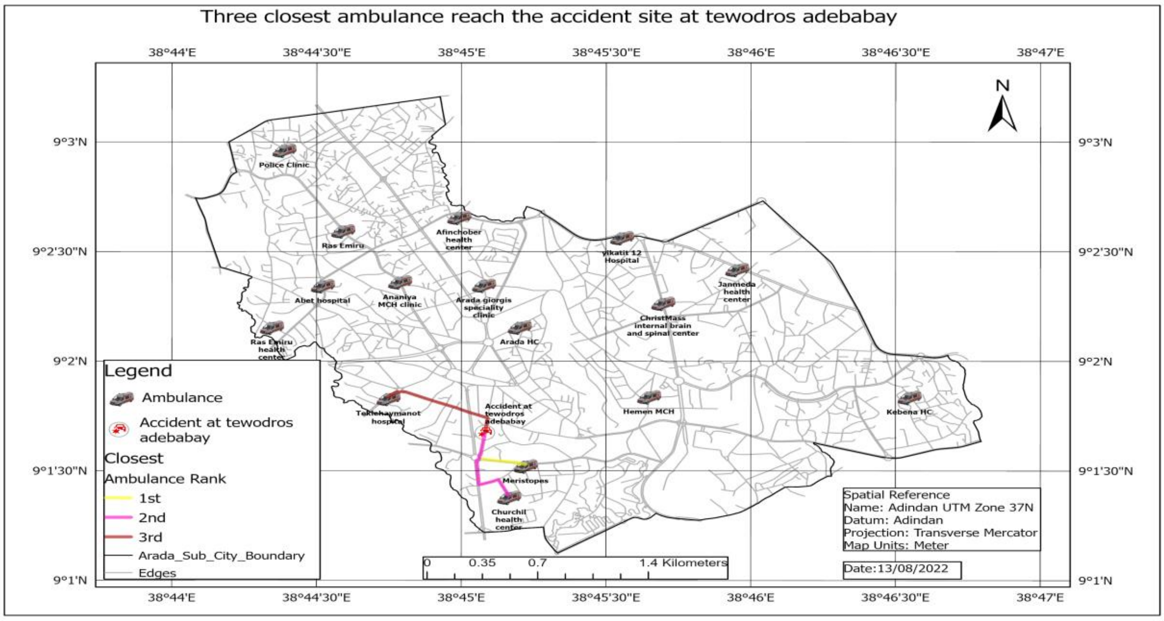

Figure 4.5 The Three Closest Ambulances to reach Accident at Tewodros Adebabay

After arriving the ambulance at accident site, the network analysis closest facility solver will choose the three closest health center that are closest from the accident scene. The first ambulance beginning from the accident at Tewodros Adebabay go to the Tesfa Medium Clinic location shown in figure 4.6. Secondly ambulance accident at Tewodros Adebabay drive to Churchill Health Center. The third ambulance, which is after arriving in accident site Tewodros Adebabay follows route to Teklehaimanot General Hospital.

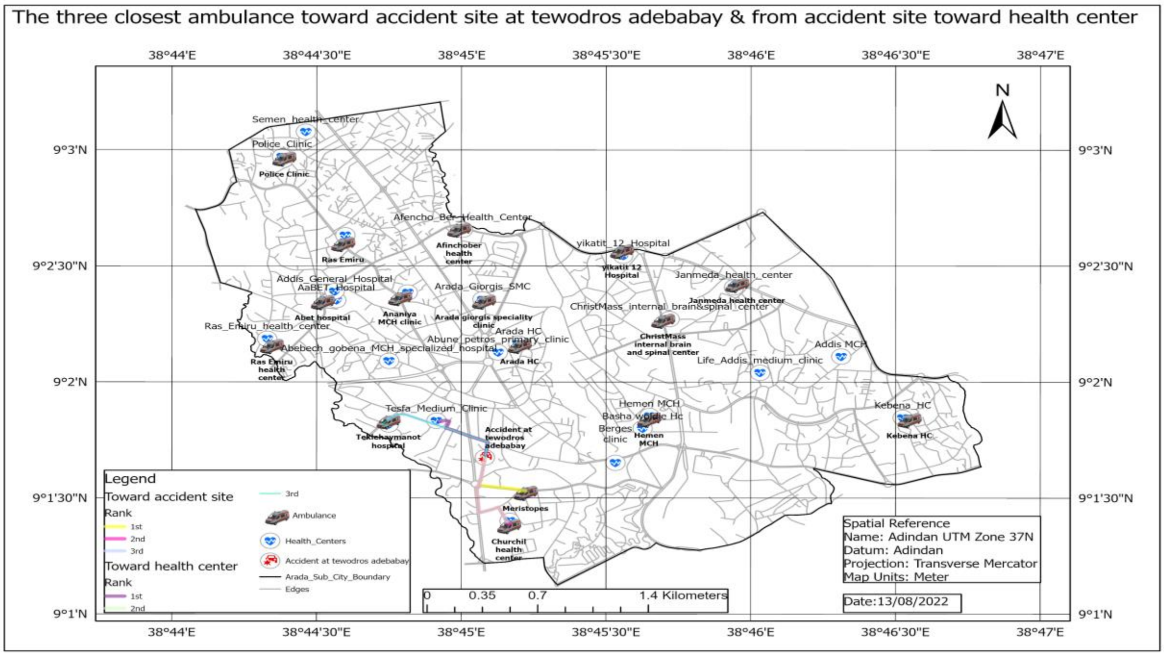

Figure 4.6 Three Closest Ambulance reach to Accident Site at Tewodros Adebabay and to Heath Center

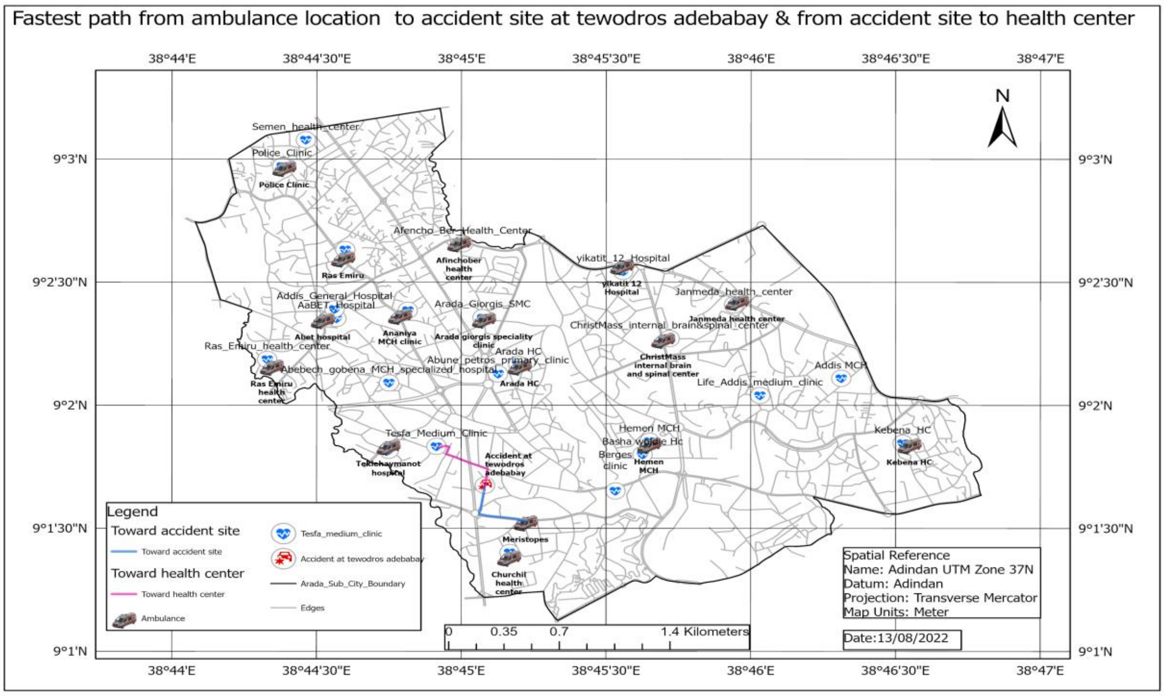

Figure 4.7 Fastest Path for Ambulance to reach Accident at Tewodros Adebabay and Tesfa Medium Clinic

4.6 Shortest Path and Closest Facility from Ambulance Location to Accident

People frequently search out the optimal route, whether it involves travelling a short distance between two points or stopping at several. Best approach, however, can vary depending on many factors.

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

Accumulated attributes play no role when computing the solution. For example, if you choose a time cost attribute as the impedance attribute and also want to accumulate a distance cost attribute, only the time cost attribute is used to optimize the solution.

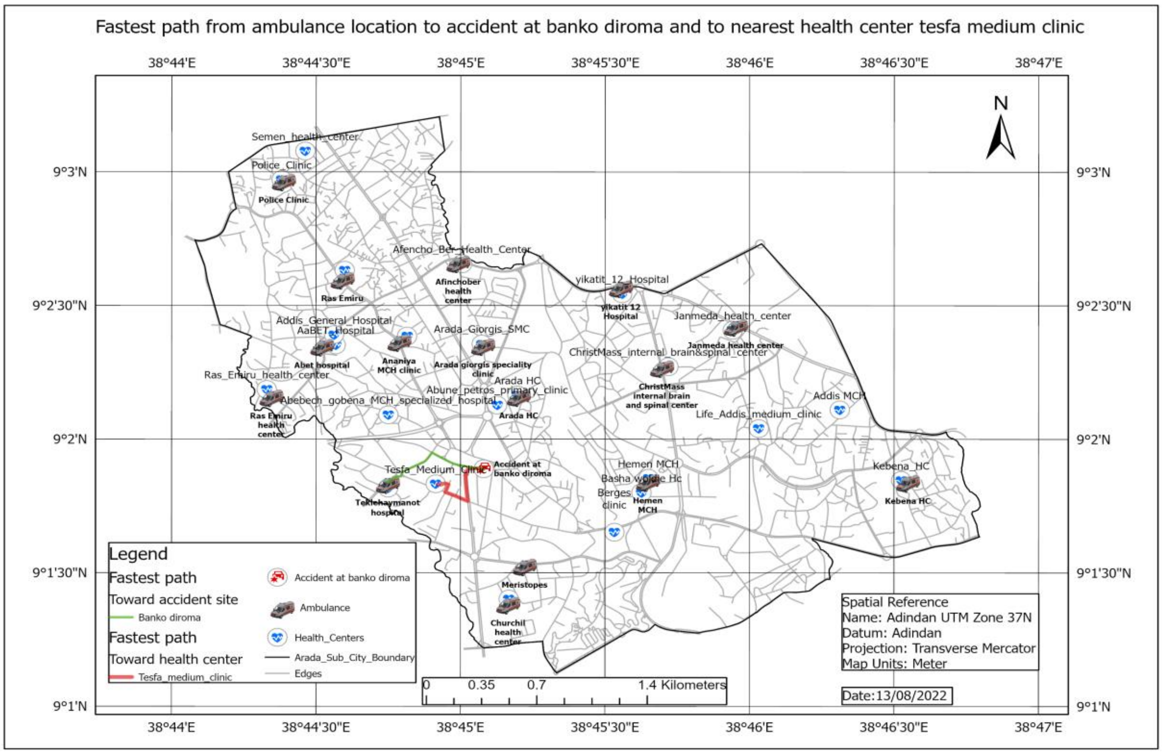

Figure 4.8 Shortest Path from Ambulance Location to Accident at Banko Diroma

The map show below the three closest ambulances reaches at accident Banko Diroma.

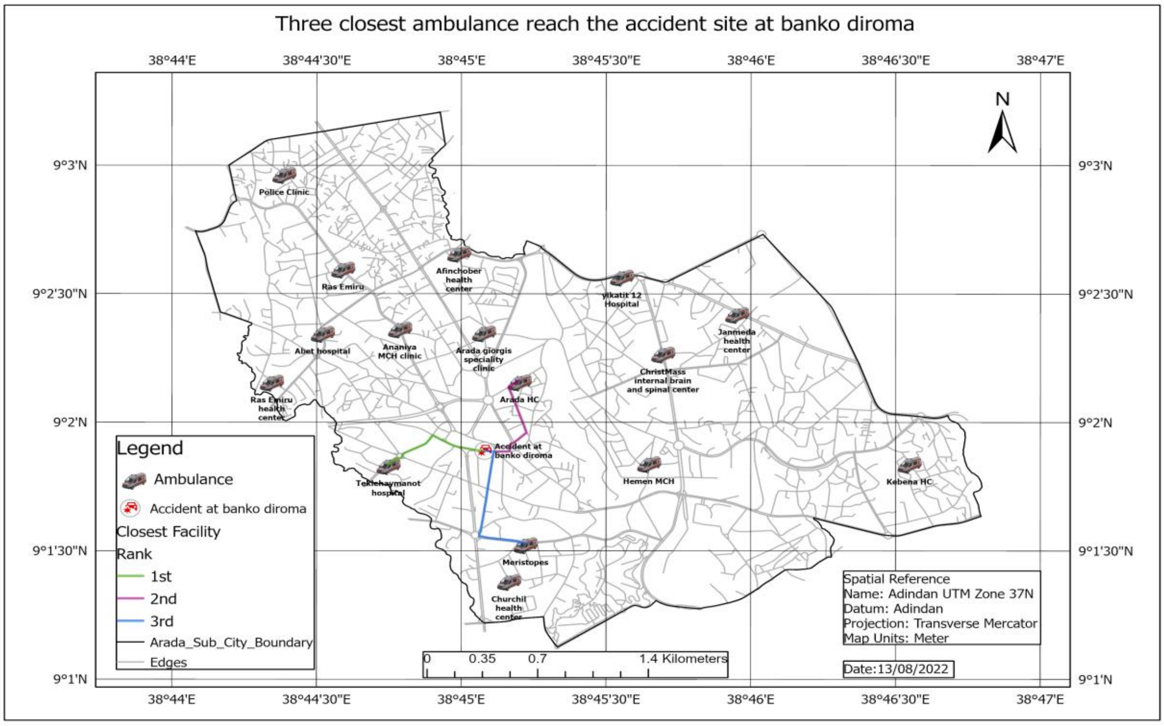

Figure 4.9 The Three Closest Ambulances reach Accident at Banko Diroma

Uses the three closest ambulance locations to the accident scene and the nearest health center for the accident at Banko Diroma.

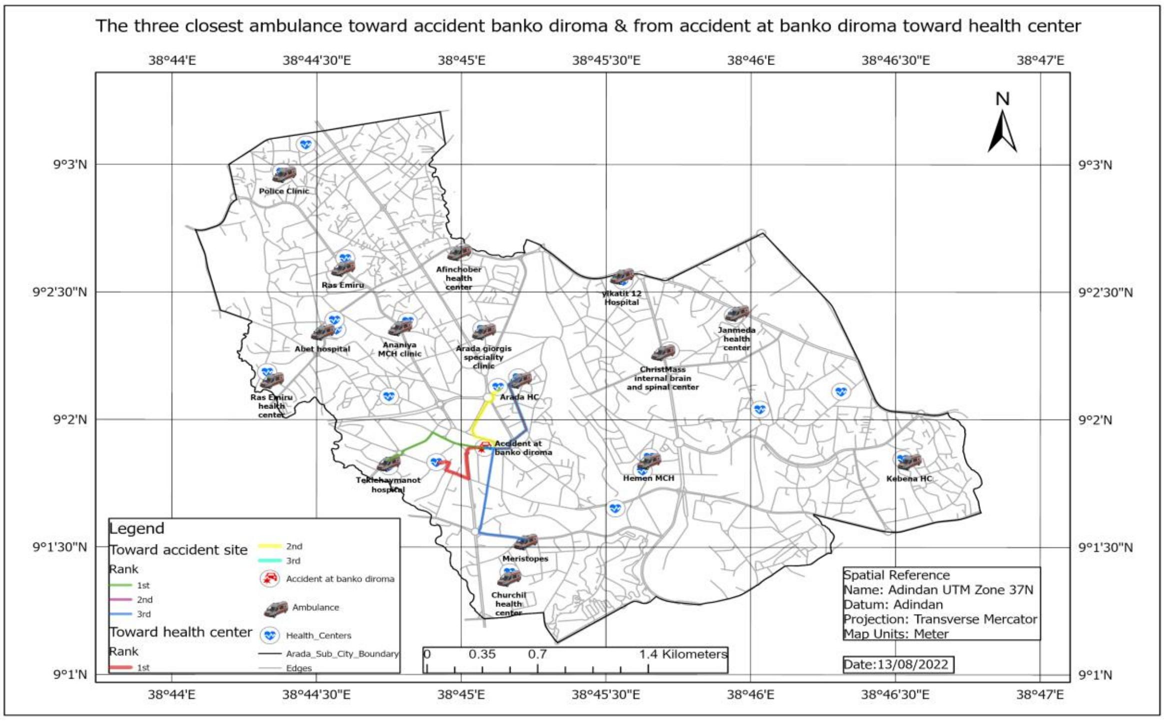

Figure 4.10 Shortest Path from Nearest Ambulance Location to Accident Site & from Accident Site to Nearest Health Center

The three closest ambulances reach to accident site Ras Amba.

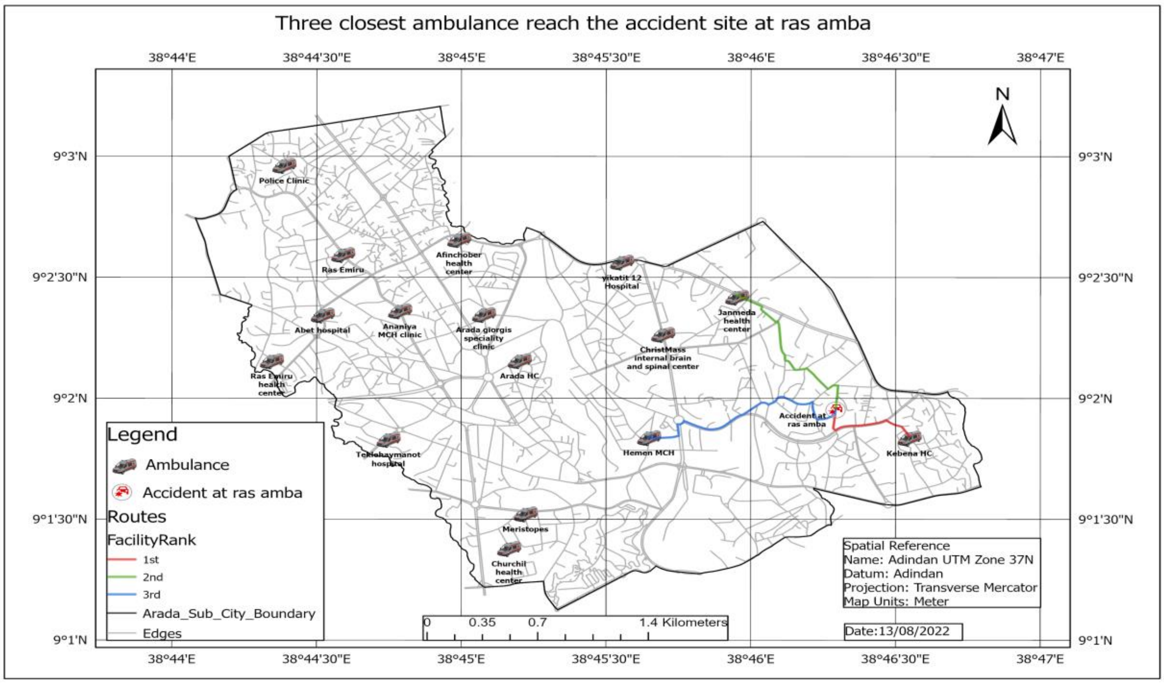

Figure 4.11 The Three Closest Ambulances reach Accident Site at Ras Amba

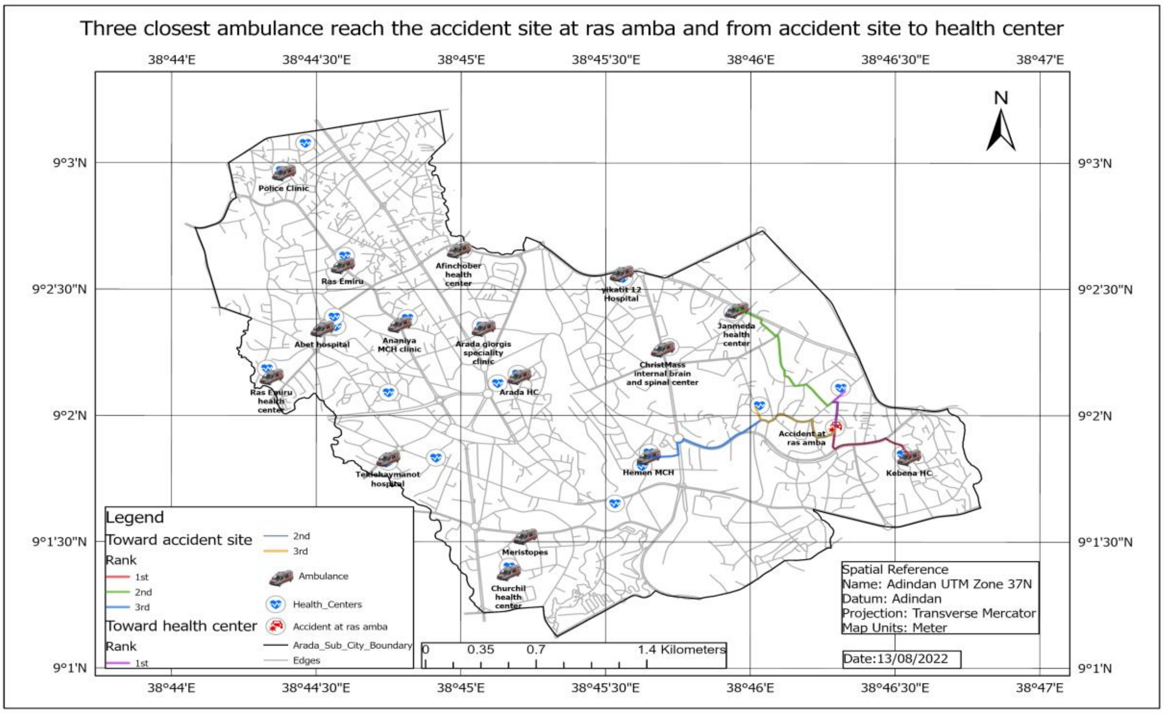

Figure 4.12 The Three Closest Ambulances reach to Accident Site and to the Nearest Health Centers

In the accident area of Ras Amba, Kebena Ambulance is on the fastest path to the incident site and to the selected closest health center Addis MCH.

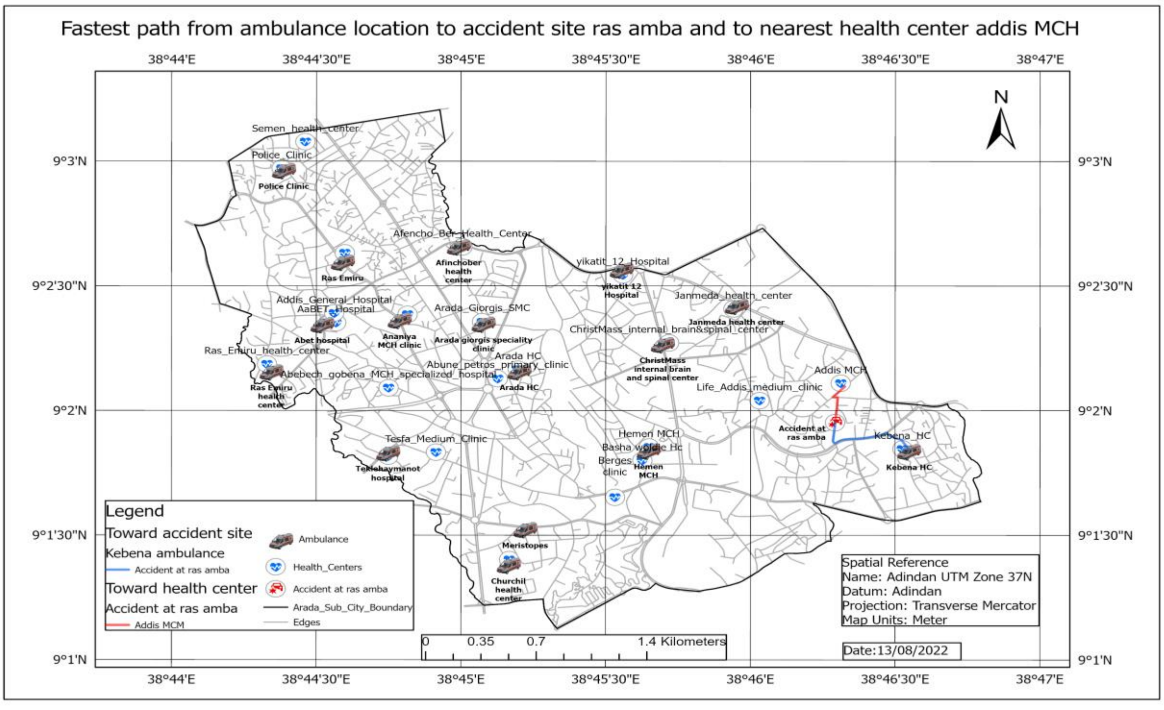

Figure 4.13 Shortest Path from Ambulance Location to Accident Site Ras Amba and to Nearest Health Center

4.7 Ambulances Allowed to use Both Roads During Peak Hours

During the peak hour most of the time roads are congested. AMS consider the congested roads and calculate the fastest route using both major and minor roads. In the normal situation fastest, route is calculated on minor roads. When the accident occurred in Ras Amba, the Hemen MCM ambulance, as can be seen in the figure below, chose a longer, more open route rather than a shorter, more congested one to get to the accident site.

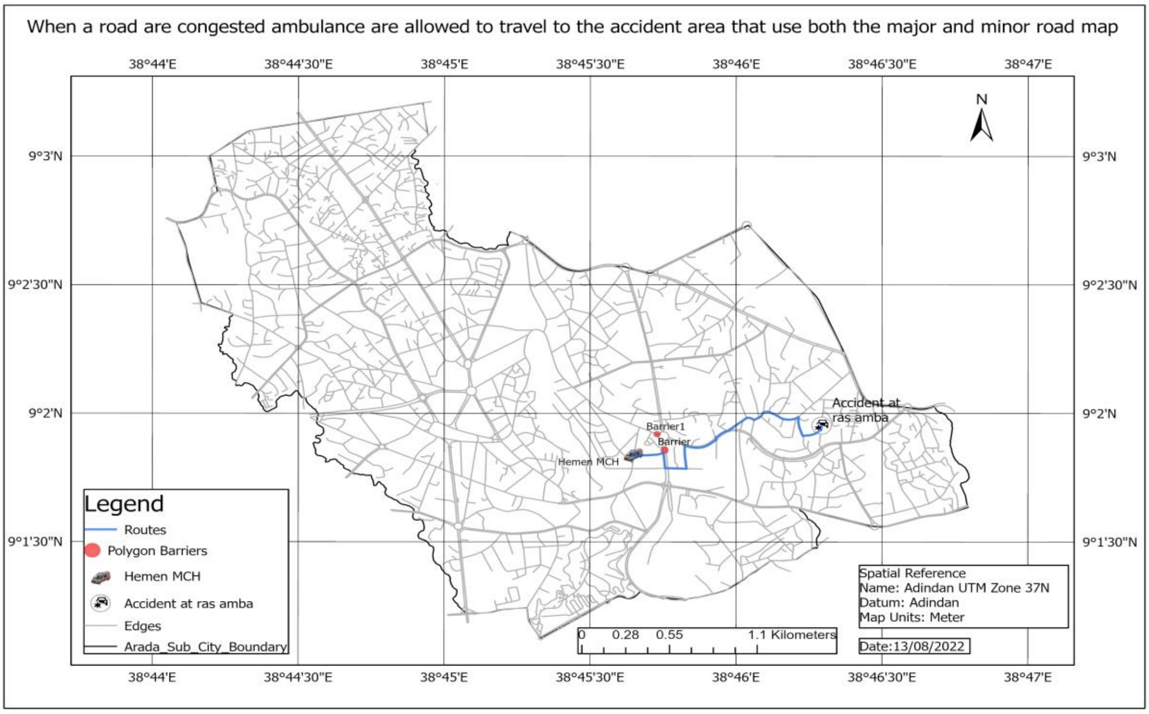

Figure 4.14 When the Roads are Crowded, Ambulances are Allowed to Proceed to the Accident Site using both the Major and Minor Route Map

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study focused on calculating the optimum route between two locations based on a specified distance (impedance), and the closest facility from a given incident, which is also based on distance as impedance, to illustrate the application of network analysis.

A Geographical Information System (GIS), which is network analyst, determined the best route, the closest facility and the service area. Data used by this study included public data and data generated using a Global Positioning System (GPS). Once analysis was completed, a route representing the (the best route) shortest travel distance and the route representing the closest facility.

Moreover, maintaining existing roads and building new ones are challenges for any growing municipality. Without coordinated digital tools for planning, scheduling, and performing work. Status reporting was activity based and did not address asset-based accounting or inventory.

Saving lives and lowering death rates are important steps in minimizing the problem's effects. Additionally, it makes the job of the ambulance driver easier and enables them to get at the scene of the accident faster than before. In general, the emergency ambulance transportation service in the Arada Sub-City is not good in-service delivery status especially at peak times. There are so many entangled factors at play in this circumstance. A few examples are the state of the roads, the amount of traffic, and the effectiveness of the ambulances. Furthermore, there is no GIS-based method for processing ordered geodatabase information that would allow for an efficient management system for ambulance transportation services. The primary goals of this study are to construct a network dataset that determine the closest emergency ambulance service facility for emergencies and to determine the shortest route for ambulance vehicles to achieve the goals in an effective manner.

The study showed that, road network analysis is essential to select the best routes from the ambulance station to the incident site and to the nearest emergency health centers. This analysis minimizes the total cost of traveling time of efficient ambulance transportation service in the sub city. It also provides route information's about driving direction that guides the ambulance drivers through the routes.

Without GIS, it is challenging to analyze issues with the ambulance transportation service on the road network. As a result, the study demonstrates that GIS has the capacity to record, store, analyze, and present information that affects the ambulance service as well as provide routing data to the ambulance driver. The Arada sub-city needs to use GIS to make decisions concerning ambulance transportation services that are easier, more accurate, and more effective.

Geo-database is highly vital for efficient ambulance transportation service management system. The attribute data of the road network, the turn table, the existing ambulance station, black spots and health center data are stored in an organized manner in ArcGIS environment. Besides, the developed network datasets are important entities for further analysis in fire and police dispatch in the network analysis environment.

The Arada sub city's emergency dispatch system will be created after careful consideration of the local environment. The patient must transfer to the closest hospital when an emergency occurs. The emergency dispatch system is crucial in resolving the ambulance's routing issue on the Addis Ababa city road network. The emergency dispatch system uses ArcGIS Mobile Apps, GPS, and GIS export call taking dispatch support centers is to the substantially resolved ambulance problems, such as the shortest ambulance route. EMS analyzes the traffic on the roadways and other events that occur during peak hours to determine the quickest path and manage many accidents.

Recommendation

A study needs to access the most recent information. This indicates that the road data was out of date. In the future, it will be necessary to address the research to confirm the road information, such as the traffic speed mode, pavement condition, and one-way streets data.

A study requires a more comprehensive database of landmarks and specific information on main and local roads in order to identify accident locations more quickly. This would take a while to construct, and EMS will be run utilizing ArcGIS Mobile Apps, GPS, and call taker dispatch.

In the future, emergency service providers will be able to use EMS to address problems with ambulance routing. The police and fire departments can also utilize the same system to carry out the following tasks:

- Locate the shortest and quickest path from the police vehicle to the scene of the incident. It is also useful for locating the scene of the crime on digital map of the city and return to the closest police station as well.
- If geo database for each city is available it will locate the fireplace on a computerized map.
- If the EMS system is used, the fire trucks will be dispatched on the city's fastest route to the fire area.

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