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Developing a Model for Fire Emergency Response Using GIS Based Solution: A Case of Addis Ababa city, Ethiopia

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Approval sheet

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DECLARATION

I certify that this research work entitled "Developing a Model for Fire Emergency Response Using GIS Based Solution: A Case Study of Addis Ababa City, Ethiopia" is my own work
And has not been presented for a degree in any other university. Where material has been used from other sources has been properly acknowledged.

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This thesis has been submitted for examination with my approval as university advisor

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Advisor Signature Date

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List of Abbreviations

VS CODE	Visual Studio Code
AACFEPRA	Addis Ababa City Fire and Emergency Prevention and Rescue Agency
ESRI	Environmental System Research Institute
GIS	Geographical Information System
WWI	World Ware First
UNFPA	United Nation Food Program Agency
UTC	Coordinated Universal Time
UN DESA	United Nations Department of Economic and Social
OSM	Open Street Map
GPS	Global Positioning System
ETB	Ethiopian Birr
GNFS	Ghana National Fire Service
NFPA	National Fire Protection Association
EPSG	European Petroleum Survey Group

Abstract

Emergency services are those that respond to various emergency situations in order to guarantee public safety. For cities, deciding where to put emergency stations is essential. When choosing the best incident location, the most crucial factors to consider are response time reduction, coverage maximization, and overall cost reduction. It is necessary to use Geographic Information Systems (GIS) in order to study on maps. The focus of this work is on developing a model for fire emergency response model based on GIS station; to deliver the fire emergency service in Addis Ababa city, locate the fire incident and the existing fire response station to arrive at the place where the incident occurs. This GIS-based approach followed identified elements such as fire response station, Addis Ababa city parcel, after identified elements then Geo coding existing fire response station and Addis Ababa city resident or parcel and to develop the database for this fire emergency response. To develop the model for the study area, Geo code at visual study code for x y coordinate of fire station and residential with attribute parcel ID. Finally the developed fire emergency response model and database integrate with web GIS. The overlay result indicates that the fire emergency response model and fire emergency database model access to locate a fire incident and timely intervention play a crucial role in managing urban fire, the Addis Ababa city parcel and existing fire response station were based on the inputs, parcel number or ID. The present study suggests GIS based fire emergency response model which helps to located fire incident with the corresponding fire response station location for the city as well as provides fire emergency response Database for the study area.

Key word: fire emergency database, fire emergency response model, fire emergency station, fire incident, web GIS.

CHAPTRE ONE

INTRODUCTION

1.1 Background of the study

Emergency services encompass those that provide a response to a diverse range of emergencies ensure public safety. These services may entail fire and rescue operations, community safety initiatives by the police to combat crime against individuals or property, as well as medical emergency services. The present research focuses on the development of a model for the "fire emergency service" in Addis Ababa, which is one of the aforementioned issues, to determine the most expedient and accurate location of incident occurrences. Urban fire is a prevailing issue faced by both developed and developing nations Nisanci (2010). The Ghana National Fire Service (GNFS) reported a total of 986 fire outbreaks resulting in significant destruction. According to Stein (2008), the United States witnessed an average of one fire accident-related fatality and one injury every 162 minutes during that year. Addis Ababa, the largest city and capital of Ethiopia, is home to a population of 2,739,551 people as per the 2007 population census.

The federal government of Ethiopia has established its headquarters in this city. The Addis Ababa City Fire, Emergency Prevention, and Rescue Agency, known as the Fire Extinguishing Services Corporation, were established in 1934. Presently, it operates through eight branches, with a fleet of 33 fire engines and 33 ambulances. The Reporter journal Report 2017, published by the Office of Addis Ababa City Fire Emergency Prevention and Rescue Agency, highlights the factors contributing to delayed response during fire outbreaks. Traffic congestion and the need to accurately determine the location of an emergency scene are two significant challenges. Furthermore, the agency lacked adequately qualified personnel for effective damage assessment. Another issue arose from the utilization of contemporary technology such as Geographic Information Systems (GIS) to locate emergency occurrences. To address the aforementioned challenges comprehensively, the deployment of skilled labor and technologies like GIS is imperative when responding to fire rescue efforts. According to the Addis Ababa fire emergency response Agency report for the years 2022 and 2023, a total of 394 fire incidents occurred within two years, leading to significant property damage and loss of life in the city.

These incidents were primarily caused by mishandled electricity lines, substandard electrical installations, and explosions of gas and oil-burning stoves. Firefighting and rescue services, commonly known as fire stations, play a crucial role in safeguarding people, property, and the environment from fire and other calamities. The study relied on a two-year report on fire incidents, specifically from 2022 to 2023, obtained from fire response agency.

Addis Ababa fire response agency was categorized based on fire incidents reported in different sub cities, with a total of 394 incidents recorded and an estimated property loss of 517,617,474 ETB. In addition to this, there were also casualties and injuries. The provision of fire emergency response services must be specified following the responding agencies and the types of situations encountered. These services are essential during the response, preparedness, and recovery phases. Moreover, appropriate procedures for resource management, such as the implementation of an emergency response plan, are imperative.

The personnel responsible for emergency management act as the intermediary between the fire incident and the GIS-based fire response model, as they are trained to utilize the tools and practice the systems in various emergency scenarios. The objective of the present investigation was to identify fire incidents for fire emergency response analysis and to address the problem of fire incidents occurring throughout the entire city. To expedite the process of locating fire incidents and selecting the nearest fire response station, an integrated approach was adopted, which involved the use of GIS methods to establish a model for fire emergency response based on the GIS station. The loading or updating of information about fire incidents into a database is crucial. In times of emergency, time is of the essence. The ability of the response unit to act promptly and appropriately will determine the severity of the consequences. Currently, there are 10 fire emergency response stations in Addis Ababa; however, given the size of the city, this number is inadequate to serve the entire area, indicating an unfair distribution of facilities among the population. The utilization of GIS based fire emergency response methods is increasingly necessary as the city grows and its population increases. Nevertheless, the fire response agency does not currently use GIS based fire emergency response techniques, resulting in the absence of a standardized database and the manual handling of fire incident information. To address this issue, the present study develops a model for the GIS based fire response station approach, which is utilized in the provision of contemporary fire emergency response analysis service.

1.2 Statement of the problem

We already know from painful experience that fire damage is caused by human ignorance, unanticipated mishaps, and natural risks. In this universe, people use fire in diverse ways and to varying degrees. In addition to being used, fire ruin lives and cause property damage. A UNFPA report states that fires cause more than $10 billion in damages annually. Since its peak around World War I, the number of fire deaths and property damage cases has decreased by about 70%. However, according to Cote (2003), Canada had the greatest fire death rate globally. The highest number of fire deaths per million persons is seen in Romania and Hungary, along with Russia National Safety Council (2007).

In Ethiopia, fire is one of the most devastating issues. In Ethiopia, fires typically occur in January, February, and March, just before the rainy season begins. It is at this period that fuel wood flammability reaches its maximum value Yetmgeta (2013). According to data from response of fire agency, 106 fire incidents happened in the aforementioned months out of the 394 major fires that happened in 2022–2023 In other situations, fire strikes and caused severe damage in cities. Urbanization and fire danger are positively correlated. For instance, in 2022–2023, about 517,617,474 million birr were damaged due to fire in Addis Ababa. There is an alarming increase in damage, so we need to figure out how to reduce the risk. Using GIS is the most effective technique to lower the risk. Since it reduces the time it takes for emergency services like fire departments, police units, and ambulances to be dispatched and arrive (2013). First, I notice two distinct gaps in the researcher's studies on fire emergency response. Abuhay (2022) a novel route study that connects each of the 10 networked fire stations to the Adrada Sub City is shown in GIS Based Network study for Locating Fire Stations and Emergency Response. There are gaps in this thesis about the integration of fire emergency response stations and fire incidents for the delivery of fire response services in the future. Another researcher's GIS-based road network analysis of Arada Sub City AWEL (2007) similarly illustrates how to follow the main route from the fire station in Arada Sub City to the incident dwelling to provide emergency services. According to this thesis, there are gaps in the way that fire incidents and fire emergency response stations are not integrated, as well as the lack of an appropriate database. The study by Alebele (2015) examines the application of GIS Based Road Network Analysis in the identification of suitable locations for fire stations and the analysis of emergency response. The

study proposes the establishment of new fire stations based on the findings. However, there are deficiencies in the current approach, as relying solely on technology-based fire response strategies proves to be more effective than constructing additional fire stations. Notably, the absence of GIS technology and a comprehensive database in certain sectors is a critical gap that needs to be addressed.

This research endeavor fills the aforementioned voids in both the realm of researchers and the fire response sectors by harnessing the power of Geographic Information System (GIS) technology to formulate a comprehensive model for fire emergency response. Additionally, it aims to establish an efficient database specifically tailored to the fire emergency response sector. In underdeveloped nations like Ethiopia, the utilization of GIS and other real-time technologies for fire service has yet to be initiated, despite the fact that this issue causes significant harm and depletion of resources on an annual basis. This glaring disparity between the projected future objective and the current state of affairs in the study area is evident. Thus, this study serves as the foundational milestone towards attaining the envisioned future objective in the designated study area. Furthermore, the compilation of a robust database for fire emergency information facilitates the effective management of fire response resources, thereby minimizing the occurrence of fire emergencies. This proactive approach not only aids in mitigating extensive property damage but also contributes to the preservation of human lives. Given these circumstances, the primary aim of this paper is to use a GIS-based station technique for the delivery of fire emergency response services by agency. This technique ensures an optimal fire response from their respective locations to any fire incident.

1.3 Objective of the study

1.3.1 General Objective

The general objective of this paper is to develop a model for fire emergency response using GIS based solution.

1.3.2 Specific objectives

The specific objective stands for to develop the fire emergency response model based on the following specific objective

- To modeling an interaction spatial data base for emergency response.
- To produce a model that shows the location of the fire response station and the fire emergency.

1. 4. Research questions

To achieve the research objective of this study, the following research questions were formulated:

1) How to integrate spatial database for emergency response in the study area?

2) How to relate fire response station with fire emergency location in the study area?

1.5 Significance of the Study

The paper addresses how to find a geographical location for a fire incident. The evaluation of the GIS base station's event reaction was done in this study. Furthermore, the investigation encompasses not only this document but also the interested parties they examine. In circumstances where the facilities are insufficient, this appropriate model will be suggested. Based on the produced fire information system, the thesis's end product is anticipated to assist personnel at the fire response station and the ambulance service in providing better services. The response time needed to get to the site of the fire will be significantly reduced by using the created model and maps that show the location of the fire event and the fire response station's close by.

1.6. Scope of the Study

One of Ethiopia's largest cities is Addis Ababa. Its entire area is 519.458 km^2, and 3,859,999 people live there. The goal of the fire department is to keep people, property, and the

environment safe from crises like fires. The fire department needs to satisfy public expectations by using the greatest technologies, procedures, and training methods in light of growing demands. The problems that fire departments face today have made risk management, readiness, and mitigation even more crucial. GIS technology is one new tool that the fire department is using to enhance the delivery of emergency services. The primary element lowering the degree of danger in this case is location. The location of the fire incident and the fire response stations are the two main determinants.

1.7 Limitations of the Study

In the study there were some limitations some of which are listed:

- The Addis Ababa Fire and Emergency Prevention and Control Agency did not easily provide data in a way that was suitable with space. This made it challenging for the study to locate and gather the coordinates of fire incidence locations.
- There was not enough quality data available, and cleaning the data required a lot effort.
- The study's inability to gather data at the specified period due to unsafe conditions during security season during GPS data collection for the fire occurrence location resulted in significant time and resource wastage.

1.8 organization of the study

This research has divided into six chapters:

The overall introduction about the study has found in chapter one.it gives a general overview of fire incident as well as information about how fire emergency response done in the study area, identification of the problems, the goal of the study, the scope of the study, limitation of the study and the significant of the study has been discussed in the first.

Chapter two describes the reviews of the related literature to the topic which is about fire emergency response and it provides brief definition of fire emergency and discusses several response techniques the using real world examples. The third chapter explains the methodologies of the study as well as the materials use. The way of data collection techniques and methods of data preparation has been discusses. following this, the fourth chapter has contain the results and The fifth chapter has contain the discussions of the study and finally the sixth and the last chapter contain the conclusions and recommendations of the study.

CHAPTER TWO

LETRATURE REVIEW

In this section the study reviews the previous literature related with the present study of GIS Based fire emergency response for locating fire event and emergency response stations are reviewed and presented under the following sections in addition to this some standard practiced across world has been reviewed.

2.1 Historical Background

The employment of various maps, reports, historical record, and tables has been necessary in conventional fire department planning techniques Johnson (2011). The paperwork associated with these techniques has filled numerous filing drawers and desk tops in offices. However, the introduction of computers has helped reduce the volume of paper. The advancement of technology has had a significant impact on the history of the fire department. In the past, fire stations used to accommodate both motorized and horse-drawn apparatus in close proximity to each other Coleman (2010). Firefighters have historically relied on expertise, quality equipment, communication, and collaboration to effectively respond to emergencies ESRI (2010). With the growth in population and building construction, the job of the fire service has become more complex and challenging ESRI (2010).

The location and geographical distribution of fire stations are taken into major account while analyzing travel lengths and emergency call response times. In the past, a fire engine equipped with a stopwatch was used to drive through an area and record trip times over the street network to assess the coverage of the region Johnson (2011). A 2009 report states that "public fire protection accounts for up to 20% of local government expenditures" Mirchandani (2009). Despite changes in the scope and complexity of fire department tasks, the current spending in Dallas remains consistent with this percentage. According to the annual fire service report for Dallas Fire Rescue Activity 2002–2003, the budget for Dallas Fire Rescue accounted for 19.9% of the total municipal budget Dallas (2009). The development of technology, the increasing responsibilities, and the refinement of techniques have played a direct role in shaping the modern fire department, which has been a crucial component of societies since ancient times Coleman (2010).

Geographic Information Systems (GIS) assist emergency responders in detecting, assessing, and deploying to incidents at a faster pace ESRI (2010). Nowadays, there is a significant exchange of geographic data among governments, which leads to cost reduction and an improvement in the overall quality of geographic data and information for public policy Baker (2008). Mutual aid agreements between cities allow local firefighters to optimize their resources. These agreements enable fire station employees and equipment to respond to alarms outside of their boundaries, as long as they are not needed within the city during a major crisis Snowden (2007). Response Time Modeling, using a fire station layer and a roadway layer, allows users to determine the station's location, set a trip time, and conduct network analysis ESRI (2010).

2.1.1 Globally

The incidence of fire has witnessed a significant increase on a global scale. In recent times, there has been a heightened focus on fire prediction due to the adverse impact of fires on human health and the environment, coupled with the shifting fire regimes. Each year, fire claims the lives of more than 300,000 individuals worldwide, with the majority of these incidents occurring within households Zhang (2006). The utilization of modern systems and information technologies simplifies the implementation of necessary precautions, thereby mitigating this issue. Notably, Geographic Information Systems (GIS) possess the capability to handle substantial amounts of data and promptly respond to spatial inquiries, making it a valuable tool for analyzing urban fire data Nisanci (2010). The likelihood of urban fire occurrences is heavily influenced by the level of urbanization within a given area Wang (2011). It is noteworthy that, for the first time in history, the number of people residing in cities surpassed half of the global population, reaching approximately 3.3 billion individuals by 2007 Khouri (2018).

Urbanization represents a worldwide phenomenon currently at its pinnacle. Presently, 54 percent of the global population resides in cities, with this figure projected to increase to 66 percent by 2050 according to the United Nations Department of Economic and Social Affairs UN DESA (2014). The growth in population makes fire incidents in urban areas more likely. The World Health Organization (WHO) report that burns resulting from fires contribute to over 300,000 deaths annually, accounting for more than 95% of all burn-related fatalities. These casualties predominantly occur in nations with low to moderate incomes. Building fires, which are primarily initiated by human activity, pose a significant threat to the safety of occupants. Large

residential complexes with numerous residents face particular challenges in terms of emergency evacuation, potentially leading to a rise in injuries or fatalities Shokouhi (2019).

2.1.2 Africa

The Fire Protection Association of South Africa (FPASA) compiles fire data from fire brigades across the nation; however, there are challenges encountered in the process, such as fires that are either incomplete or unreported Potts (2012). Consequently, their statistical records tend to underestimate the actual frequency of fire incidents. In 2016, FPASA reported a total of 41,873 fire callouts nationwide, which translates to an approximate average of 115 fires per day. From 2003 to 2016, there was an annual increase in the occurrence of fires ranging from 1.5% to 1.7%, along with a yearly rise in mortality rates ranging from 5% to 10%. Zimbabwe, situated in the southern region of Africa, is recognized as one of the country's most susceptible to fires Chinamatira (2016). Annually, these wildfires result in the destruction of over one million hectares of land.

The fire season in Zimbabwe spans from July to November, during which fires are prevalent. There are various factors contributing to the occurrence of wildfires. Chinamatira suggested that the recent surge in fire incidents may be linked to the relocation of smallholder farmers. Regrettably, the fires led to the destruction of numerous significant historical records, some of which dated back to Ghana's independence. At the beginning of 2015, the Central Medical Store of Ghana Health Service (CMSGHS) in Tema, which served as a storage facility for medical supplies destined for healthcare facilities nationwide, was completely ravaged by fire. The estimated value of the property lost between January and September of 2016 amounted to GHC 86 million. Ghana experiences substantial damages from fire incidents each year, resulting in the destruction of critical infrastructure and economic sectors. The total value of the damaged goods in Ghanaian dollars was 916,355 GHC between January and September of 2016. Towards the end of 2016, Ghana was struck by another significant fire outbreak, this time at the Ghana International Trade Fair Center, which tragically claimed the lives of six individuals Ibrahim (2016).

2.1.3 Ethiopia

Taking into consideration the data from Osuteye (2017), it is evident that there were a mere 159 reported fire catastrophe incidents in Ethiopian urban areas from 2010 to 2012. These fire incidents in Ethiopia can result in various hazards, which may arise from natural causes or human actions, as mentioned by the NDRMC (2016). Such hazards pose risks to individuals, objects, and the environment, and can potentially lead to severe consequences such as death, physical injuries, psychological distress, and substantial financial losses. For instance, between 2000 and 2016, Ethiopia witnessed a staggering number of 9,755 fires, resulting in 853 fatalities, over 5,421 non-fatal injuries, and economic losses worth more than 615 million birr due to property destruction. However, it is noteworthy that more recent incidents related to fire, traffic, and constructions have occurred in Ethiopia during the period of 2020/2021, which could potentially be attributed to the country's ongoing urbanization. These incidents have caused significant damage to properties and have resulted in fatalities. Reports of fire occurrences have been documented in numerous Ethiopian cities, including Addis Ababa, Gondar, Woliyta Soddo, Bahir Dar, Dire Dawa, among others, as indicated by Abuhay (2022).

2.1.4 Addis Ababa

The greatest concentration of industrial zones, such as kality is found in Addis Ababa. Furthermore, because of the presence of crowded business and residential areas and the growing population every day, more and more people are at risk of fire events. Utilizing a two-year report of fire event data which was obtained from AACFEPRA, the study classified incidents based on sub-cities and reported property losses totaling 517,617,474 (ETB). In addition to this, there were also fatalities and injuries.

Table 2.1 fire incident

Sub City Name	Fire Incident In 2022/2023	Property Damage(in birr)
Addis Ketema	43	34,320,000
Akaki-Kality	74	363,565,500
Arada	34	14,061,000
Bole	36	28,348,400
Gulele	40	5,123,000
Kolfe Keranyo	53	43,256,574
Lideta	9	615,000
Kirkos	31	5,212,000
Nifas Silke Lafto	43	12,396,000
Yeka	31	10,810,000
Total	394	**517,617,474**

2.2 Selection of Service Station Locations

With the advancement of modern software and computer technology, Geographic Information System (GIS) emerges as the most precise approach for the selection of service station locations. Unlike previous methods that relied on grid and concentric circle analysis, GIS accurately replicates the actual road network of the region under investigation Serra (2009). This accuracy is achieved through the incorporation of real trip distances, vehicle velocities, time delays caused by various road conditions (such as traffic congestion, turning radius, weather conditions, and inclines), consideration of one-way or unsuitable roads, and the application of user-defined risk factors. All of these factors contribute to ensuring a high level of precision. In the context of fire station planning, an extensive research based on GIS can be the foundation for a master plan of fire station sites. This master plan can serve as a blueprint for future fire station coverage, employing either the provided trip time criteria or alternative criteria. Moreover, it can also be used to evaluate the strengths and weaknesses of the existing fire station coverage in relation to the designated travel time.

2.3 Location Problems

The selection process for fire station placements in order to optimize efficiency is commonly known as a Covering issue. Each facility addresses demand within a specific proximity when dealing with such issues; this includes the application of distance requirements as examined in this investigation. Depending on the specific objectives, the Covering issue can assume various manifestations. While the primary objective of the Maximal fulfilling Location Problem (MCLP) is to utilize a limited number of facilities to meet the greatest amount of demand, the Set Covering Location Problem (SCLP) concentrates on satisfying all demand with the fewest possible facilities Serra (2009). Additional concerns related to location encompass several scenarios, such as the Maximum Available Location Problem Ball (2008), which seeks to account for "system congestion" or simultaneous calls to the same station.

2.4 Service Areas

The initial step in ascertaining the demand for studies such as this one, which take into consideration currently operational stations, is to evaluate the effective response area of each station. This assessment is often conducted by implementing limitations based on time or distance. Due to computational constraints Liu (2006) or unavailability of requisite network data, a majority of researchers have opted to employ a linear or Euclidean buffer for delineating the response region, as opposed to a network buffer Tong (2009). A comparative analysis between the two approaches revealed that Euclidean buffers tend to overestimate service areas Palomar's (2008), especially in rural settings characterized by a scarcity of stations or inadequate road networks. To address this issue, certain scholars have focused their attention on non-circular service domains. For example, Murray (2009) examined the Planar MCLP with continuous demand and irregular service regions, which were based on road networks. In the present study, the locations of fire stations were analyzed using the Set Coverage Location Problem (SCLM). This entailed determining the maximum distance or time from the existing station in order to gauge the number of demand points that could be covered by each potential facility site. These criteria will serve as the basis for selecting requests that meet the established standards, as well as those that do not. Subsequently, the Analytical Hierarchy Process (AHP) will be employed to select additional stations following the determination of the demand level.

2.5 Accessibility of Road Networks

The concept of accessibility was initially introduced by Hansen (2012), who provided a definition of it as the potential for interaction among various nodes within a transportation network. Subsequently, research and the planning, construction, and evaluation of road networks have heavily relied on the notion of accessibility. The assessment of accessibility within the road network has been identified as a significant concern within the transportation system. Nevertheless, a unified concept of accessibility has not yet emerged. In a general sense, accessibility pertains to the relative significance of a location in relation to another location, considering its fundamental extent and efficacy. Yang and Zhou posited that the degree of accessibility of a location determines its level of convenience for individuals to travel to. According to Yixing (2008), this degree may be influenced by factors such as trip distance, topological distance, spatial distance, journey duration, or transportation expenditures. Accessibility encompasses both temporal and geographical dimensions. Time represents the primary obstacle to accessibility, and it illustrates the level of convenience a location possesses as a spatial entity. In order to ascertain the path of least impedance within the network connecting two facilities, it becomes necessary to evaluate accessibility in this study, since it enables the determination of the level of impedance between the facilities and the demand locations.

2.6 Using GIS for emergency response

In the realm of emergency response management, the authors Sharma (2013) have developed a desktop-based Geographic Information System (GIS) specifically tailored for the city of Delhi, India. This system seamlessly integrates real-time traffic data with a comprehensive transportation network, thereby enabling efficient emergency management. Network analysis, including functions such as the Origin-Destination (OD) cost matrix, proximity analysis, and buffer analysis, among others, are executed within this GIS platform.In a separate study conducted by Hoyos (2015), the authors outline a systematic approach to emergency management, dividing the tasks into five distinct stages: preparation, mitigation, response, planning, and recovery. Of particular interest is the mitigation phase, which incorporates analytical modeling techniques to elucidate the geographical variations in risk, hazard, and vulnerability associated with emergencies. Furthermore, Nguyen (2006) emphasizes the

criticality of readiness in emergency situations. The author highlights the impact that adequate planning and implementation of fire emergency response databases can have on human lives and financial damages incurred in fire-affected regions. By effectively preparing for emergencies, lives can be saved and the extent of financial losses can be mitigated. Moving on, Hay (2019) presents a GIS-Based Fire Emergency Response System designed specifically for the Mandalay Road Network. The authors utilize the Dijkstra routing algorithm to construct this system, which aims to optimize emergency response in the event of a fire. However, the authors caution that if this system is not meticulously planned and executed in a timely manner, the consequences can be dire, potentially resulting in loss of human life. Additionally, the article delves into the significance of identifying the nearest fire stations and emergency services to an accident scene, taking into account the prevailing traffic circumstances. Another notable contribution to the field of emergency response management is the upgraded GIS-based network study conducted by Sayed (2017) on the Greater Cairo Road network.

Through the utilization of historical traffic data, this study explores the optimal route between two locations on the road network and identifies the healthcare providers that are in closest proximity to incident locations, based on response travel time. The findings of this study reveal a notable improvement in journey time, ranging from 20% to 22%, depending on the length of the trip. However, it is important to note that this method does not account for other potential factors that may lead to delays while utilizing the road network.

2.7 Fire response time

Fire stations must be strategically positioned in order to minimize the time it takes for fire trucks to reach fire scenes, even if it is crucial that their placement is optimized to ensure sufficient coverage Liu (2006). The response time of a fire department refers to the duration between the moment the department receives a call and the arrival of a fire truck at the specified location Flynn (2009). Swift reaction times are of utmost importance in combating fires. Given the changes in land use and urbanization, it is imperative to conduct a cost-benefit analysis of the spatial distribution of fire stations and fire risk. Geographic Information Systems (GIS) are being utilized to address and support these issues due to their inclusion of a geographical component Landré (2008). The National Fire Protection Association (NFPA) 1710 mandates that countries respond to fire incidents within eight minutes or less, excluding call-processing time periods.

This standard establishes significant benchmarks for 90% of events. In terms of the fire department, the baseline is the total response time, which encompasses the duration from the moment a call is received at the public safety answering point to the arrival of the first unit at the incident location. It is essential to monitor and report effective response times and the presence of all necessary units.

2.8 Network analysis with ArcGIS

An extension of ArcGIS, known as ArcGIS Network Analysis, facilitates the spatial examination of a network, encompassing the routing between nodes, the establishment and distribution of facilities, and the definition of service areas, among other capabilities. The utilization of the actual state of the road network, which includes factors such as direction, speed limitations, and obstructions of various kinds, represents a significant advancement in the tools provided. Turn restrictions, speed limitations, high constraints, and traffic conditions are just a few examples of the authentic network circumstances that users can dynamically simulate at different times of the day using the ArcGIS network analysis tool Kumar (2016). Three works by authors Badri (2016); Ali (2010); Zhang (2005) present a common-sense perspective on ArcGIS network analysis. It employs Dijkstra's algorithm to compute the least accumulated cost between the destination node and all other nodes. The evaluation of this algorithm is also provided.

2.9 The use of GIS in responding to fires

Research on the use of GIS in fire station placement selection was also conducted by Yang (2004). The author of Jasso (2009) has located fires from 911 emergency calls whose locations could not be reliably determined. In the shortest period of time, GIS helps locate fires or accidents by comparing coordinate information with address information. The research indicates that for the past ten years, the fire service has used GIS more and more Corcoran (2007). GIS technology is now a potent tool for enhancing fire service delivery systems in every way. Effective response necessitates careful planning, risk management, thorough training, and strategic deployment via preparedness given the numerous obstacles that emergency responders face today ESRI (2006).

CHAPTER THREE
MATERIAL AND METHODS

3.1 Description of the Study Area

Geographically, Addis Ababa is found in the center of the country, in the UTC + 3 (East Africa Time) time zone, between 9°2' N latitude and 38° 45' E longitudes. A total of 519.458 km^2 is its area. The city has an average population density of 7,430 persons per km^2, with an annual population growth rate of 2.3%, and is bordered by a mountainous region.

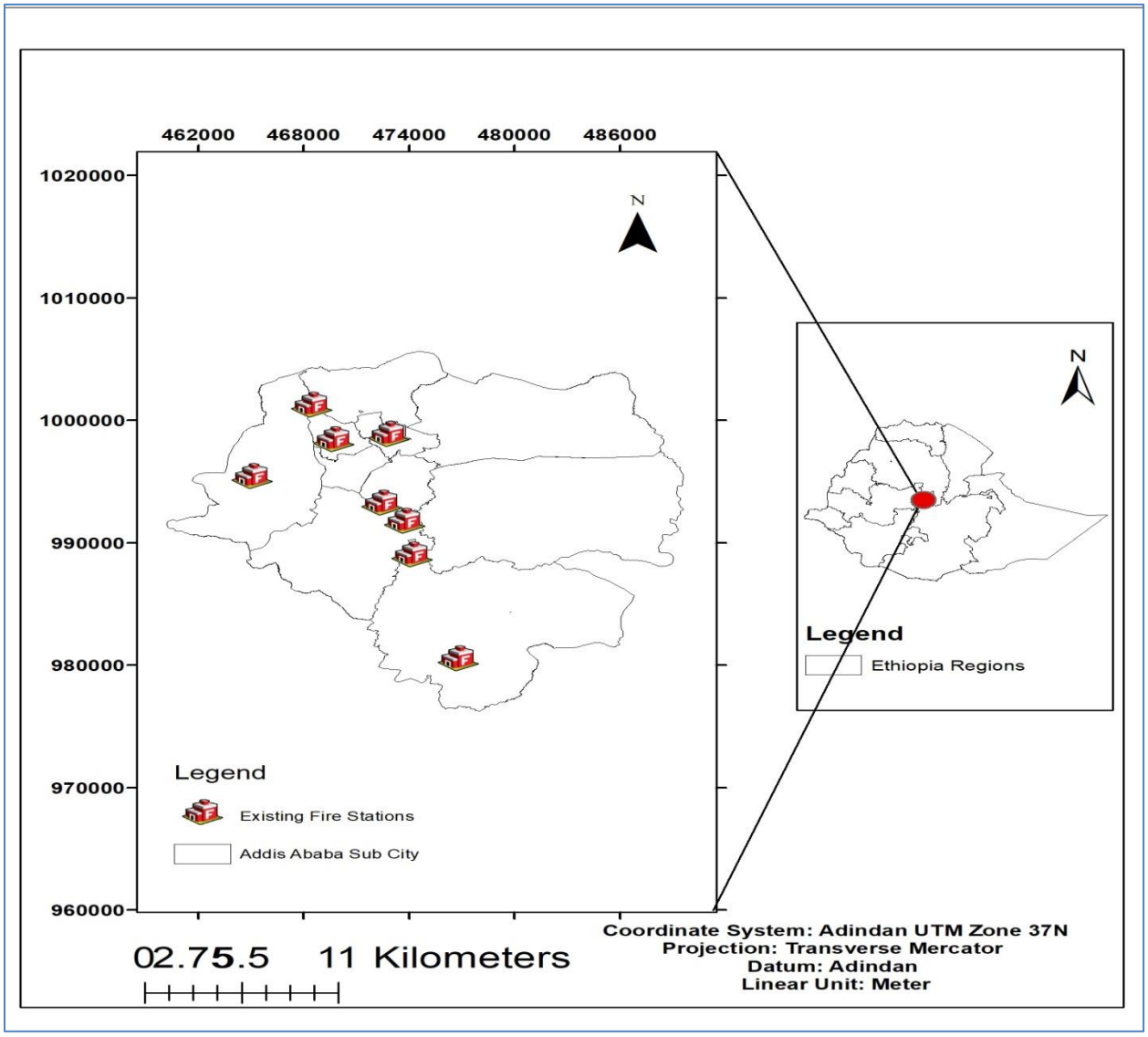


Figure 3. 1 Location map of the study area

3. 2 Land use

One of the main factors taken into consideration while choosing possible locations for Addis Ababa City's fire response is a land use map. The land usage map was gathered from the 2013 E.C. development commission and the Addis Ababa municipal government plan. The following table shows the proportion and area coverage of each form of land use.

Table 3-1 land use

No	Land use type	Area (sq.km)	Area (%)
1	Administrative Services	7.4	1.42
2	Commerce and Business	7.6	1.46
3	Environmental protection	156.24	30.03
4	Historical Building and Site	0.18	0.03
5	Utility and Infrastructure Service	6.27	1.21
6	Manufacturing & Storage	6.15	1.18
7	Mixed Residence	220.51	42.38
8	Municipal Service	28.66	5.51
9	Social Service	14.17	2.72
10	Special Project	7.57	1.45
11	Street network	36.87	7.08
12	Transport	11.49	2.22
13	Urban Agriculture	9.99	1.92
14	Religious Institution	3.69	0.71
15	Special Use	3.31	0.64
16	Sport Field	0.19	0.04
Sum		**520.29**	**100**

The data collected in 2013 E.C. is used to analyze the land use map of Addis Ababa. Out of the various uses, sixteen significant land use types have been mapped in an ArcGIS. Based on

various reviews, the land use analysis of the study area helps us identify which areas are more likely to experience fires, and fire response activity is not that simple. As shown in the above table, mixed residences make up the largest portion of the study area, covering an area of 220. 5km^2 (42.38%). However, historical buildings and sites account for the lowest portion of the city's land use, with 0.18 km^2 (0.03%).

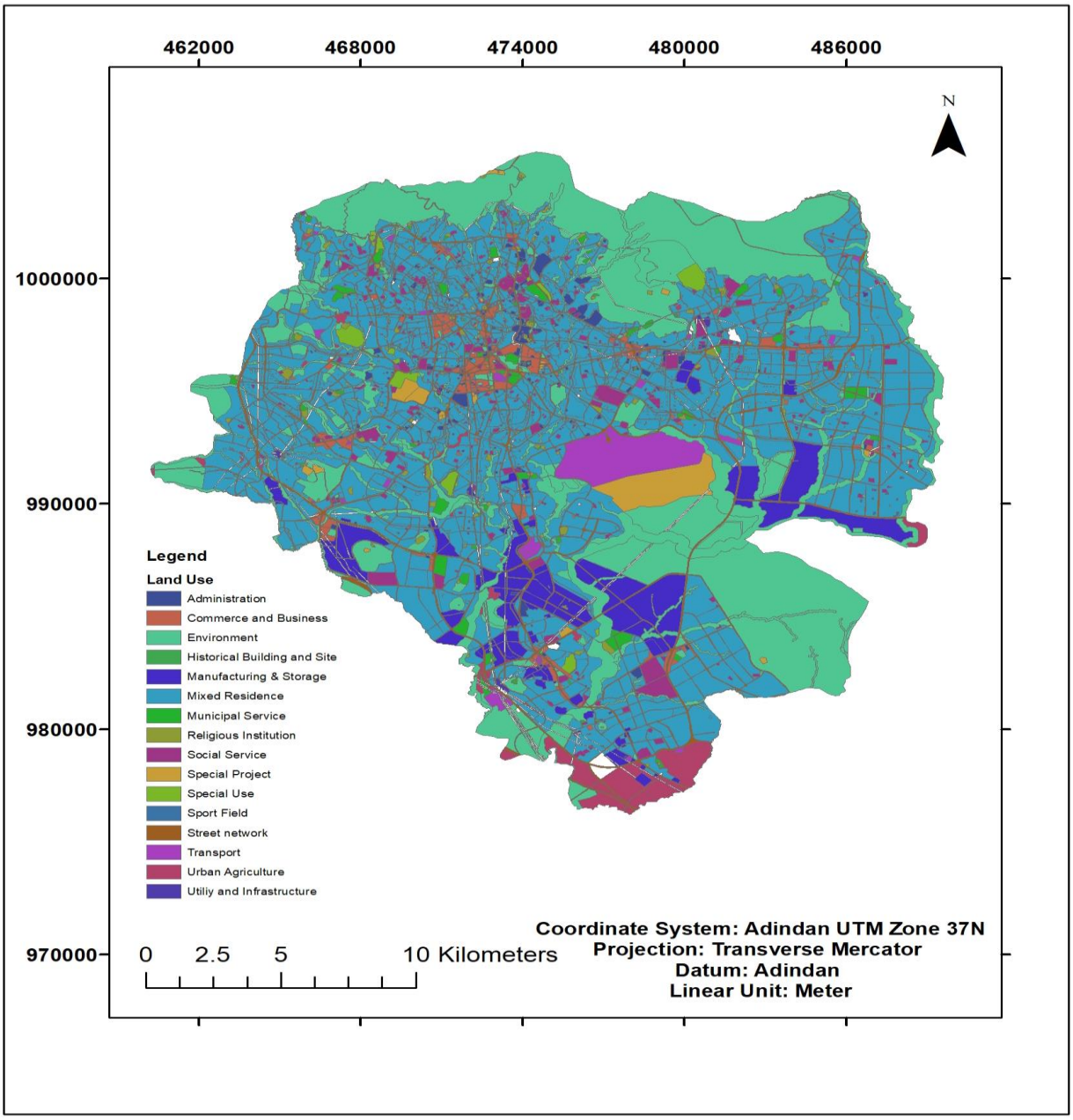


Figure 3. 2 Land use pattern of Addis Ababa

3. 3 Population

The Central Statistical Agency of Ethiopia performed a population census in 2007, and the results show that 2,739,551 people call Addis Ababa home overall, including those living in the city and the countryside. The capital city's 628,984 dwelling units had 662,728 households, or an average of 5.3 persons per family. In conjunction with this, the population of Addis Ababa city is growing yearly as a result of a significant rise in migration brought on by social and economic issues. The population is projected to reach 3,859,999 based on the CSA census of 2023, with 1,822,000 men and 2,037,999 females, with an annual population growth rate of 2.3%.

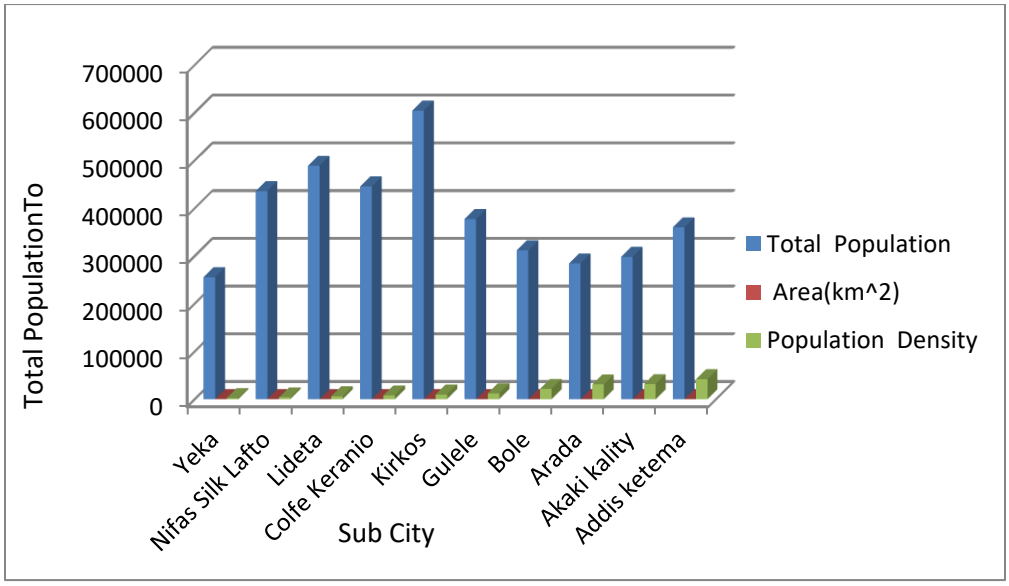


Figure 3. 3 Population census of Addis Ababa city in year 2023

3.4 Rain Fall

The climate in Addis Ababa is subtropical highland with consistent moderate rainfall, with lowest and maximum amounts occurring in July and August. The driest months are February, May, and December. These are the months without rain. With an average of 432.7 mm, July has the highest amount of precipitation, with around 33.9% of that quantity expected to be rain.

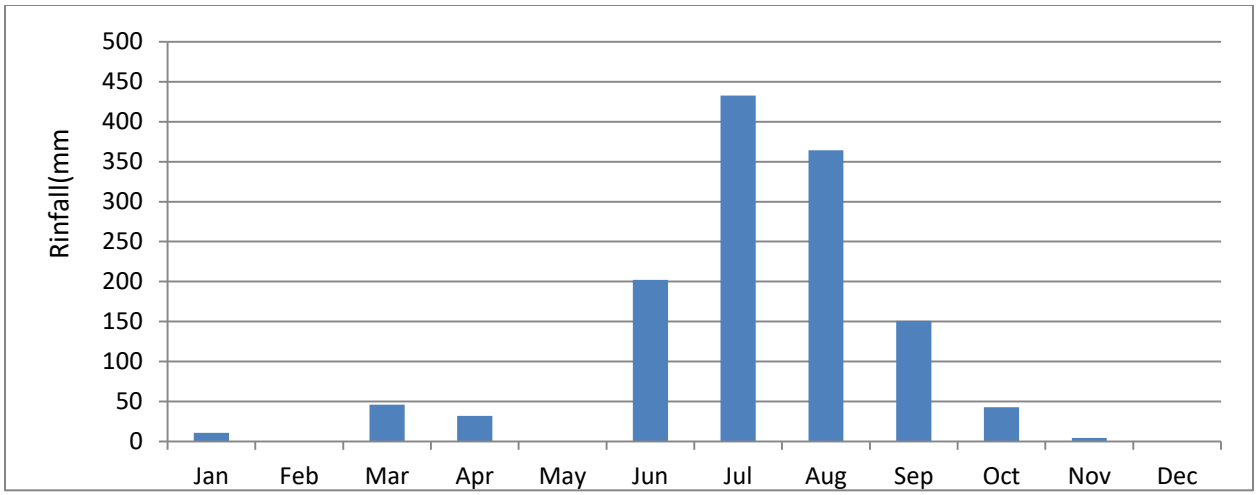


Figure 3. 4 Average monthly rainfalls in the study area (2022)

3. 5 Study area boundary

There were 10 sub-cities under the Addis Ababa municipal administration. As of right moment, Addis Ababa has eleven sub-cities in total due to the addition of Lemi Kura by the municipal government. This Sub City's lines are drawn from those of the Yeka and Bole Sub Cities. As shown in the table below, the boundaries of the research area was obtained in Esri file format from the Addis Ababa City Land Registration and Information Agency.

Table 3.2 Data and data source

Data Set	**Data Source**	**Format**	**Data Purpose**
Study Area Boundary	Addis Ababa City Land Development Management Office	.shp	For defining the study location
Parcel Map of Addis Ababa	Addis Ababa City Land Registrations &Information Agency	.shp	Link with existing fire emergency station
Population data	Central Statistics Agency	.pdf	To show population Density Map
Land Use map of Addis Ababa	Addis Ababa city government plan and development commission	.shp	Generate land use classification
Existing Fire Stations	https://www.addismap.com/fire stations	Easting & Northing	Link with parcel For fire emergency response
Fire Incident information	AACFEPRA	Excel format	Link with fire emergency response station

3.2 Data Source and procedure

3.2.1 Data source

Several data were employed to address the study's purpose. Visits to various agencies, including governmental and private consulting offices in Addis Ababa, yielded all of the source data for this study. Secondary data: The Addis Ababa Plan Office, the Addis Ababa Urban Land Registration and Information Agency, and the Addis Ababa City Fire and Emergency Prevention and Rescue Agency provided the geospatial data for this thesis. These include the Addis Ababa City land registration and information agency parcel and the fire emergency response station. Shape files are used to store all data.

3.2.2 Data Collection and Preparation

The study area map, various data in shape file format, road data from the Addis Ababa City Planning Office, Addis Ababa City Fire Emergency Response Station data obtained from Google Maps, and parcel data from the city's land registration and information agency are all collected during this phase.

3.2.3 Data Processing

The data processing step is crucial after data collection and preparation since it is one of the procedures for converting raw data into a format that is more appropriate for additional analysis and easier for the user to understand. The primary and secondary data for this study were gathered and stored in Excel. A shape file format was imported into the post-GIS shape file format (shp).

3.2.4 Primary Data

The main source of information for the input data for the fire risk location is the direct collection of fire event spatial location using a mobile GPS device with a 3 meter horizontal precision level. Because of this, the majority of the primary information utilized in the development of this study is the locations of fire incidents. Stakeholders also participate in an oral interview.

3.2.5 Fire incidents locations

Primary fire incidence data was used in this investigation, and attribute information was obtained. Excel sheet type is used to hold the Addis Ababa Fire and Emergency Prevention and Rescue Agency (AACFEPRA) report for 2022–2023. Names of the sub-cities, special names, district, kind of accident, time and date of the incident, and amount of property losses were all included in this. We gathered 30 fire incident sample field data on the locations of fire incidents based on this information and put it into the Arc Map.

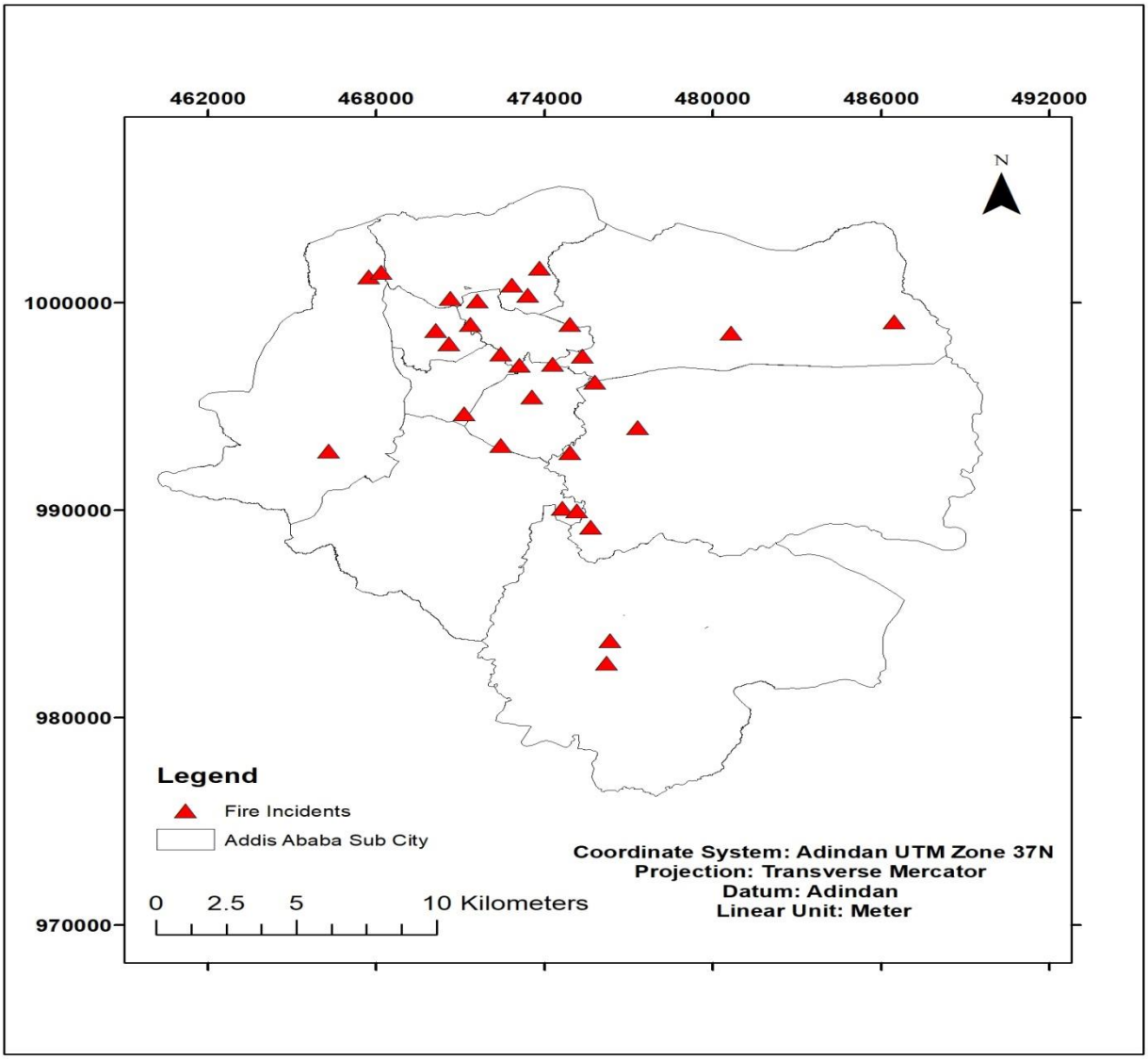


Figure 3. 5 Incidents locations map

3.2.6 Secondary data

The additional sources of data, which were gathered from a variety of sources, including institutions, records of organizations, and individual professionals, were crucial to producing the intended outcome of this investigation. The locations of the current fire stations, land use, study area borders, and demographic statistics were the most often used secondary data for this investigation. To completely comprehend and resolve the study topic at hand, in addition to this official report, books, journal articles, and online resources were also consulted.

3.2.7 Existing Fire Response Station Locations

Google Maps was used to obtain the precise geographic locations of every fire station that currently exists. The Addis Ketema Sub City Fire Response Station, Nefas Silk Lafto Sub City Fire Response Station, Kirkos Sub City Fire Response Station, Akaka Kiltie Fire Response Station, Bethel Fire Response Station, Tigist Fire Fighting Equipment, Addis Ababa Fire Stations Headquarters, Gulele Sub City Fire Response Station, Addis Ababa Fire Emergency Management Authority, and Arada Fire Response Station are the ten fire stations that the Addis Ababa City currently operates as of 2022–2023.

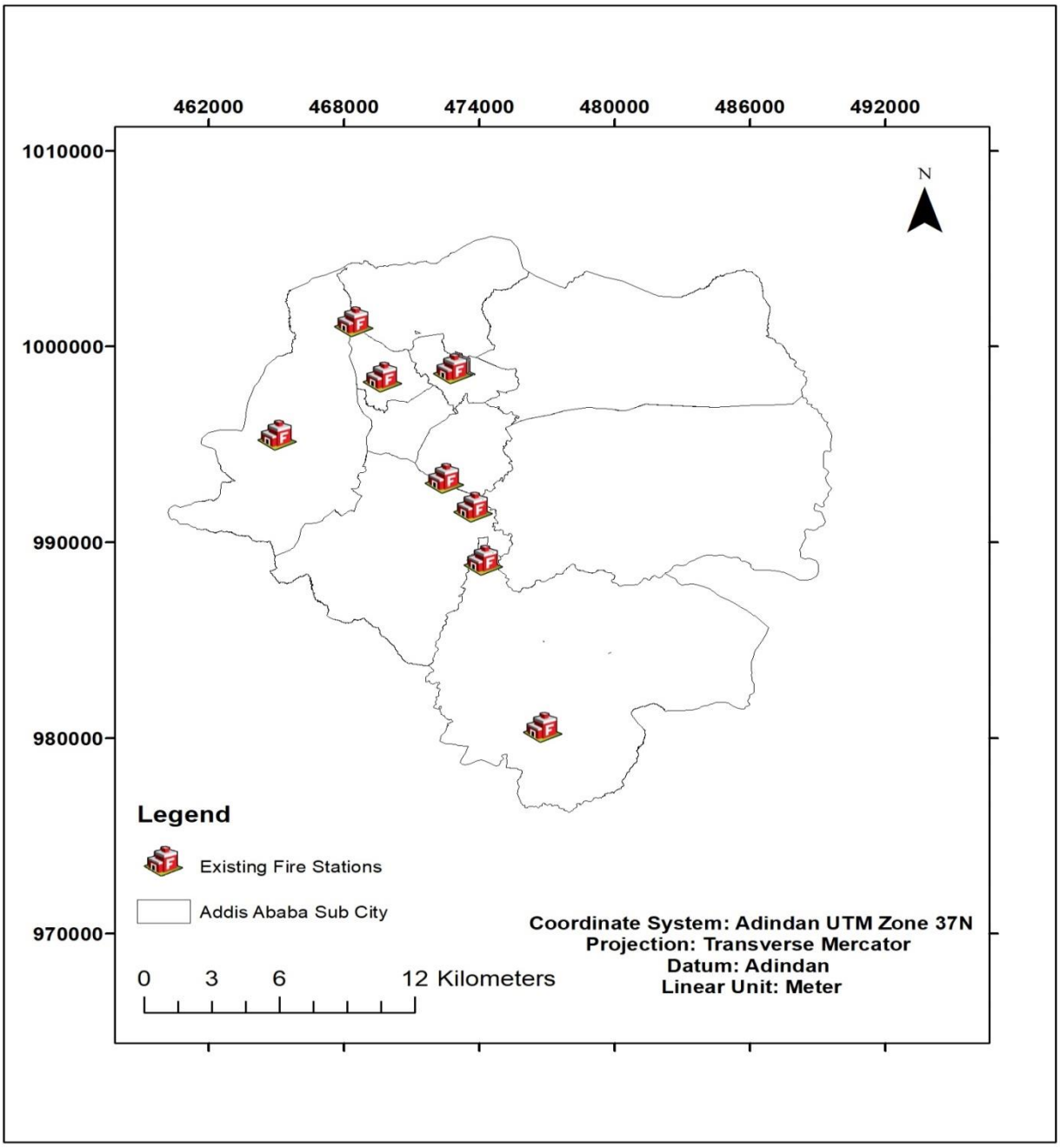


Figure 3. 6 existing fire response station location maps

3.3 Software and instrument used

Some of the tools and resources utilized in this study's further data analysis are the tools and resources used in data processing and collecting.

Table 3.3 software use

Type	**Purpose**
Arc GIS	data preparing
MS-Office excel 2010	to complete the analysis and produce the research text
a mobile GPS	Gather the fire incidents' X and Y coordinates.
Postgresql	creating data base
PostGIS	importing data
Geo server	link data base to the internet
visual studio code	Geo-coding Java script
tomcat apache	To call the Geo server

3.3.1 Creation of Geo data base

The basic data format and native data structure used in Postgresql is called a geo-database. Utilized for data administration as well as editing. It offers the basic data structure needed for data management and modification. It has the ability to organize, query, and store data, both geographic and non-spatial. Parcel data and current fire stations are handled by it.

3.3.2 Importing data

Importing the data on post-GIS from the created data base at postgresql. Creating geo databases on Postgresql, such as parcels and fire response stations.

3.3.3 Add data into the Geo server

Adding data on the Geo server that is importing the data on post-GIS from the created data base At Postgresql, adding this data to the Geo server means exploring the data on Tomcat Apache to access the map.

3.3.4 Geo coding

The process of encoding a place name or address into geographic coordinates (latitude and longitude) is known as geocoding. It allows for the identification of a fire emergency location and a fire emergency response station at a specific point on the Addis Ababa parcel surface based on its parcel ID address. Geocoding is the process of using the code used in mapping applications and services to display accurate locations on a map.

3.3.5 Location Allocation analysis

In order to achieve coverage over the whole issue region, the fire response station's optimal risk position was identified using geocoding location allocation. In order to determine fire risk sites and assign locations to them, this approach was used in the study (distance calculation at vs. code).

3.3.6 Calculating distance

From the existing fire response station to the fire risk location. The way of calculating distance Simple mathematical calculation of distance from geographical coordinate base

$[(XE - XS)^2 + (YE - YS)^2] = D^2$

D stands for distance from the emergency to the fire response station, where

XE stands for the geographical coordinate of emergency.

XS stands for the geographical coordinates of the emergency response station.

YE stand for the geographical coordinate of emergency.

YS stand for the geographical coordinate of the emergency response station.

Select the nearest emergency response station with fire incidence; in geocoding vs. coding, the 10 existing fire response stations in Addis Ababa are assigned by coding integrated with each other's to respond to the fire risk by calculating distance and analyzing the shortest distance from emergency response to fire risk, the distance calculating based on geographical coordinates, and selecting the nearest one among the ten existing fire response stations. First, identify the risk location, search the risk location by parcel ID, calculate the distance from the fire risk to the whole ten existing fire response stations, and then select the nearest existing fire response station among the ten. Based on this information, the fire response agency will properly respond to the fire risk.

3.4 Methodology

The study employed an integrated approach to fire response station with fire incidence location using GIS software. The process began with the collection and preparation of primary and secondary data for model development. Subsequently, the data was processed and subjected to further analysis. The geographical coordinates (x, y) of the parcel were then geocoded. Additionally, ten existing fire response stations in Addis Ababa City were geocoded the fire incident data was prepared in the visual studio code (vs code) and the study area was prepared in the Geo-database using Postgresql, both of which are freely available software that stores the prepared data and fire emergency incident data. The first step involved the development of a model for identifying emergency locations and calculating the distance from the fire emergency to the nearest fire response station. This enabled the selection of the appropriate fire response station based on the shortest linear distance. The entire process encompassed all fire response stations within Addis Ababa City and expressed the distance in meters from the fire incident to the fire emergency response station, along with the name of the selected fire response station. Furthermore, the fire emergency data was updated or loaded from the database.

Subsequently, the fire incidence was searched using the parcel identification number and integrated with the fire response station by using the GIS base station developed model for fire emergency response. This model was based on the geographic location of the (x, y) coordinates and facilitated the search for fire incidents using the unique parcel identification number of the Addis Ababa City parcel. The results were then displayed using web GIS. The final application of the developed model involved the interaction of spatial database with fire emergency response for fire incidents and existing fire response stations.

The main objective of this study was to simplify the complex and manual fire emergency response system in Addis Ababa City by implementing a GIS-based digital database system. The data holding and management activities are straightforward to access, and the quality of the fire emergency database is deemed sufficient. The following section provides a detailed description of the methodology steps.

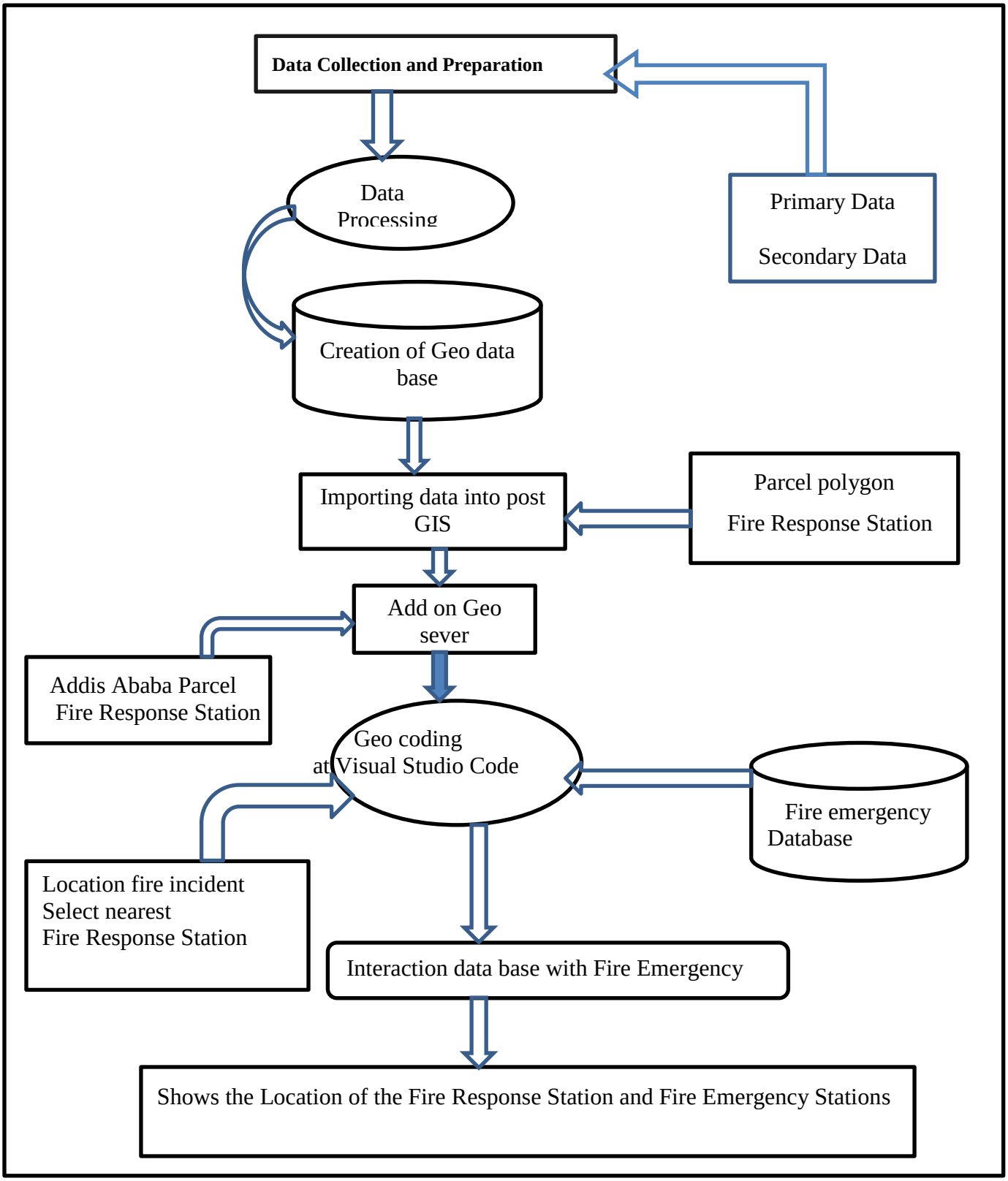


Figure 3. 7 methodology work flow

CHAPTER FOUR

RESULT

4.1 Geo code Fire Response Station and Parcel

The emergency service provider acquires incident information from the Client about the parcel ID, and then proceeds to identify the precise geographic location of the fire incident through the use of the GIS base fire response developed model on a local browser's web map. Simultaneously, the provider selects one fire response station out of the entire collection of Addis Ababa fire response stations, based on the shortest linear distance between the fire response station and the fire incident. In most cases, geographic information systems (GIS) represent these features using geographical location of x and y coordinates. However, although these systems work well for preserving elements with fixed characteristics, the GIS-based fire emergency response models have implemented one-dimensional linear referencing systems to show fire incident and fire response station on web GIS. The need to visually depict features on a map whose coordinates are based on a geographic map, by calculating the distance from the station to the incident using the x-y coordinates, results in a relatively short distance when compared to the other 10 fire response stations.

4.1.1 Geo-Code Parcel

Geo code the Addis Ababa City parcel at visual studio code for a parcel base map that talks about the parcel geographical x y coordinate and its attribute of parcel ID with an integrated existed fire emergency response station based on coordinate.

4.1.2 Geo Code Existed Fire Station

Geo code existed fire response stations was developed at visual studio code the whole Addis Ababa has ten fire response stations taking the geographical location of x y coordinate to syntax at vs code and integrated with Addis Ababa parcel base map geographical location of x y coordinate with its attribute parcel ID.

4.1.3 Geo Code Calculate Distance

Show the fire emergency response station that is closest to the incident, out of the ten currently operational fire stations. The fire response station and the fire incident x y coordinates are used to determine the distance between them. Estimating the distance, comparing the ten fire response stations closest to the fire incident geographic location based on x y coordinates, filtering the shortest distance, and displaying the name of the fire response station closest to the incident along with its distance in meters.

4.1.4 Geo Code the Line from Station to Incident

The line that shows from the existed fire risk location to the fire emergency response station clearly shows where the fire incident and where the fire emergency response station. The line indicates the location of the incident and response station, as well as the geographical location of the fire emergency station and the fire incident address.

4.2.1 Develop Fire emergency Database

The database was developed at visual studio code that emergency information comes from the incident location. At the incident, when calling the fire incident station at 939 for Fire Emergency Station, the operator talks about the incident parcel ID and, based on this parcel ID, finds the location of the fire risk and fire response station on the web GIS. The Developed fire emergency database model collects information from the incident and enter data entry boxes such as user name, sub-city, wereda and phone number, house number, saved property, and damaged properties that are updating this information in the developed database.

Figure 4.1 Data entry plate form

4.2.2 Get Station box on Web GIS Display

At get station box load the fire incident ID number on the get station box to locate for the geographical location of the incident and the nearest fire response station among the ten fire response stations based on x y coordinates, calculating the distance and shows, filtered the shortest fire response station.

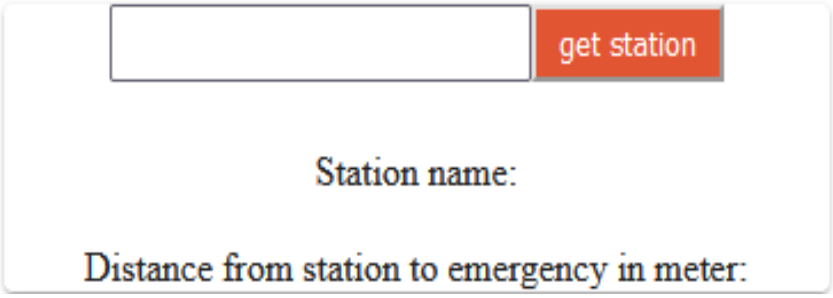


Figure 4. 2 Get station

4. 2.3 Update Data into the Fire Emergency Database

To update means to make changes or modifications to the new data in order to bring it up to date or improve current information. In this database, updating involves making changes to the data stored within the database to store the new data that has loaded the data entry plate form, then pressing update, which means save the updated data or storing in the database at Postgresql.

It is important to note that updating a database should be done carefully and properly to avoid data loss or corruption.

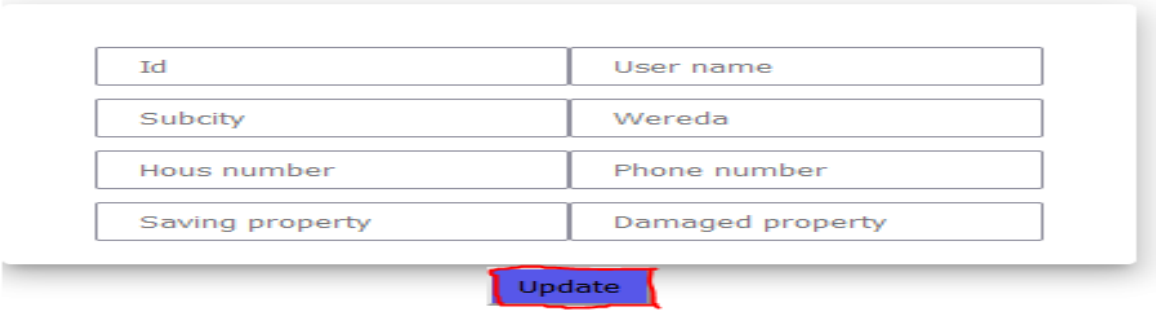
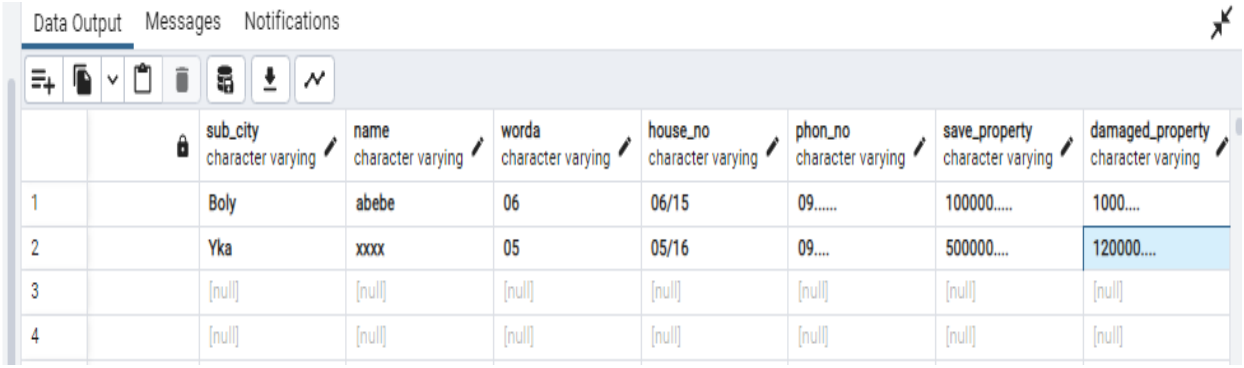


Figure 4. 3 Updating

4.2.4 PG admin Database

In Postgresql data base, the data refers to fire risk information that is relevant to within an organization. This can include data about risk holding, parcel ID, Sub City, woreda, user name, phone number, house number, saved property, and damaged property. This is relevant information that is used to make decisions and manage the risk. This data is crucial for organizations to analyze and make decisions about their fire risk problems.


Data Output Messages Notifications

	sub_city character varying	name character varying	worda character varying	house_no character varying	phon_no character varying	save_property character varying	damaged_property character varying
1	Boly	abebe	06	06/15	09.....	100000.....	1000....
2	Yka	xxxx	05	05/16	09....	500000....	120000....
3	[null]	[null]	[null]	[null]	[null]	[null]	[null]
4	[null]	[null]	[null]	[null]	[null]	[null]	[null]

Figure 4. 4 sample fire incident information at PG admin

4.3.1 Integrate spatial database for emergency response

The interaction of the developed fire emergency database with the fire emergency response model that is to integrate the database with the model to explore the developed fire emergency model on web GIS.

4.3.2 Database connection with web GIS

Geo code the database used to connect the database 'fire_emeregency_response' with web GIS.

```
const express = require('express')

const { Client } = require('pg')

const dataBase = new Client({
   user: 'postgres',
   host: 'localhost',
   database: 'fire_emeregency_response',
   password: '1221',
   port: 5432,
  })
```

4.3.3 connect Server with web GIS

Geo code the geo-server mainly to connect the geo-server link with web GIS that is, to explore the map on the web GIS.

```
<WMSTileLayer
        url="http://localhost:8080/geoserver/fire_emeregency_response/wms?"
        version="2.20.1"
        opacity={5}
        transparent
        layers={"fire_emeregency_response:parcel"}
        srs="EPSG:20137"
       />
```

4.3.4 Web GIS

The geocoding process culminates in the presentation of results on a Web GIS platform rather than the code responsible for manipulating the information. This manipulation occurs within the web GIS application, specifically concerning to the geo-coding of data in the VS Code. The data in question pertains to the fire emergency response, which is stored in the web GIS database. The database contains information on the ten existed fire response stations of the AACFEPRA, as well as the cadastral base map of parcels in Addis Ababa, including attributes such as parcel- ID. The web GIS interface displays a window in the top right corner where users can input the parcel ID and retrieve the nearest fire response station to a given incident. This page not only shows the closest fire response station, but also provides the linear distance between the fire station and the fire incident. This distance is calculated based on the geographical coordinates (x and y) of the ten existing fire response stations relative to the incident. Additionally, the web GIS interface features a data entry table in the bottom right corner, containing various fields such as parcel ID, user name, Sub City name, Wereda, Phone Number, save property, and damaged property. This table allows for data updates by loading information into the postgreSQL database. Finally, users can zoom in and out on the displayed Addis Ababa parcel base map within the web GIS interface.

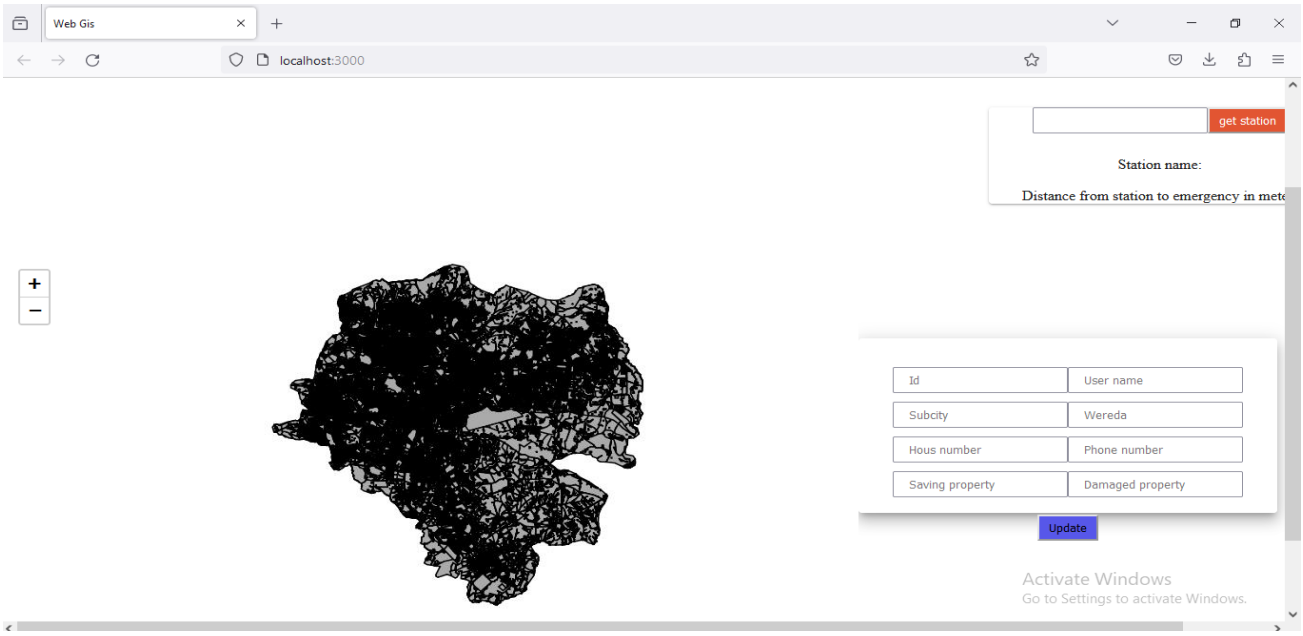


Figure 4. 5 Web map

4.4 Shows fire incident location with corresponding closest fire response station

By developing a model using GIS-based fire emergency response, one can perform all types of simplified methods, like finding the location of a fire incident and finding the closest fire emergency response station to the incident based on geographical distance. Finding the location of a fire incident refers to identifying the specific place where the incident has occurred. In this developed model, the concept of location holds significant importance and is generally regarded as more precise than the notion of place. Information regarding a fire emergency is obtained through a phone call made to the Addis Ababa City Fire Emergency Agency at the designated number 939. The operator receiving the call from the fire emergency user collects relevant details, such as the incident's parcel identification number. Subsequently, the operator at the fire response station takes the incident's parcel identification number provided by the fire incident caller at 939. The fire response station's database manipulator then find for fire incidents based on the parcel identification number, utilizing the developed model of the GIS at the web GIS display of the fire response station.

To inputting the sample parcel identification number AA000051306082 into the designated field and retrieving the corresponding information, the output is displayed as follows. The web GIS visually presents the exact location of the fire incident concerning the fire response station, including the direction from which the incident originated. In the case of parcel identification number AA000051306082, the fire response station nearest to this particular incident is located in Arada. This station is considered the closest among the ten existing fire response stations.

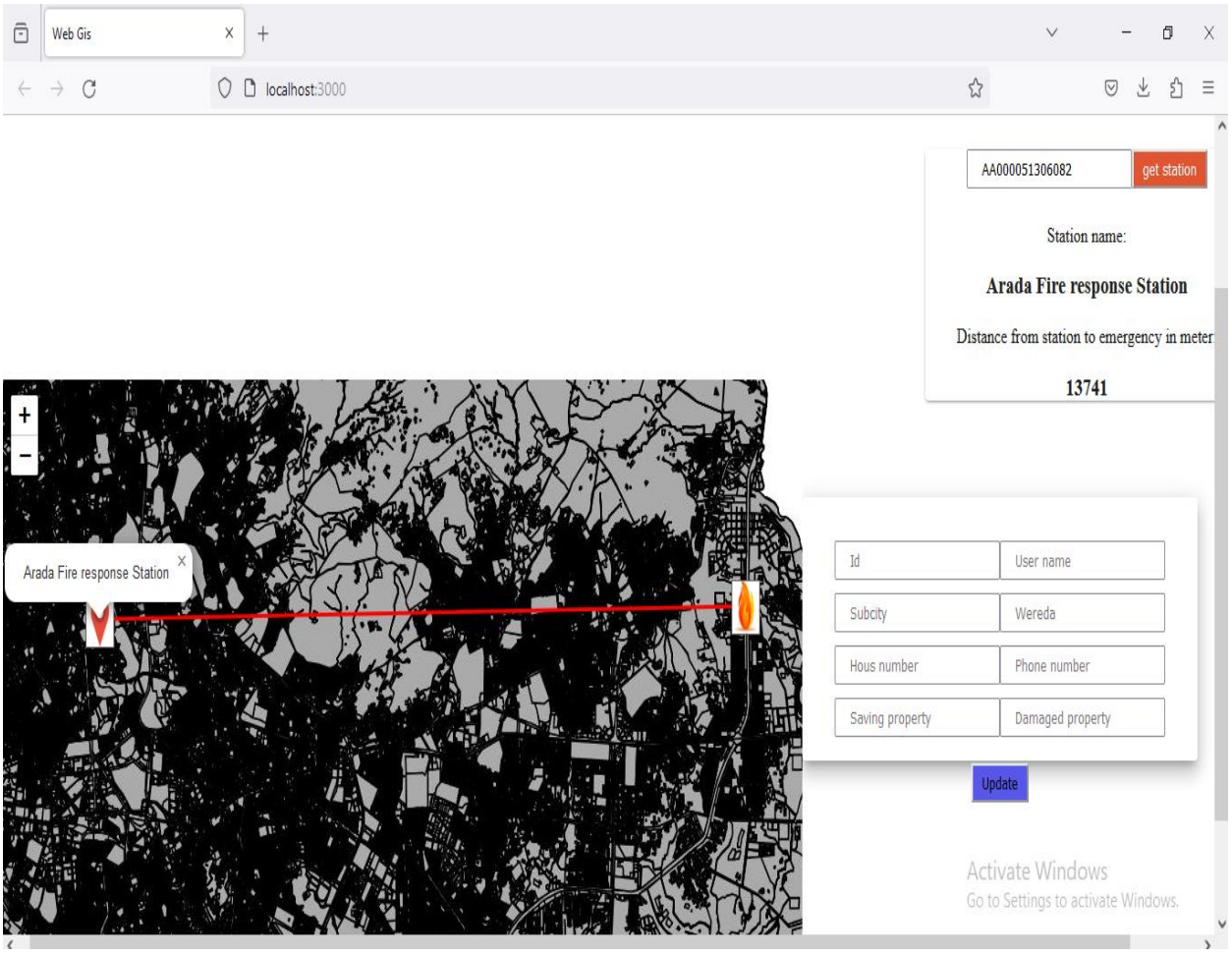


Figure 4. 6 Arada station to incident

Taking samples of fire incident standing from incident parcel ID AA000010400419 and searching this parcel id from get station boxes, the output is shown below.

The fire response station is Addis Ababa Fire emergency management authority is nearest to a fire incident based on the developed model. The distance from the fire incident to the fire response station is given in the web GIS display as 1576 meters. Fire incident parcel IDAA000010400419 is nearest to Addis Ababa fire and emergency management authority to compare and display the fire response station and incident location to select the developed model of GIS base fire response station from other fire response stations. The model also shows the direction of the fire event location from the fire response station.

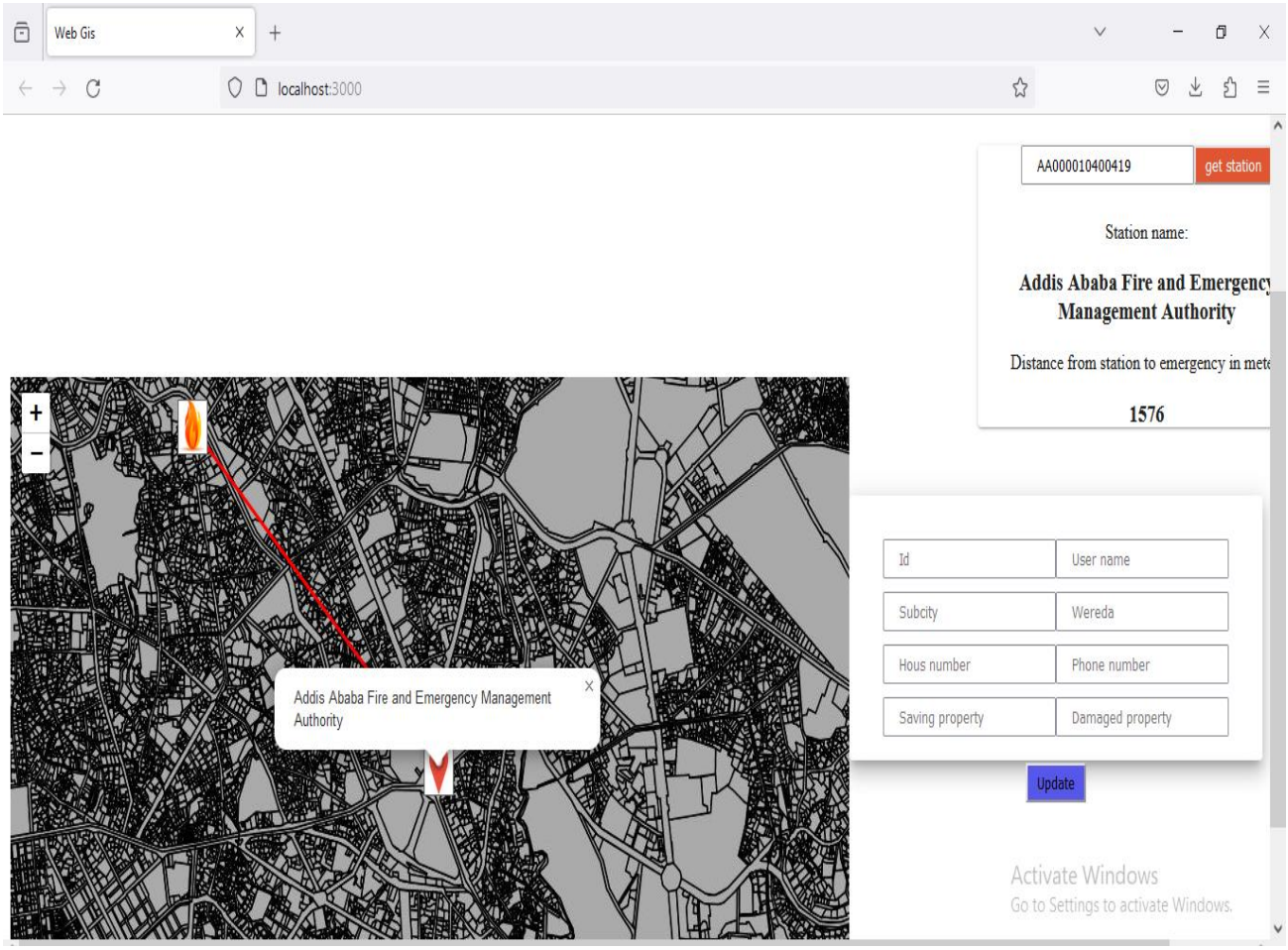


Figure 4. 8 Addis Ababa fire management Authority to incident

The developed GIS-based fire emergency response model for displaying fire occur and fire response station location, direction of fire incident from the fire response station, and distance between fire incidents and the fire response station is 539 m. It is the shortest distance from all the fire response station locations. Standing sample fire incident parcel ID AA00020901506 and entering get station box to search this parcel id from the developed fire response model, the output shows to respond to this parcel incident ID AA00020901506 is Adis Ketma fire response station to respond to this incident nearest to the incident from the other fire response station.

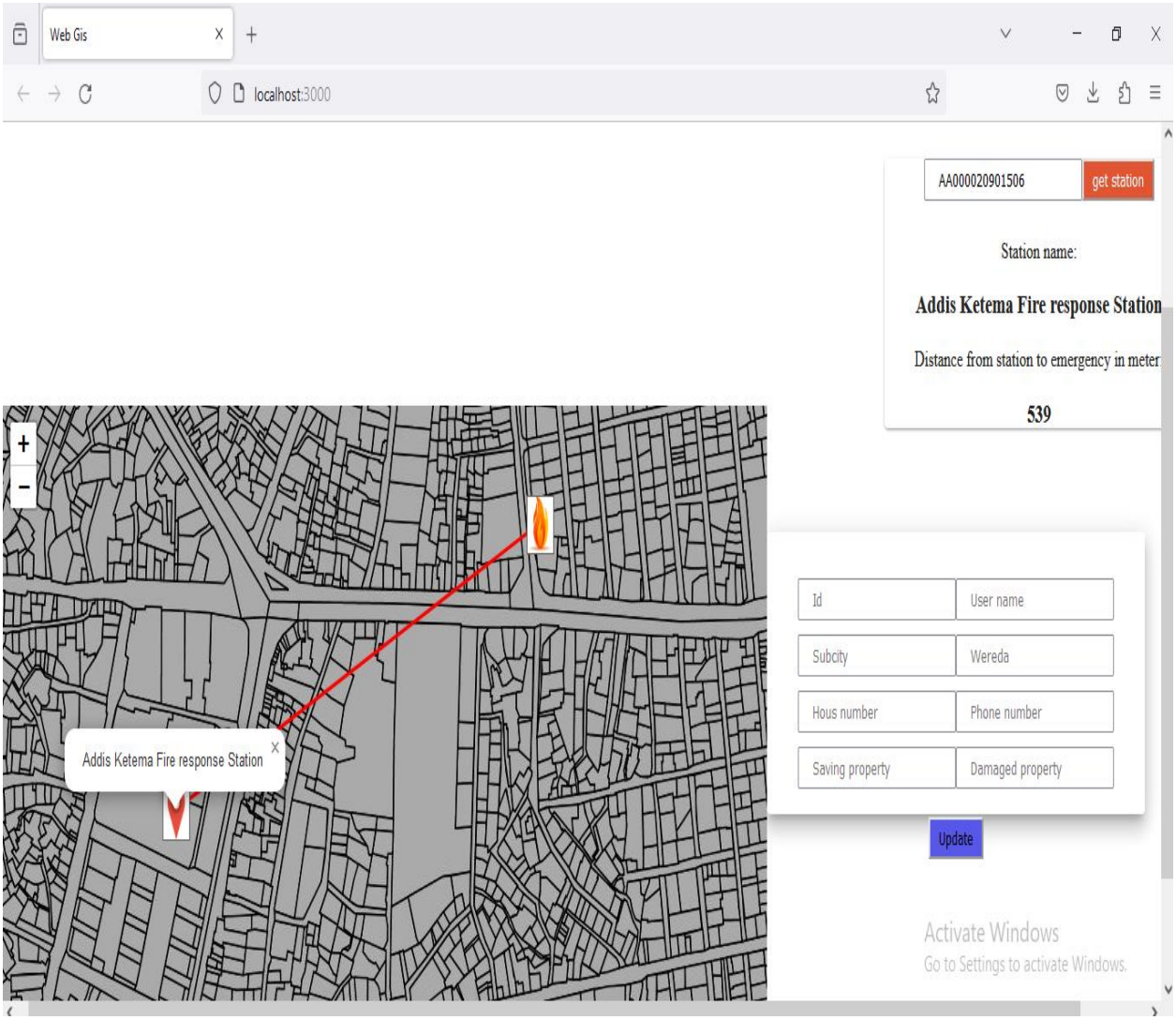


Figure 4. 8 Addis Ketema fire station to incident

The fire incident occurring at parcel ID AA000080901222 is simply the operator talking about the incident parcel id and entering the get station box, which displays the location of the fire incident and fire response station. Nefase Selke Lafeto fire response station is the shortest distance from the ten existing fire response stations to the incident parcel ID AA000080901222. The distance is 746 meters from the fire incident to the fire response station. The GIS-based fire response model can display fire response stations and fire incidents based on calculating geographical distance based on the shortest distance from the fire response station to the fire incident.

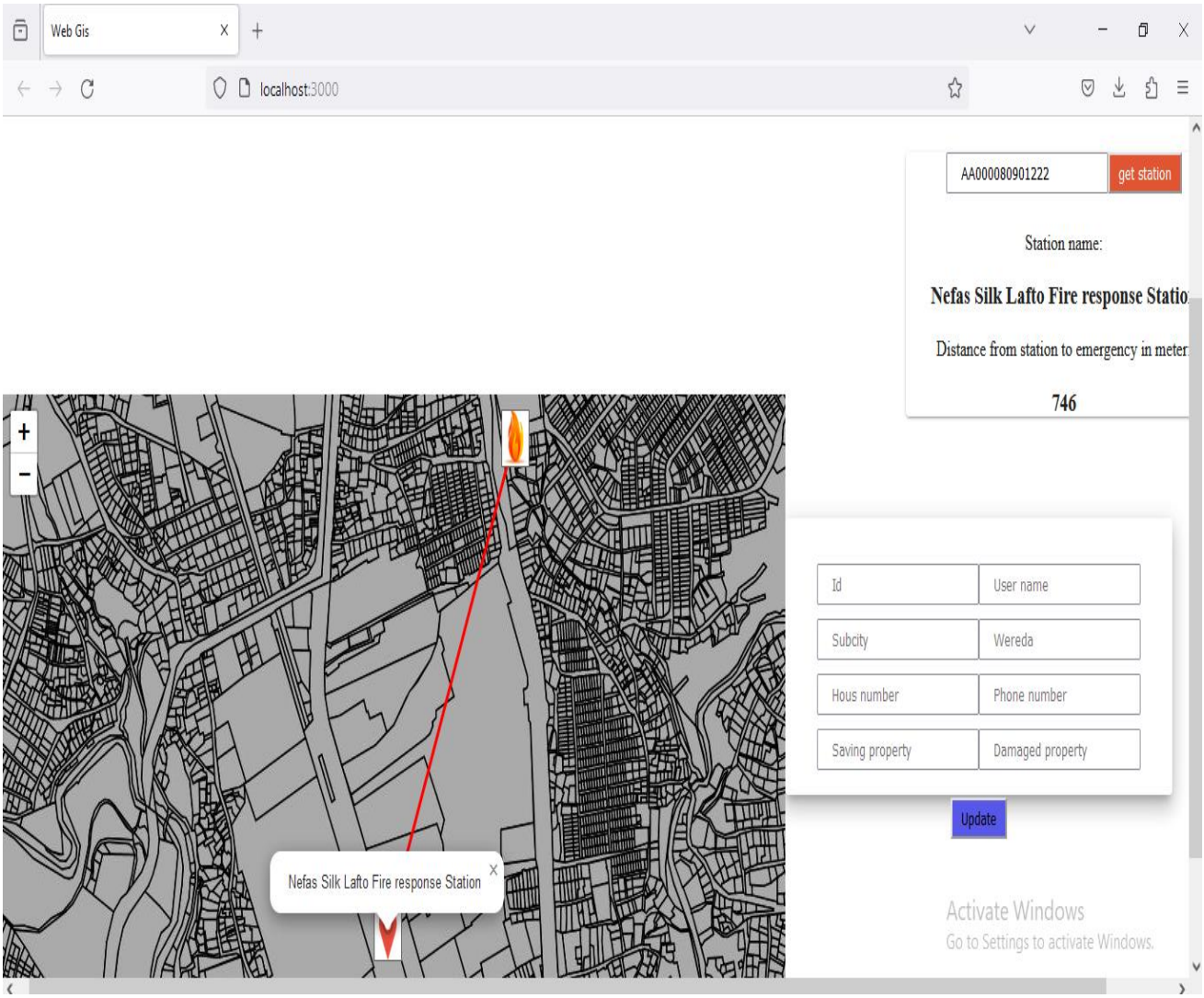


Figure 4. 9 Nefase Silk fire station to incident

Fire incident problem was reported at cell phone 939 to the fire response operator, to talk about the fire incident parcel ID AA000090407912, and then the operator entered the parcel id into the get station box, processing and displaying the location of the fire incident and fire response station. This incident was responded to by the Bethel Fire Emergency Response Station. Bethel Fire Response Station is nearest to the fire incident. This parcel ID AA000090407912 has an incident distance of 2500 meters from Bethel Fire Response Station. The location and direction are shown below from the Bethel Fire Response Station.

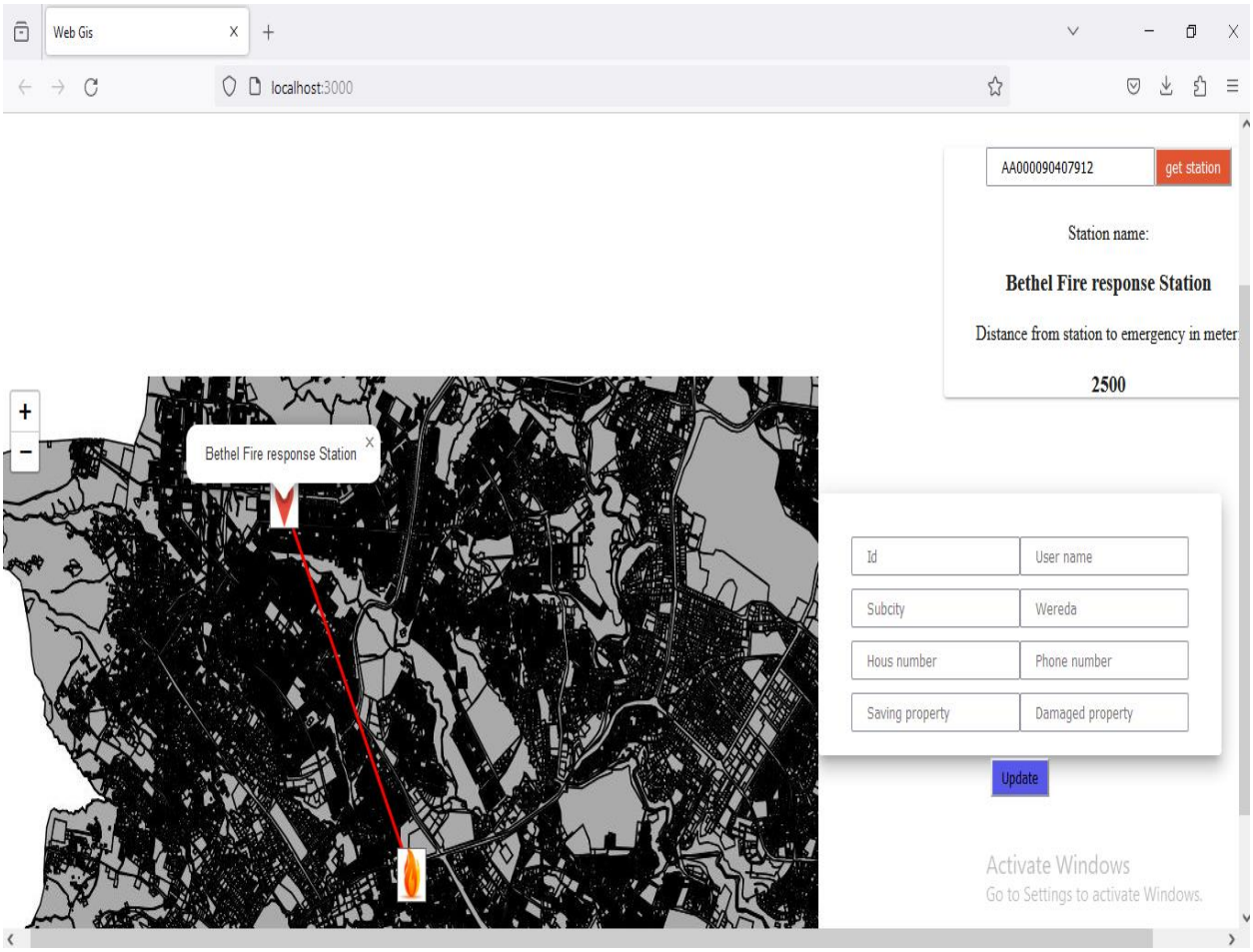


Figure 4. 9 Bethel fire station to incident

The incident that occurred, parcel ID AA000060101030, which is found in the Bole Sub-City, is near the fire equipment fire response station. The distance is 1570 meters from the fire response site to the fire incident to respond to this fire incident based on the developed model output. Shown below is the web GIS display.

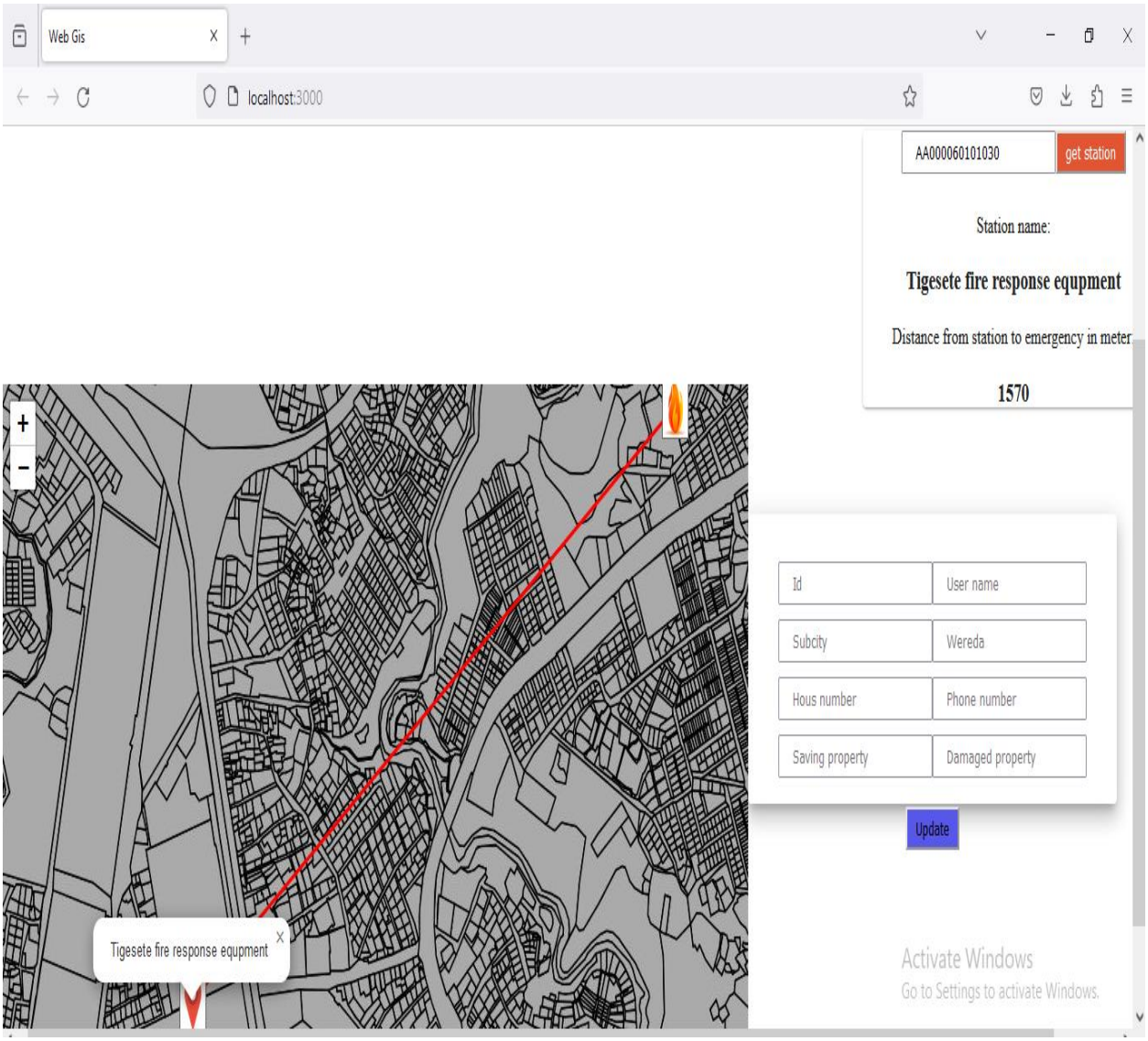


Figure 4. 10 Tigest fire station to incident

Based on the developed model of a GIS-based fire response station, the fire incident occurring in the Bole Sub-City is accessed by the fire response data base manipulator, which accesses the developed fire response model by entering the fire incident parcel ID AA000060304379 into the get station box. The model displays and shows the nearest fire response station, Tigeset fire equipment, and the location and direction of the fire incident from the fire response station. The distance is 4192 meters from the fire response site to the fire risk.

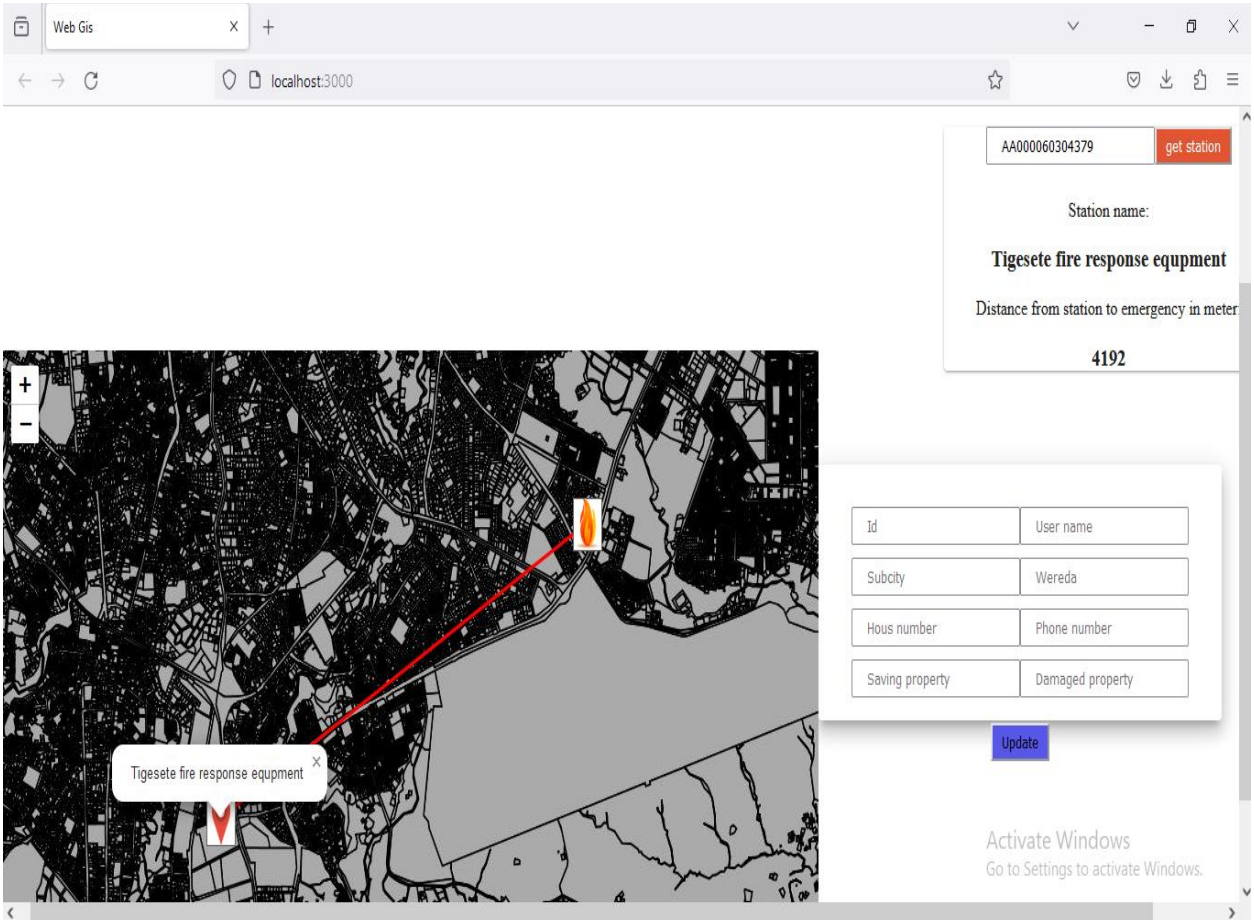


Figure 4. 11 Tigest fire station to incident

The fire response developing model database manipulator (user) entered fire incident parcel ID AA000070500355 at the get station box, and the model displayed the fire response location and fire incident location and direction of fire incident from the fire response station with a distance of 2192 meters between the fire response station and the fire incident.

Nefase Selek Lafeto Fire Response Station is nearest to the fire incident parcel ID AA000070500355. The fire incident is occurring at the Akaki Kality Sub City. The model shows the nearest fire response to a fire incident. It is clear from the response of the fireman.

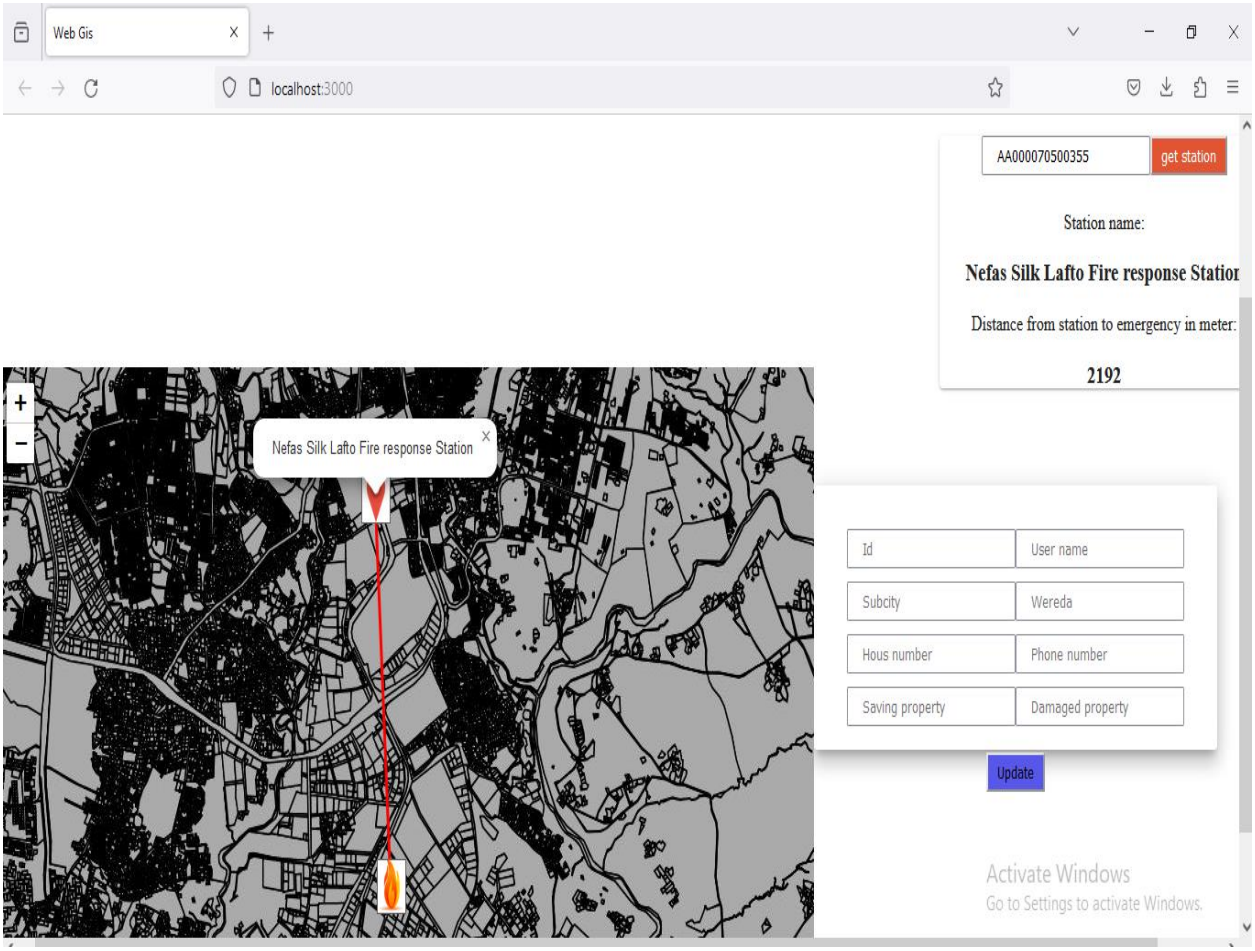


Figure 4. 12 Nefase Silk fire station to incident

GIS base fire response station model showing the location of the fire risk and the fire response station at get station box entering fire incident parcel ID AA000070803399. The model displays the location of the fire response station, the fire incident, and the direction of the fire incident from the fire response station. The distance is 2458 meters from the fire response station to the fire incident.

Fire incident occurring at Akaki Kality sub city, the developed fire response model to respond to this incident based on the nearest fire response station from the whole existing fire response station is Akaki Kality fire station.

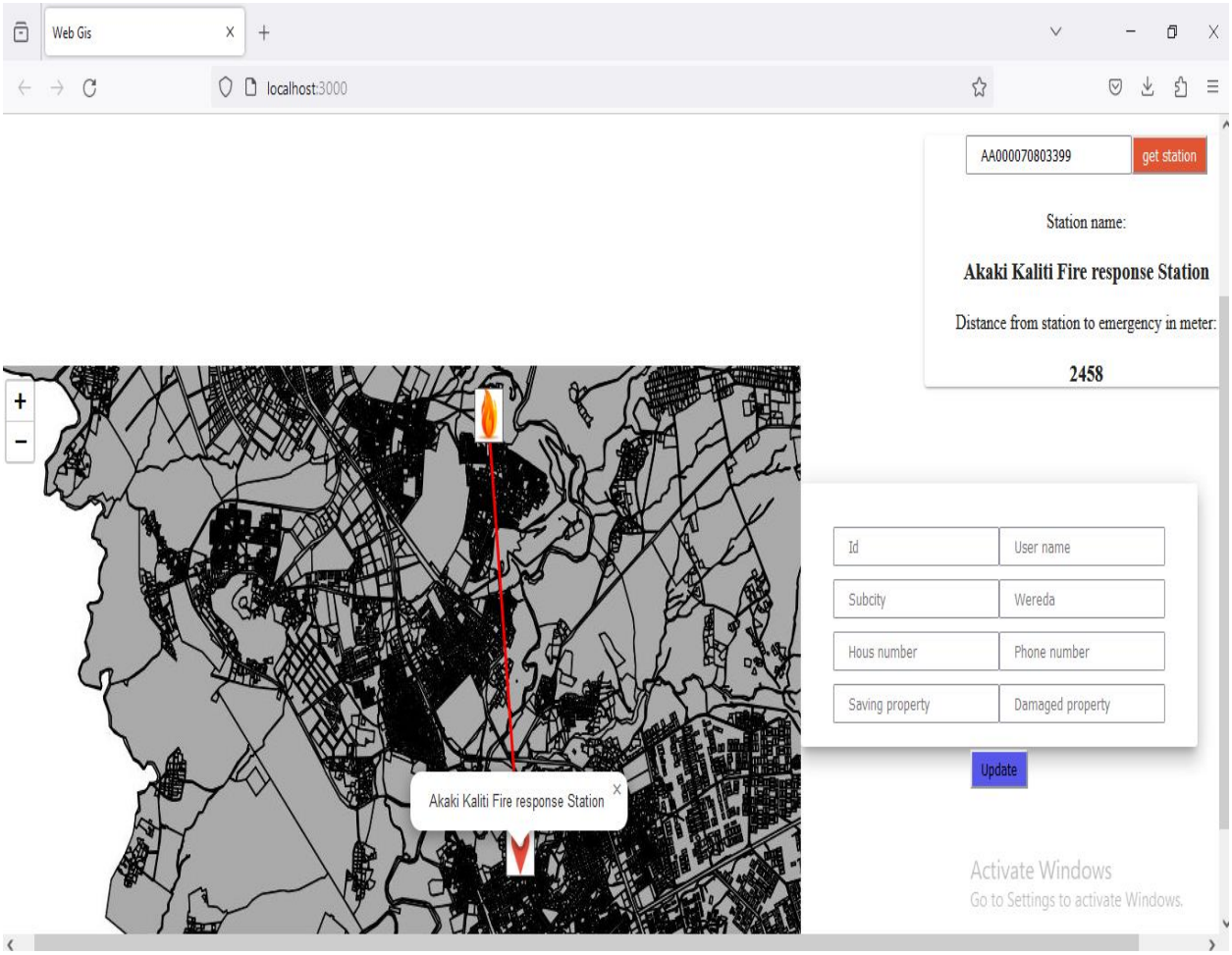


Figure 4. 13 Akaki Kality fire station to incident

The GIS based fire response model is to respond to fire incidents based on the developed model using a fire incident parcel id to enter the get station box. The model displays the fire incident and fire response station with the fire risk site from the fire response station. The distance is 2051 meters from the fire incident to the fire response station. Kirkos Fire Station is nearest to the fire incident parcel ID AA000031001063. To respond to this fire incident based on the developed model GIS fire response station, the Kirkose fire response station is as shown below.

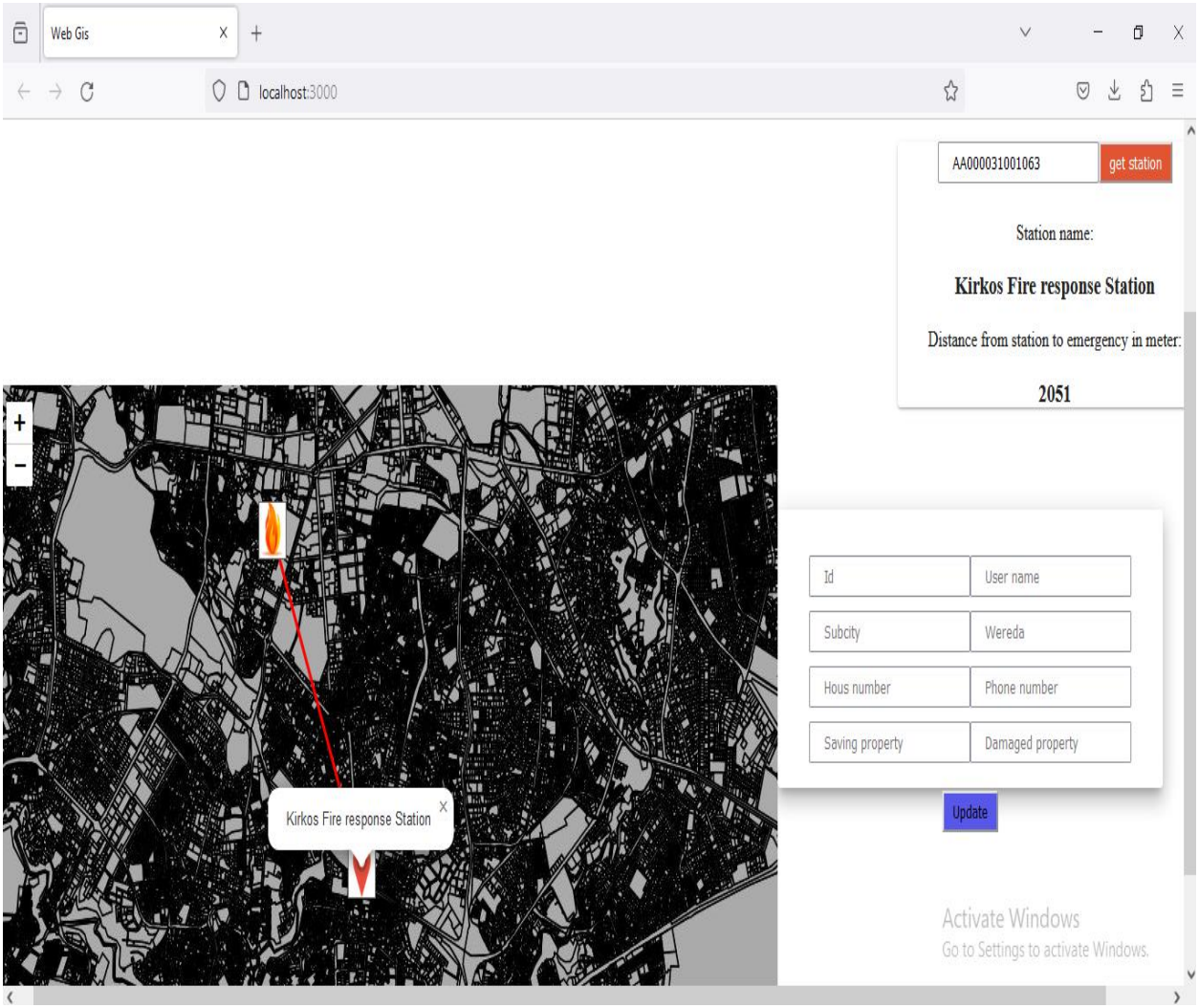


Figure 4. 14 Kirkose fire station to incident

A fire incident occurred at parcel ID AA000091502113. To enter this fire incident ID into the fire response model of the get station box, the model displays the fire response and fire incident locations with the direction of the fire irisk from the fire response site. The distance is 537 meters from the fire incident to the fire response station.

Gulele Fire Response Station is one of the Addis Ababa city existing fire response stations, so the fire incident occurring at Kolfy Sub City of parcel ID AA000091502113 is a response by Gulele Fire Response Station because Gulele Fire Response Station is nearest to the fire incident parcel ID AA000091502113 based on the developed fire response model.

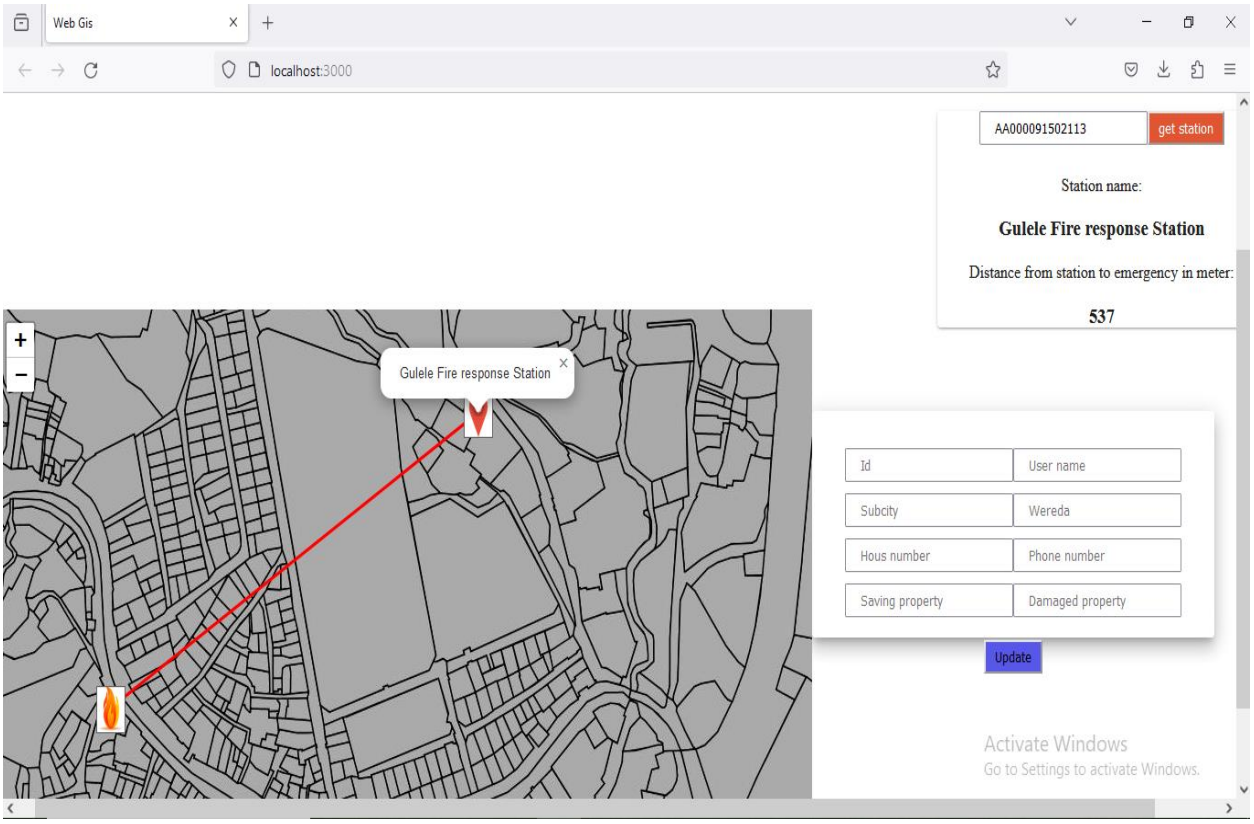


Figure 4. 15 Gulele fire station to incident

CHAPTRE FIVE

DISCUSSION

5.1 Comparative Analysis

In the current study, to develop a model for fire emergency response based on Geographic Information System (GIS) stations. This model developed the standardized fire and emergency services provided to Addis Ababa city. Additionally, it will identify fire incidents based on parcel identification number and select the shortest distance for fire emergency response station. Alebele (2015) focuses on Finding Fire Stations using Road Network Analysis and Emergency Response assessment. Ten extra fire stations were suggested by the researcher in order to expand the study area. But rather of adding more fire stations, the present study's GIS-based fire emergency response database has been implemented for the study area. One of the initial tasks of the study was to define the demand for fire emergency response. Since there were already existed fire stations and parcel polygon to integrate this two spatial data by GIS based fire emergency develop model, the main issue that needed to be addressed was the preparation of a potential fire emergency response database for the study area.

The Addis Ababa fire response agency did not have an efficient database for fire incident information. As a result, fire incident data was collected manually, on paper and in Excel. This method of data collection led to poor data quality, with issues such as data repetition and missing information being common. To address this gap, this study aimed to develop a comprehensive and accessible database for the Addis Ababa City Fire and Emergency Prevention and Rescue Agency. This database would hold full fire incident information and would be accessible to anyone efficiently and effectively. It would serve as a basis for budgeting purposes and for the input of data by researchers. Lots of structured fire event data may be managed and stored in these systems. Advantages of this database, no data redundancy, enhanced data security, higher data consistency, cheaper updating costs, cheaper data entry and storage expenses, and better data access through host and query languages. Abuhay (2022), GIS-based network analysis, It focuses on finding the optimal route the road network analysis. The researcher focused on GIS based road network analysis, but the current study focused on geo-coding geographical location of x y coordinate for fire response station and fire incident, the fire emergency response stations

and the fire incident in Addis Ababa City parcels. The Addis Ababa City Fire and Emergency Prevention and Rescue Agency have ten Fire Emergency Response station, and it is anticipated that resident would be aware of developed model and get their deliveries. When a Fire incident occurs, the caller is expected to provide the parcel identification number. Using the parcel identification number and locate incident techniques developed for this study area, the site of the fire incident can be determined. The nearest fire emergency response station can be selected based on the developed GIS fire emergency response model geographical x y coordinates and the shortest linear distance.

For the study that is being presented, the location of the fire occurrence is the most critical component of evidence. This data element is integrated with the fire emergency response station to ensure efficient and effective emergency response. The record of the site reference of an accident can be done in various ways, depending on the agency responsible for collecting accident data. According to Alexia (2016), the Traffic Police in Greece record the location of incidents by either using the postal code for accidents that occur in metropolitan areas or the kilometric point for accidents that occur on regional highways. To accomplish the current study, the use of a geo-code method is necessary. In contrast, other countries may simply provide the coordinates of the accident as the location reference, making the process of finding and responding to fire incidents more streamlined. This study utilizes a geo-code technique that combines the address of the Addis Ababa city parcel with the data stored in the fire emergency response station database.

Each fire incident point is associated with its attribute data (parcel ID) to facilitate fire response based on the parcel ID and the geographical coordinates (x, y) of both the fire incident station and the fire emergency station. Additionally, the distance from the fire incident site to the fire emergency response station can be calculated and displayed the result. This study aims to identify the gap in the sector and to fill the gap of the sector by develop the fire emergency response model based on GIS station, In addition to this to build standard database for Addis Ababa city fire emergency response frame work for the sector.

CHAPTER SIX
CONCLUSIONS AND RECOMMNEDAIONS

6.1 Conclusions

The purpose of the present study is to develop a model for the study area's fire emergency response, Geo code the existed fire response station and the fire incident address (parcel). In this study GIS based solution fire emergency response model developed and proposed to apply for the fire response sectors. Based on the proposed model of geographical x y coordinate, it focuses on locating the fire incident site on the parcel (resident) and locating the closest fire response station service providers to an incident location. Additionally, the suggested model incorporates the data on fire occurrences that have been gathered for 2022 and 2023 for inclusion in the study, which results in more accurate findings appropriate for practical fire emergency response.

The developed GIS based database model for the study area using different elements, such as the fire incident parcel ID, sub-city, wereda, house number, user name, phone number, saved property, and damaged property are attribute table that developed database for fire emergency response. This model can assist The Agency and the Addis Ababa City residence. A Fire Emergency Response Database is essential for updating fire-related attribute information. Moreover, future fire management role will focus on this developed database of fire incident information and the development of digital metadata standards for fire records' attribute and spatial components. From this study the developed model was the combination of the web GIS and database for fire emergency response. It has extended the web GIS on local servers used to locate fire incident and emergency response station. To provide quickly and easily to access online map viewing, locate fire incident and Select the nearest fire emergency response station, displaying minimum distance from incident to fire emergency stations, data storage, and update fire incident information.

The developed model to quickly locate fire scenes and fire response station by utilizing the geographical x y coordinate and attribute data parcel ID, Additionally a model has been assisted properly utilized existing fire response stations based on minimum distance from fire incident to fire response station for the nearest fire response station in the event of a fire incident within

Addis Ababa City. This GIS-based model allows for the identification of the optimal existing fire emergency response station based on the shortest linear distance from the fire response station to the location of the fire incident. Furthermore, a spatial database has been established to perform geospatial analysis and build a fire emergency database for the fire emergency response sectors in the study area. This database enables the querying of fire incident locations and their corresponding fire response stations.

The model effectively reduces the time delay to find the site for a fire incident and the fire response station. By comparing the distances from the fire incident to all fire response stations, the model selects the station with the shortest distance and displays it as the web GIS. The Addis Ababa city Fire and Emergency Prevention and Rescue Agency used parcel ID for fire emergency response service delivery, relying on the Geographic Information System (GIS) that is built upon the developed fire response model. This model simplifies the delivery of fire emergency services for the study area, resulting save time, human resource and property. This study is a frame work for both the Addis Ababa city residential and the Addis Ababa city administration fire emergency response agency used GIS-based fire response model for efficient and effective fire emergency response.

6. 2 Recommendation

The following suggestions have been made for the study area based on the study's findings.

- Taking into account the fire hydrate location develop model for GIS station base fire emergency response will help to achieve better results for fire emergency response.
- The Addis Ababa city administration fire emergency response agency and residential use this model for successfully response fire emergency incident.
- This study, the GIS based solution developed fire emergency response model helps to identify any incident in the study area and for any incident response institution will support to identify the location of the incident with empirical evidences.
- This study strongly suggests that, in order to facilitate future interpretation and ease of research, attribute data for fire incidents should be gathered and stored at the time of emergency occurrences utilizing GPS.
- The fire emergency response model considering developing emergency response taking road data.

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Appendices

Existing Fire response stations Geographic Coordinate points

no	Fire Stations Name	x	y
1	Arada Fire Station	472923	998867
2	Gulele Sub city Fire Station	468423	1001289
3	Tigist Fire Fighting Equipment	473723	991810
4	Bethel Fire Station	465034	995490
5	Akaki Kaliti Fire Station	476799	980562
6	Kirkos Sub City Fire Station	472436	993292
7	Addis Ababa Fire and Emergency Management Authority	472784	998812
8	Nefas Silk Lafto Sub City Fire Station	474155	989088
9	Addis Ketema Sub City Fire Station	469693	998469
10	Addis Ababa Fire Stations Head Quarters	472869	998856

Sample Fire Incidents Coordinate points

No.	Sub City	The Special Place	x	y
1	Guleley	Mennen Condominiums	473415	1000387
2	Guleley	Shero meada woga sefre	473835	1001678
3	Guleley	Kicheny medehaniyalme	472838	1000880
4	Arada	Around Tadse Chekol bulding	471600	1000101
5	Arada	Near Sanford school	474903	998987
6	Arada	Ras Emeru health center	471371	998969
7	Kirekose	Back of Helton hotel	474285	997058
8	Kirekose	Back of Kiara Ateklete tera	472438	993149
9	Kirekose	Around Bulgaria Embassy	475811	996188
10	Ledta	AroundGola Mikael	472445	997555

11	Ledta	Around Ambassador Hramby Hotel	473106	997007
12	Ledta	Around Shewa Bakery	473548	995477
13	Adise Ketma	Back of Shewa Tsega Building	470139	998689
14	Adise Ketma	pastor Alme Tsehay Bridge	470650	1000228
15	Adise Ketma	Around Sebatgna	470598	998043
16	Nefase Silk	Mechary Mieda	471146	994677
17	Nefase Silk	Aday Bbaba Adis Sefer	474653	990113
18	Nefase Silk	Sarise Adisu Sefere	475157	989985
19	Kolefie	Gulele fana shool Around	467743	1001263
20	Kolefie	Ayere Tiena Secondary school	466309	992869
21	Kolefie	Near Mulugita Menafsha (Awaleya)	468194	1001491
22	Yka	Near Yka Worda 13 Health Center	486471	999088
23	Yka	Awary Sietoche Adababay	475353	997461
24	Yka	Koteby 02 electrical station	480645	998559
25	Bole	Around Bole mikale	474912	992796
26	Bole	Bole Bulebula Medehaniyalme Church	475650	989200
27	Bole	Around Bole Beras	477321	993991
28	Akakay Kality	Infrontofe shegre bekery fabrika	464608	1002953
29	Akakay Kality	Around Chefie Mareyam Condominiums	476334	983722
30	Akakay Kality	Deraretu school	476206	982639

Property damaged (2022/2023)

	የደረሰ ዳት													
ክ/ከተማ	ሐምሌ	ነሐሴ	መስከ	ጥቅም	ህዳር	ታህሳስ	ጥር	ይካቲት	መጋቢት	ሚያዚያ	ግንቦት	ሰኔ	በክፍለ ከተማ ደረጃ የደረስ	የወደም ንበረት(ብር)
አቃቂ	8	6	4	6	7	8	4	7	4	7	8	5	74	363,565,500
ቂርቆስ	3	8	0	5	1	3	3	2	2	1	2	1	31	5,212,000
አራዳ	3	5	0	5	4	3	2	1	3	2	4	2	34	14,061,000
ጎ/ስልክ	5	4	5	8	2	2	3	4	4	3	1	2	43	12,396,000
አ/ከተማ	4	7	1	5	2	2	2	7	7	2	4	0	43	34,320,000
ኮልፌ	7	5	2	5	5	3	4	8	6	2	5	1	53	43,256,574
ጉለሌ	4	3	3	4	1	3	3	5	2	6	2	4	40	5,123,000
ቦሌ	3	6	2	6	2	2	1	4	5	1	4	0	36	28,348,400
ልደታ	0	1	0	1	0	0	1	2	2	1	0	1	9	615,000
የካ	0	4	2	3	2	6	4	1	4	3	0	2	31	10,810,000
													ድምር=394	ድምር=517,617,474

Geo-Code Parcel

```
let resultParecl = await dataBase.query(
    `SELECT * FROM parcel WHERE id IN ('${id}')`
  );
  if (!resultParecl.rows[0]) {
    return res.status(201).send({ message: "This number does not exist" });
  }
  proj4.defs(
    "EPSG:20137",
    "+proj=utm +zone=37 +ellps=WGS84 +datum=WGS84 +units=m +no_defs"
  );
  proj4.defs("EPSG:4326", "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs");
  const utmCoords = [
    Number(resultParecl.rows[0].x),
    Number(resultParecl.rows[0].y),
  ];
  const lonLatCoords = proj4("EPSG:20137", "EPSG:4326", utmCoords);
  console.log(lonLatCoords[0]);
  let resultX = lonLatCoords[0];
  let resultY = lonLatCoords[1];
```

Geo Code Existed Fire Station

```
dataBase.query(`Select * from existing_fire_station`, (err, result) => {
    if (err) {
      console.log(err.message);
      return res
        .status(201)
        .send({ message: "something is wrong" + err.message });
    } else {
      for (i = 0; i < result.rows.length; i++) {
        var point1 = { lat: lonLatCoords[0], lng: lonLatCoords[1] };

        //Second point in your haversine calculation
        var point2 = { lat: result.rows[i].x, lng: result.rows[i].y };

        //The haversine formula is a very accurate way of computing distances between two points
        // on the surface of a sphere using the latitude and longitude of the two points.

        var haversine_m = haversine(point1, point2); //Results in meters (default)
        if (shortDis === 0 || shortDis > haversine_m) {
          shortDis = haversine_m;
          stationName = result.rows[i].fir_statio;
          stationLat = result.rows[i].x;
          stationLong = result.rows[i].y;
        }
      }
      let numberWithoutDecimal = Math.trunc(shortDis);
      dataBase.end;

      return res
        .status(200)
        .send({
          stationName,
          numberWithoutDecimal,
          resultX,
          resultY,
          stationLat,
          stationLong,
        });
    }
  });
```

Geo code database

```
<Grid>
          <Paper elevation={10} style={papreStyle}>
            <div className="update-div">
            <input className="input_for_station" type="text" placeholder="Id" onChange={(e) =>
setId(e.target.value)}></input>
          <input className="input_for_station" placeholder="User name" type="text"
onChange={(e) => setUserName(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Subcity" onChange={(e)
=> setSubCity(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Wereda" onChange={(e)
=> setWereda(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Hous number"
onChange={(e) => setHousNumber(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Phone number"
onChange={(e) => setPhonNumber(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Saving property"
onChange={(e) => setSavingProp(e.target.value)}></input>
          <input className="input_for_station" type="text" placeholder="Damaged property"
onChange={(e) => setDamagedProp(e.target.value)}></input>

            </div>

          <div className="up-button-div"><Button className="update-button"
onClick={updateParcelData} >Update</Button></div>
          </Paper>
        </Grid>
```