APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) IN MAPPING AND EVALUATION OF FIRE PREPAREDNESS

CASE STUDY: NAIROBI CENTRAL BUSINESS DISTRICT (C.B.D) AND ENVIRONS-KENYA

BY

MAKOKHA MICHAEL SIMIYU

F19/1455/2010

A project report submitted to the Department of Geospatial and Space Technology in partial fulfillment of the requirements for the award of the degree of:

Bachelor of Science in Geospatial Engineering

SUPERVISOR: DR. DAVID NYIKA

April 20
**Declaration**

I, Makokha Michael Simiyu, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

MAKOKHA MICHAEL SIMIYU

Name of Student

This project has been submitted for examination with my approval as university supervisor.

DR. DAVID NYIKA

Name of supervisor

Date
Dedication

I dedicate this project to my late mother, Christine Nakhumicha, for her emphasis on a child’s education, to my sisters; Jane, Rose, Everlyn, Hellen, Cynthia, to Mr. and Mrs. Eng. Andrew Maniafu, to my sponsor; Brother David Mahoney to my Church; Triumphant Church for Moral and Financial support throughout my academic Journey.
Acknowledgements

I acknowledge the Almighty God for His faithfulness to my provisions, good health, inspiration and guidance throughout my studies as he promised in Haggai 1:13

I acknowledge my supervisor, Dr. David Nyika with a profound gratitude, for his support, assistance, guidance and advice offered at every stage throughout the preparation and conduction of my project research, without which successful completion of this project would have been in vain.

The entire staff of the Department of Geospatial Engineering and Space Technology, University of Nairobi, for vital input through teaching and guidance that made me a competent and all round geospatial engineer.

Sincere appreciation to my Sponsor and Former employer, Mr. and Mrs. Kokonya for their support and encouragement throughout my project period.

Special appreciation to My Best and Dear Friend, Caren Wafula for her encouragement and understanding of my engagement throughout my project period.

I thank the members of Western Outreach (W.E.S.O) for the continuous prayers and my classmates class of 2015 geospatial Engineering.

I also wish to convey my sincere appreciation to my classmates, geospatial engineering 2015 for their positive criticism throughout my academic time as well as those whose names do not appear here but contributed in one way or the other to my academic journey.
Abstract

Fire Breakout prediction is difficult, therefore, it is vital that preparations for fighting fire in case it occurs to be made. Fire Preparedness is a state of readiness to respond to a disaster, crisis, or other fire emergencies. A fire disaster preparedness plan ranges from a broad mitigation and preparedness strategy to detailed contingency plans for responding to the fire hazard. In most plans, the operational priorities need to save human life, meet people’s emergency needs (principally medical care, food, shelter and clothing) and restore facilities that are essential for health, safety and welfare (for example, hospitals, water and sanitation, power and transport).

The dangers of fire, justify the need for mapping firefighting facilities and assessment of the readiness of a capital city like Nairobi to combat fire incidences and management of post-fire effects. The assessment were done in terms of the number of fire stations in the entire Nairobi County and how equipped they were, distribution of water hydrants, accessibility, response time by fire brigades to areas of fire breakouts, availability of medical facilities in the proximity and public awareness on dealing with fire. The greater need of a database of firefighting facilities within the city, highly informs this project especially in the use of GIS in capturing, analysis, manipulation, storage and dissemination of data and information.

From this study it was evident that the study area suffers setbacks in fire preparedness in the sense of Traffic congestions (both human traffic and motorists), especially during the day, inadequate public sensitization on how to respond to fire breakouts and conducting fire drills. With a population of close to 4 million people (according to JICA population projections 2009), the City of Nairobi has only one main fire station and two other substations, with only six fire engines and strained firefighting personnel. This study also establishes other government agencies like NYS and KDF take part in extinguishment of public fires. Despite of their slow response due to long military protocols. This implies that the city of Nairobi in which the case study area is located, is partially prepared to combat major public fire disasters, with major factors in fire preparedness such as fire stations, fire engines and personnel appearing as if neglected.

The findings of this study will play a major role in guiding other state funded projects on fire preparedness especially in major cities, as the country cascades towards achieving vision 2030 where industrialization will be a major economic driving engine. This information will be invaluable to the academia in the intensified study of the concept of fire, to fire experts for identification of gaps in their engagements and formulate a solutions for the challenges as well as the general public to understand the concept and importance of readiness to fire disasters.
# Table of Contents

Declaration.............................................................................................................................. i
Dedication ............................................................................................................................... ii
Acknowledgements .............................................................................................................. iii
Abstract................................................................................................................................. iv
Table of Contents .................................................................................................................. v
List of Figures ........................................................................................................................ vii
Table Summary ..................................................................................................................... viii

## CHAPTER 1: INTRODUCTION ........................................................................................................ 1

1.1 General Background ......................................................................................................... 1
1.2 Statement of the Problem ................................................................................................. 2
1.3 Project Objectives ............................................................................................................ 4
  1.3.0 Main objective ........................................................................................................... 4
  1.4.0 The Study Area ......................................................................................................... 5

## CHAPTER 2: LITRATURE REVIEW ............................................................................................ 8

2.1 Introduction ....................................................................................................................... 8
2.2 Classification of fires ......................................................................................................... 8
2.4 Review of previous studies ............................................................................................. 10
2.5 Concept of GIS ................................................................................................................ 13

## CHAPTER 3: METHODOLOGY .................................................................................................. 15

3.1 Data Sources and Tool .................................................................................................... 15
  3.1.1 Data Sources ............................................................................................................ 15
  3.1.2 Tools ....................................................................................................................... 16
3.2 Methodology overview ................................................................................................... 17
  3.2.0 Data Collection ........................................................................................................ 18
  3.2.1 Data Preparation and Editing ................................................................................ 18
3.3 Database Development ................................................................................................... 20
3.4 Data Processing .............................................................................................................. 20
  3.4.0 Vector to Raster Conversion .................................................................................... 20
  3.4.2 Inverse Weighted Distance Interpolation (IDW) .................................................... 21
  3.4.3 Proximity Analysis ................................................................................................. 21
  3.4.4 Network Analysis .................................................................................................... 21
3.5 Administering Questionnaires

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Overview

4.2 Results

4.2.0 A geodatabase populated with various data elements for the project

4.2.1 A land use map of the CBD and its environs

4.2.2 A map of distribution of fire stations in Nairobi County and their particular location

4.2.3 Fire assembly points distribution and Prediction map

4.2.4 Fire hydrants distribution map

4.2.5 Fire hydrants 70M buffer map

4.2.6 Streets and road network map

4.2.7 Network analysis dataset

4.2.8 Health facilities within an approximate 2 kilometers Radius from Uhuru highway-Kenyatta Avenue Round-about

4.2.9 Service area map; 3minutes, 5minutes, 10 minutes and >10minutes service areas

4.3.0 Route layer (dynamic map); optimal routes from a fire station to a point of fire incident at Uchumi Supermarket

4.3.1 Questionnaire study results and analysis

4.4 General Analysis

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

5.2 Recommendations

REFERENCES

APPENDIX : QUESTIONNAIRE SURVEY
List of Figures

Figure 1.1. The geographic extent of the area of study ........................................................................... 5
Figure 2.1.mandatory of signs .................................................................................................................. 9
Figure 2.2.Fire equipment sign-fire point ............................................................................................... 9
Figure 2.3.Fire equipment sign-dry riser .................................................................................................. 9
Figure 2.4.Fire evacuation Procedure ................................................................................................... 9
Figure 2.5.Fire Action Plan ..................................................................................................................... 9
Figure 2.6.Fire Exit sign ......................................................................................................................... 9
Figure 2.7.Fire assembly point .............................................................................................................. 10
Figure 2.8.Dry powder extinguisher ....................................................................................................... 10
Figure 2.9.Water extinguisher .............................................................................................................. 10
Figure 2.10.Hose reel ............................................................................................................................. 10
Figure 3.1.Overview of methodology .................................................................................................... 17
Figure 3.2.Georeferenced and Mosaicked tiles of Nairobi CBD and its environs used as base map ......... 19
Figure 3.3.A flow chart of road Network analysis process ....................................................................... 22
Figure 3.4.The figure showing conversion of polygon buildings to building centroids using ArcGIS software .......................................................... 23

Figure 16.Network analysis model ...................................................................................................... 25
Figure 4.1.A personal Geodatabase and the datasets that are stored ..................................................... 27
Figure 4.2.Land Use Map of Part of CBD and its environs .................................................................. 27
Figure 4.3.A Bar graph of land use within the CBD and its environs ...................................................... 29
Figure 4.4.A graph indicating number of buildings in respective land use zone ...................................... 29
Figure 4.5.A bar graph of possible fire sources within CBD and its environment .................................. 31
Figure 4.6.The map of distribution of public fire station within Nairobi County .................................... 31
Figure 4.7.Locations of Existing Fire stations in Nairobi County .......................................................... 32
Figure 4.8.Map showing the distribution of fire assembly points and prediction by interpolation contours .......................................................... 33

Figure 4.9.Distribution of fire hydrants within the area of study ............................................................. 34
Figure 4.10.Fire hydrants buffer map of 70 meters divided in 30m, 50m, and 70m radii from each hydrant .......................................................................................................................... 35

Figure 4.11.distribution of road networks and major streets within the area of study, map ......................... 36
Figure 4.12.A map of road network connectivity done by network analyst tools in ArcGIS software ..... 37
Figure 4.13.A map of health facilities within 2kilometers radius from Uhuru highway-Kenyatta avenue roundabout .................................................................................................................. 38

Figure 4.14.A map of zones of time taken to respond to a fire, from a fire station head office ................. 40
Figure 4.15.A dynamic map showing of optimal fire response route determination using GIS ............. 41
Figure 4.16.Textual direction display of optimal route shown in fig 31 above ....................................... 41
Figure 4.17.Most to least likely cause of fire in the CBD and its environs (fire expert’s response) ........ 42
Figure 4.18.Most to least likely cause of fire in the CBD and its environs (general public’s response) .... 42
Figure 4.19.Public participation in fire drills and trainings .................................................................. 43
Table Summary

Table 1.1. Summary of organization of the study. .......................................................... 7
Table 2.1. Colour of the fire extinguishing cylinders and the extinguishing agent contained. ..... 10
Table 3.1. Summary of the data and various data sources .................................................. 16
Table 3.2. Global turns network settings ........................................................................... 24
Table 4.1. Statistical analysis of land use within the study area.............................................. 28
Table 4.2. Possible fire sources within the study area.......................................................... 30
Table 4.3. Population projection estimates of Nairobi County from 2009 to 2030 Error! Bookmark not defined.
Table 4.4. Number of healthy facilities within neighbouring county wards in 2KM radius from study area ........................................................................................................................................ 38
Table 4.5. A proximity table indicating approximate distances each building is from the firefighting facilities ............................................................................................................................... 39
CHAPTER 1: INTRODUCTION

1.1 General Background
Fire is the rapid oxidation of a material in the exothermic chemical process of combustion releasing heat, light and various reactive products (Pyne, 1982). Fires may start accidents (censure of appliances), deliberate ignition or from equipment failure. Fire produces smoke and toxic gases which could be fatal to those exposed to it. Hence the need for prevention and protection from spreading fires by for instance delaying ignition period to allow people more time to escape and for the fire brigade to arrive at the incident. Fire can make homes unsafe. It can lead to the collapse of houses, loss of property or even death (Supermedia, 2011). Nairobi’s industrial area for instance suffered massive losses due to electric failures in November, 2012 after a Kenya power substation caught fire forcing the company to resort to power rationing (Muchira, 2012).

Fire Breakout prediction is difficult, therefore, it is vital that preparations for fighting fire in case it occurs to be made. Fire Preparedness is a state of readiness to respond to a disaster, crisis, or other fire emergencies. A fire disaster preparedness plan ranges from a broad mitigation and preparedness strategy to detailed contingency plans for responding to the fire hazard. In most plans, the operational priorities need to save human life, meet people’s emergency needs (principally medical care, food, shelter and clothing) and restore facilities that are essential for health, safety and welfare (for example, hospitals, water and sanitation, power and transport).

The dangers of fire, justify the need for mapping firefighting facilities and assessment of the readiness of a capital city like Nairobi to combat fire incidences and management of post-fire effects. The assessment could be done in terms of the number of fire stations in the entire area of coverage, distribution of water hydrants, and response time by fire brigades to areas of fire breakouts as well as availability of medical facilities in the proximity. In this study, geographical information system (G.I.S) technology, was used in the mapping and evaluating the fire preparedness in a section of the city of Nairobi.

GIS is a technology that integrates geographic features with tabular data to assess and better understand real-world problems. What is now GIS began around 1960 with the discovery that maps could be programmed using simple code and stored in a computer, allowing for future modification
when necessary. This was a tremendous change from the era of cartography when maps had to be painstakingly created by hand, even small changes required the creation of a new map.

The earliest version of a GIS was known as computer cartography and involved simple line work to represent land features. Unlike a flat paper map, a GIS-generated map can present many layers of different information that provide a unique way of thinking about a geographic space. By linking maps to databases, GIS enables users to visualize, manipulate, analyze, and display spatial data in form of layers. A layer represents geographic data in a GIS environment, such as a particular theme of data. Examples of map layers include streams and lakes, terrain, roads, political boundaries, parcels, building footprints, utility lines, and orthophoto imagery.

GIS map layers that fire departments use include: Streets, Parcels, Fire hydrants, Utility networks, Topography Lakes and rivers, Commercial and government buildings, Fire station locations, Police station locations, Hospital locations among others. Map layers can be selected and displayed (overlaid). These layers are linked to data tables that contain detailed information about the geographic features being displayed. The most powerful aspect of GIS is its comprehensive analysis capabilities. GIS analyzes and displays patterns, relationships, and trends through the geographic data layers to help users understand how the world works, make the best choice from among options, or develop plans through what-if scenarios. This makes GIS an appropriate tool in Mapping and evaluation of fire preparedness as compared to other conventional methods.

1.2 Statement of the Problem
Nairobi is not only the capital city of Kenya, but also a commercial, industrial, trading and administrative hub of the nation, hosting many international agencies. Moreover, it has high rise buildings housing many institutions. Therefore, the property in the study area have high economic value compared to other parts of the city, which implies that, in case of a fire breakout, it can lead to immense economic loss, in terms property value and employment loss.

Reduction of fire breakouts is difficult, therefore, mitigation is essential to reducing the loss of homes, property and resources especially in the urban interface. Communication, planning processes, response time and materials development is critical in dealing with incidences of fire occurrences.
Urban fire disasters receive a baffling lack of response from aid agencies whenever it occurs indicating major gaps in urban preparedness (UN Habitat, 2011). This shows that Kenya is faced with inadequacy in responding to fire disasters of high magnitude. Rescue teams have failed in many of the occasions to live up to their billing by either arriving late at tragedy struck scenes or making it on time but half equipped hence failing to counter the tragedy.

The World Bank and US Geological Survey estimated that economic losses worldwide from natural disasters in the 1990s could be reduced by $280bn if $40bn were invested in preparedness, mitigation and prevention strategies (Dilley and Heyman, 1995). On the Kenyan case most areas especially cities have been lacking fire prevention and mitigation plans. Occupants of building have also fallen victims to fires due to perceived lack of preparedness. This has increased exposure to frequent fire disasters which have led to loss of lives and property.

Many cases of fire incidences have occurred in Kenya with most of them having been fatal. The cases include the 2009 fires in Nakumatt Downtown in Nairobi on 28th January 2009 (The International Federation’s Disaster Relief Emergency Fund (DREF) report of 12 August 2009), Sachangwan in Molo District on 31st January (DREF report, 12th January 2009), fires in Muthurua slums and the 2006 Fire incident at Elburgon where 7 members of the family burned beyond recognition and the Fire incident at Libra House in Nairobi where 11 workers died and three remained missing (unidentified bodies) the same year, Prior incidences listed also involved the 2005 Wild fire in Rift Valley (which caused Extensive environmental and ecological damage though no human life was lost), the 2004 Fire at the City Hall, Nairobi where the entire 3rd floor and valuable documents and property worth KShs.70 million were destroyed. (Mutungi And Maingi , full research paper 2010)

The 2001 Fire at Kyanguli Boys (Machakos) where 68 students burnt to death and property destroyed, the 2001 Fire at Free Market (Uhuru Park– Nairobi) where the entire market and property was destroyed by fire, the 1998 Petrol Tanker explosion along Kisumu/Busia road where 36 people died, the 1990 Fire at Lamu where 20 people died, the 1982 Fire at Nairobi where 10,000 people were affected and the 1982 Fire at Lamu where 4,000 people were affected amongst others (Republic of Kenya, 2009). The Sinai slums fire where over 100 people died and between January-March 2011
where an estimated population of 25,000 people was left homeless from what was perceived slow response from authorities and agencies. (Mutungi & Maingi, 2010)

It’s against this background that this study sought to examine whether past occurrences of fire disaster had elicited establishment of prevention and mitigation measures in business premises in Nairobi CBD and its environs.

1.3 Project Objectives

1.3.0 Main objective
To evaluate fire preparedness within Nairobi Central Business Districts (CBD) and its environs using geographic information systems.

1.3.1 Specific Objectives
The specific objectives of this study are;

1. To map firefighting systems and facilities, their suitability and distribution within the CBD of Nairobi and its environs

2. To evaluate the awareness of the public to fire prevention measures, response measures and the readiness to execute them in case of

3. To apply GIS technology in analyzing state of fire preparedness in the study area, establish the gaps and make recommendations.

1.4 Scope of the Study
The geographic scope of study is the CBD and its environs where the environs are represented by university of Nairobi main campus including students’ halls of residence, part of Ngara area and part of Nairobi railways. This study area was chosen because of its convenience, and being the capital city of Kenya, with a large cosmopolitan population with properties of high value. The project is conceptually limited to investigation of the level of preparedness of the Kenyan cities to combating fire disasters.

The firefighting preparedness will be assessed against the recommended level and standards of firefighting facilities in an urban setting. The Planning and Building Regulations of Kenya (2009) legislation will be used to assess the required levels of provision of firefighting infrastructure. The project will not inquire in depth into firefighting installations in individual buildings in the study area, for example fire alarms and detectors, fire extinguishers and their types, fire emergency exit routes because of the limited time to complete the study and financial constraints. On the other hand, this study will focus on the details on how the entire study area is prepared to combat fires in terms
of water reticulation and fire hydrants distribution, number and distribution of fire station, accessibility of the study area and proximity of health facilities for emergencies in case of fire casualties, as well as response time by fire brigades from a fire station to a fire scene. The choice to study these parameters is informed by recent fire occurrences in and around the city despite the measures put in place at buildings level, thus sending a strong message of a call for a large scale planning of the city to swiftly respond to fire Breakouts and neutralize them before loss of significant properties.

1.4.0 The Study Area

Figure 1.1: the geographic extent of the area of study

Figure 1.1 above shows map insets of the case study area, the Nairobi county map and the map of Kenya. The arrow from Kenya map to Nairobi county map and to the case study map implies that Case study area is a subset of Nairobi County, and Nairobi County is a located in Kenya. From the map, the study area lies within Nairobi central ward and Kilimani ward. A ward is the smallest administrative area in Kenya represented by member of county assembly (MCA).
1.5 Significance of the Study

In the recent past, many lives and property worth huge amounts of money have been lost. A significant number of these incidences might have been prevented, controlled or at least their effects minimized if the affected areas were prepared to combat such incidences in terms of swift response time by fire brigades, accessibility of the areas, availability of water hydrants and proximity to a fire station.

The aim of this study is to apply GIS technology in the mapping and evaluation of how urban areas are prepared against possible fire disasters. The study will be done through evaluation of the extent of water reticulation in the study area, number of fire stations and their area of coverage and accessibility within the area of study. This will be compared against the recommended standards of fire preparedness in urban areas according to National planning and building regulations (2009). The project will strive demonstrate how the power and importance of GIS technology in decision making process, proposing suitable areas for location of fire stations and medical facilities. The method makes interpretation easy and fast therefore, saving time for making developmental decisions.

In future, due to rapid development of towns, cities and urban areas in Kenya, there will be need for a comprehensive setting up of fire safety infrastructure. Thus the study could be important as a basis for development of the projects and therefore, the project is significant to the planners in case of planning or re-planning of urban areas. The study is also undertaken as a partial requirement for the fulfilment of the award of a degree of Bachelor of Science in Geospatial Engineering.

1.6 Organization of the Study

The report is comprised of five chapters; chapter one is the introductory chapter which contains general background of the study, problem statement and objectives of the study. Chapter two is comprised of a review of other literatures previously done by other authors covering the topic of study, as well as explaining exhaustively the basic concept of GIS such as GIS modules, systems, and analysis and data management. Chapter three outlines the main materials and methodology used in the execution of the research. Chapter four provides the results achieved from the research work and the analysis of the same whereas chapter five gives a summary of the study with conclusions and recommendations that came as a result of completion of the entire research.
Table 1.1 Summary of organization of the study.

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 1</td>
<td>General background of the study, problem statement and objectives of the study.</td>
</tr>
<tr>
<td>Chapter 2</td>
<td>Literature Review</td>
</tr>
<tr>
<td>Chapter 3</td>
<td>Methodology</td>
</tr>
<tr>
<td>Chapter 4</td>
<td>Results and Analysis of the project</td>
</tr>
<tr>
<td>Chapter 5</td>
<td>Conclusions and recommendations</td>
</tr>
</tbody>
</table>
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction
Fire safety studies have been carried out by several researchers. This chapter presents studies undertaken by others and how it is related to mitigation and preparedness of not only fire in urban areas but also other disasters such as floods, earthquakes et al. Varied perceptions of different researchers on application of GIS in mapping and evaluation of disaster preparedness are dealt with in this chapter.

Review of Classification of fires and facilities installed within building as part of fire preparedness gesture is necessary, before the review of previous projects on application of GIS in preparedness against disasters. This knowledge is vital especially to the general public;

2.2 Classification of fires
Classification of fire forms a basis upon which choice of extinguishers is made. Jain (2010) classified fire into classes A, B, C, and D; Class A are fires whose fuel is combustible solid fuel material of organic nature such as wood, grass, paper, cloth and product thereof. This type of fire is extinguished by reducing the temperature of the burning materials by spraying water. The combustion of this materials results in the production of carbonaceous materials. Class B are fires whose fuel is volatile and inflammable liquids like petroleum products (example, petrol, kerosene, naphtha, denatured methylated spirit, alcohol and benzene) chemicals, paints, solvents, grease and lubricants. Extinguishing of this fires involves absorption of oxygen by creating a smothering atmosphere around the flame. Class C are fires whose fuel is flammable gases under pressure including liquefied gases. The extinguishment of this type of fires involves inhibiting the flammable gas by using inert gas or vaporizing liquid. Class D are fires whose fuel is combustible metals such as magnesium, aluminium, sodium and potassium. Class E are those involving electrical equipment due to short circuit, leakage and overloading. The firefighting techniques used should be non-conductive and non-magnetic.

2.3 Common Firefighting equipment and signs within buildings
2.3.0 Fire Signs
Fire signs in buildings and in the environment are extremely important in giving information to occupants and fire fighters. They are truly necessary since most building occupants and the routes users are not familiar with layouts of buildings and street links of the city. They are basically meant to guide people out of buildings .they indicate alternative routes to use which are not part of normal
circulation routes, in case of fire. According to Maina (2009), signs which are necessary to indicate action that should be taken are ‘mandatory signs’.

![Figure 2.1 mandatory of signs](image1) ![Figure 2.2 Fire equipment sign-fire point](image2) ![Figure 2.3 Fire equipment sign-dry riser](image3)

Source: Paul and John (1991)

![Figure 2.4 Fire evacuation Procedure](image4) ![Figure 2.5 Fire Action Plan](image5) ![Figure 2.6 Fire Exit sign](image6)

Source: Field Survey, 2015

![Figure 2.7 Fire assembly point](image7)

Source: Field survey, 2015

2.3.1 Fire Fighting Equipment in buildings

2.3.1.0 Firefighting cylinders and horse reels
These firefighting equipment require operation by buildings occupants. Some are portable and are usually located at accessible point especially along escape routes which ensures they can be easily reached by occupants during a fire emergency. The portable firefighting equipment are cylinders containing water, foam, carbon dioxide or dry powder in a compressed state. The horse reels are
always connected to water mains within buildings. Different extinguishing agents are used to different classes of fires. The cylinders bear different colours signifying different types of extinguishing medium they contain, as follows:

**Table 2.1: Colour of the fire extinguishing cylinders and the extinguishing agent contained.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Extinguishing Agent</th>
<th>Colour of the cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>Red</td>
</tr>
<tr>
<td>2</td>
<td>Foam</td>
<td>Cream</td>
</tr>
<tr>
<td>3</td>
<td>Dry powder</td>
<td>Blue</td>
</tr>
<tr>
<td>4</td>
<td>Carbon dioxide</td>
<td>Black</td>
</tr>
<tr>
<td>5</td>
<td>Vaporizing liquid</td>
<td>Green</td>
</tr>
</tbody>
</table>

*Source: Author*

Example of firefighting cylinders and horse reels common in buildings:

*Figure 2.8. Dry powder extinguisher*  
*Figure 2.9. Water extinguisher*  
*Figure 2.10. Hose reel*

*Source: Field Survey, 2015*

The above discussed firefighting equipment within buildings are samples to indicate effort that has been undertaken to ensure occupants in buildings can help extinguish fire in its earlier stages before it grows beyond manageable levels.

**2.4 Review of previous studies**

According to Ogut J.C 2001, in the study; Use of GIS in Fire Disaster Management in Mathare area, he points out that, due to a large number of unemployed people in Kenya, there is high population of dependent people who flock the cities in search of employment. This people cannot afford decent housing and so they end up in slums which are around cities. The employment they get mostly within the city or in the environs of the CBD.

In this study, the scope lies within the CBD and its environs because many companies, industries, businesses and higher education institutions are within and around the city and so, any fire disaster
within the city can lead to darkening of many peoples’ fortunes. Therefore mapping and evaluation of fire preparedness state of the city is vital.

Ogut J.C points out that the Nairobi fire department strain beyond its full service limit because it serves a larger area (according to department of NCC). No community within Nairobi area has the sufficient resources to cope with serious fire emergencies. This calls for many research on the preparedness of Nairobi city to combat fire and recommendation of appropriate measures to be put in place to ensure every corner of the city is safe from destructive fire disasters. According to Ogut, to plan for and even place any disaster assistance utilities within the city, the local authority must adequately map the area in consistence with its dynamic changes and again this utilities should have a geographical relationship with other features so that their spatial locality should be known.

Ogut J.C emphasizes that both residents and developers will highly need the spatial location of utilities in the area to incorporate them in their internal disaster response plan. The greater need of a database of firefighting facilities within the city, highly informs this project especially in the use of GIS in capturing, analysis, manipulation, storage and dissemination of data and information.

Ogut J.C 2001, discussed how the community can be involved in fire management plan through the formation of local fire management committees which will be responsible for educating the community on fire handling skills especially with regards to ensuring improved management flammable materials and smoldering materials. However, Ogut did not scientifically establish the level of knowledge of the public towards fires and fire disasters, say through administering questionnaires and interviews. If this is done, then it could help in easier inclusion of the society in implementation of fire rescue plan. However Ogut admits that simulation in the form of joint community response in extinguishing fire Breakout have been tried but majorly failed due to lack of procedural guiding plan to effect it.

An undergraduate Project on identification of new firefighting facilities within the CBD and its environs, by Kimore Karanja, 2006, attempts to evaluate fire preparedness in the city by mapping firefighting facilities, although it focused on just a few of this facilities. Kimore focused on; the response time of fire engine from a fire station to the fire disaster scene, service areas of fire hydrants and proposition of new fire hydrants and fire stations. Kimore’s study turned a blind eye on assessing fire preparedness within buildings and evaluation of public knowledge in case of fire breakout. Other
firefighting facilities such as open grounds for evacuations, accessibility, location of police stations and distribution of fire assembly points among many others.

A M.Sc. Thesis on ‘Investigation of fire risk in Kiandutu slums, Thika’, by Jennifer Gachago, 2013, alludes that; Collective local action and proactive interventions to reduce fire risks are more effective but have rarely been documented in urban Africa. The relative paucity of such collective solutions is probably a function of lack of research studies as much as the weakness of social capital and governance regimes. While many governments in Africa have disaster risk management legislation and national bodies such as Kenya’s NADIMA, there continues to be very little capacity to undertake risk awareness on the ground. Underlying this is a lack of political priority allocated to urban disaster risk (GOK, 2004; ISDR, 2005; Pelling and Wisner, 2009).

Jennifer indicated in the findings of her thesis that; The sample population scored very poorly on the aspects of mitigation including waste dumping (73.1%), presence of smoke detectors (98.5%), willingness to upgrade their houses and settlement (56.7%), communication networks (57.7%), fire drill involvement (97.1%) and priority action in case of a fire where 50.7% said they would go back to the house to try and save property. According to the results it shows that most of the respondents have low mitigation skills. According to GoK (2004), even where firefighting implements are available, the staff are not adequately trained to handle fires.

Jennifer notes that any fire starts as a simple and small action and awareness of which can prevent such fires can be very crucial in disaster mitigation. In most instances, ordinary citizens are not aware of this and therefore are not helpful in preventing and mitigating such occurrences due to ignorance and lack of awareness. This calls for collaboration with other stakeholders in dissemination of the information through purpose created campaigns or through convenient fora like schools, churches among others. Also, collaboration with other organizations like the Red Cross, the police and the army can provide direct support in fighting fires and reducing loses.

The review of previous research and theses points out to non-comprehensive of research in fire disasters. This calls for more research in the topic to make sure that sufficient knowledge about the causes of fires and how to mitigate such disasters is documented conclusively. This shortcomings also calls for application of GIS in conclusive projects research to develop databases of firefighting
facilities and development of fire management plans of fire risk zones, and high potential zones where an occurrence of fire causes huge losses, for example in the city like Nairobi.

### 2.5 Concept of GIS

Geographic Information System (GIS) is a special type of information system that is used to input, store, retrieve, process, analyze and visualize geospatial data and information in order to support decision making. It is essentially a spatial decision support tool. GIS is the merging of cartography, statistical analysis, and database technology. The ability to separate information in layers, and then combine it with other layers of information distinguishes GIS from other information systems and is the reason why GIS holds such great potential as a research and decision-making tool.

As observed by Foote et al., (2009), GIS is now used extensively in government, business, and research for a wide range of applications including environmental resource analysis, land use planning, location analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis. It has been extensively used in natural resources management, facilities management, lands management and in the management of street networks like address matching, location analysis or site selection, development of evacuation plans. GIS is highly suitable for analyzing all forms of data, revealing trends and interrelationships that would be more difficult to discover in tabular format.

GIS is commonly composed of a number of software modules. Some of the modules entails; Data capture module-facilitates the conversion and verification of analogue data or information into digital format compatible with the system. Data transform module-the major function being changing of data from one format to another without alteration of information content. Transformation modules include, generalization, reclassifications, map scaling and projection change.

Display and reporting module- is concerned with the presentation and dissemination of information to the end users. Data may be presented as maps, diagrams, tables and graphs both in soft and hard copies. Spatial Analysis module involves interrogating and retrieving information from geographic database in response to user query. Database is a central system of collection of maps and associated information in a digital form. Spatial analysis include; statistics analysis, spatial data integration and spatial modeling. Geographic database management- Database management system (DBMS) is always used as the basis of this module. It is concerned with the way the geometry and attributes of
geographic features are stored and related. With a DBMS, it is possible to enter attribute data such as tabular information and statistics. It also allows extraction of specialized tabulations and statistical summaries to provide new tabular reports.

GIS contains Cartographic Display System which is a software component surrounding the central database. This allows GIS user to select elements from the database and produce map output on the screen or through hard copy devices such as printers and plotters. The range of cartographic production capability in GIS softwares is significant. Map Digitization capability in GIS allows conversion of hard copy paper maps into digital form thus further developing the database and saving cost of physical data capture. This system allows editing of already digitized data. Digitizing packages, Computer Aided Design (CAD), Coordinate Geometry (COGO) and Arc GIS are example of software system that provides the ability to add digitized map information to the database, in addition to providing cartographic display capability.

GIS has data analysis capability extensively as compared to traditional database query. It includes the ability to analyze data based on their location. Traditional database query performs only when attributes belongs to the same feature and not when features are different. GIS has ability to compare different features based on their common geographic occurrence. This analysis is achieved through a process called overlay-identical to overlaying transparent maps of the two entity groups on top of one another.

GIS can be used assessing preparedness against fires by providing a tool for incorporating both spatial and non-spatial information into the planning processes, some of which are; noting of optimal routes in responding to fire break out, monitoring operations within the area affected-priority given to previous fire occurrences, reasons and regions in which they occurred and new measures put in place. GIS also helps in keeping track of trends and characteristics of various localities by the authorities, noting the upcoming development especially the nature of the structures established in relation to the vulnerability to fire.
CHAPTER 3: METHODOLOGY

This chapter represents the procedure that was followed to achieve the objectives of the study.

3.1 Data Sources and Tool

3.1.1 Data Sources
The following are datasets that facilitated the execution of this project;

3.1.1.0 Topographic Map
It is a detailed, accurate cartographic representation of features on the earth surface. It shows the accurate location of both natural and man-made features. These features include, cultural features, hydrographic features, relief and vegetation (source: geoscience Australia). Nairobi CBD and environs topographic map tiles at a scale of 1:2500 obtained from Nairobi County Council, done by Japanese International Corporation Agency (JICA), were mosaicked and used to give the base information relating to Nairobi Central Business District and its environs.

3.1.1.1 Water Reticulation data
This data shows the distribution of water systems in an area. Shape files of fire hydrants covering Nairobi area were obtained from Nairobi Water and Sewerage Company.

3.1.1.2 Roads and Buildings data
This data indicates the location, size, type of buildings and roads. The descriptions are attached on the data attribute table. The shape files of this data were obtained from Nairobi County Council. And a few were digitized from the topographic map.

3.1.1.3 Health Facilities data
A soft copy record of 2009 general census was obtained from ArcGIS Online. It was a Comma delimited (CSV) format. This data was converted to shape file using ArcGIS software before being used.

3.1.1.4 Fire Assembly points, data
Data indicating designated places to assemble in case of fire breakout in buildings. This places are always marked with metal sign post bearing the name ‘Fire Assembly point’. This data was obtained through field work using GNNS receiver (GPS receiver), for Data capturing. The data was downloaded to the computer as a shape file.

3.1.1.5 Fire occurrences summary and statistics
These summary was obtained from Nairobi County Council Fire station head office. The summary indicated, time and date of fire alert, time of engine dispatch, type appliances dispatched, engine arrival time at the fire scene, the place of fire incident, service rendered and response time.
Table 2.1: summary of the data and various data sources

<table>
<thead>
<tr>
<th>DATA SETS</th>
<th>CHARACTERISTICS</th>
<th>DATA SOURCE</th>
<th>FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic map</td>
<td>Scale 1:50000</td>
<td>Nairobi City Council</td>
<td>Base information</td>
</tr>
<tr>
<td></td>
<td>Format: digital</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Author: JICA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Reticulation</td>
<td>Shape file</td>
<td>Nairobi water &amp; sewerage company</td>
<td>Developing fire hydrants distribution map</td>
</tr>
<tr>
<td>Roads and buildings</td>
<td>Shape file</td>
<td>Nairobi City Council</td>
<td>Developing Road network and building accessibility map</td>
</tr>
<tr>
<td>Fire Stations</td>
<td>Shape file</td>
<td>Nairobi county council Fire station head office</td>
<td>Developing fire stations distribution map</td>
</tr>
<tr>
<td>Fire assembly points</td>
<td>Shape file</td>
<td>Field Work</td>
<td>Developing Fire assembly points distribution map</td>
</tr>
<tr>
<td>Health facilities</td>
<td>CSV</td>
<td>ArcGIS online</td>
<td>Accessibility to health facilities assessments</td>
</tr>
<tr>
<td>Fire Occurrences summary and their causes, in Nairobi county</td>
<td>Text</td>
<td>Nairobi county council Fire station head office</td>
<td>Fire Risk assessment based on historical fire occurrences and losses.</td>
</tr>
<tr>
<td>Land use Data</td>
<td>Shape file</td>
<td>Ramani Geosystems</td>
<td>Developing of Land use map</td>
</tr>
</tbody>
</table>

Source: Author

3.1.2 Tools

3.1.2.0 Hard ware overview

Computer hardware refers to a collection of all physical elements that make up a computer system. A laptop with the following specifications was used: 300 Gigabyte hard disk drive, an AMD E-300 APU with Radeon HD graphics processor, 1.3GHz speed and a 2 Gigabyte Random Access Memory (RAM). A flash disk of 8 Gigabytes was used in the transfer and storage of datasets in digital formats. The project was printed using a HP Deskjet colour Printer.
### 3.1.2.1 Software overview

Computer software is a collection of computer programs that furnish the computer with instructions for directing it in the processes it should carry out. Windows 7 professional operating system was used to run the laptop due to its compatibility with professional softwares that were used in this project. ArcGIS 10.1 software package; GIS software developed by Environmental System Research Institute (ESRI) was used for maps development, data preprocessing, relevant GIS analyses and managing the relevant geographic information in a database. The geo-referencing and mosaicking of topographic map was done by using Global mapper version 13. Microsoft office version 2013 provided the excel spreadsheet for manipulation of statistical data as well as Microsoft word and PowerPoint for project report writing and projecting respectively.

### 3.2 Methodology overview

**Figure 3.1: Overview of methodology**

- Identification of suitable datasets
- Data Collection
- Non-spatial data
- Data Editing and Preparation
- Data Analysis and Result
- Result Evaluation
- Database Development
- Data Processing
- Review of previous research findings
- Review of concepts and theories
- Definition of project problem
- Project Design
- YES

Source: Author
3.2.0 Data Collection
This stage involves getting the identified relevant data from relevant sources. It is the most time consuming and expensive exercise yet vital in any GIS process. The two main methods of data collection are data capture and data transfer (Longley & Goodchild, 2006). In this project, both the two methods of data collection were employed. Data transfer involves importing digital data from other sources using a portable memory device (8GB flash disk). Data collected through this means were: digital topographic maps, roads and buildings shape files, water reticulation shape files, fire occurrence summaries, land use data shape file.

The data of health facilities was downloaded from ArcGIS online website, in CSV format. This geographic data resource site has a geolibrary and a geoportal that have been created as part of national and global spatial data infrastructure initiatives (SDI). The data was evaluated for quality, completeness and complexity before collection. Data capture method was employed when collecting fire assembly point data. Data of fire assembly points within the area of study were collected using GNNS receiver (hand held GPS receiver, type: germin. The collected data was downloaded to the computer by Map source software in GPX format before being converted to shape file.

3.2.1 Data Preparation and Editing
Data preparation or data pre-processing refers to manipulation of data in to a form suitable for further analysis and processing. This place involves many tasks and hence cannot be fully automated. This process is essential because data might be incomplete, wrong or inconsistent.

3.2.1.0 Conversion of Excel worksheets
Excel worksheets could not be used with Arc GIS in text formats. They were converted into comma delimited format (CSV) which is compatible with ArcGIS software. The data converted into this format were geographic coordinates of health facilities.

3.2.1.1 Georeferencing
Georeferencing refers to referencing spatial data to actual ground coordinate systems. Which facilitates overlaying with other geographic data, querying, and spatial analysis. Georeferencing may involve, shifting, rotating, scaling, skewing, and in some areas warping, rubber sheeting or ortho-rectification. Topographic map images were loaded using global mapper version 13, map mounting was done using four corner points as ground control points (GCP). The geographic coordinates of
the four corner points were read from the map images. The universal transverse Mercator projection was used and the datum was WGS_84. The georeferenced map tiles were mosaicked and exported in TIFF format for use in Arc GIS. The root mean square error (RMS) was zero, which was acceptable for subsequent use in the project. The topo map provided base information for the project.

Figure 3.2. Georeferenced and Mosaicked tiles of Nairobi CBD and its environs used as base map

Source: Nairobi County Council, done by Japanese International Corporation Agency (JICA)

3.2.1.2 Harmonization
Harmonization process involves confirming and ensuring that the datasets were in the same projection system and datum, through defining map projections and reprojecting the collected spatial data. This process was done using Arc Catalogue module in Arc GIS before carrying out any form of processing. The projection and datum set for all datasets was UTM projection zone 37S and WGS_84 datum. This projection was used because they are an excellent basis for analysis and also distances can be calculated from them for points within the same zone with no more than 0.04 % error (Longley et al, 2006)
3.2.1.3 Clipping
Clipping refer to spatial extraction of features from a coverage that resides entirely within a boundary defined by features in another coverage. Clipping was done to all the data (raster and vector) collected to extract data that spatially cover the study area. The ArcGIS analysis clip tool was used for this process.

3.3 Database Development
A geodatabase is the collection of geographic datasets of various types used in GIS and managed in either a file folder or a relational database. Geographic database is an important geographic information model in organizing spatial data into thematic layers and spatial representations. A personal geodatabase and multi-user geodatabase exists under ArcGIS package. In this study, personal geodatabase was implemented to store data components that could be applicable in the final analysis for the designed objectives. A personal Geodatabase was created in Arc catalogue and named Fire_preparedness.Gdb. Feature datasets were created inside the geodatabase and feature classes were created inside the feature datasets. More datasets were exported to the geodatabase in form of feature classes and tables.

3.4 Data Processing

3.4.0 Vector to Raster Conversion
The vector data was converted into raster data using the polygon to raster conversion tool in ArcGIS. This was done to facilitate reclassification of data. The data converted to raster were the open grounds, fire assembly points, fire hydrants and road networks.

3.4.1 Euclidean Distance Calculation
The Euclidean distance function describe each cell’s relationship to a source or a set of sources. Euclidean distance gives the distance from each cell in the raster to the closest source. The Euclidean distance output contains the measured distance from every cell to the nearest source. The distance are measured as the crow flies (Euclidean distance) in the projection units of the raster, such as feet or meters and are computed from one cell center to the next cell center. The Euclidean distance function is often used as a standalone function for applications. This function can be used when creating a vulnerability map when data representing a distance from a particular object is needed. For this study, the distance from fire hydrants points was computed with reference to standards set by the National planning and building regulations (2009). According to this regulations, a fire
hydrants should serve a maximum of 70 meters radius. A Euclidean buffer of 70 meters at an interval of 30 meters, 50 meters and 70 meters radii from a hydrant forming rings were created using Euclidean distance under spatial analysis tools in Arc GIS software. Enabled to show the areas that are served optimally by fire hydrants and those that are stretched from service of the hydrants.

3.4.2 Inverse Weighted Distance Interpolation (IDW)
The IDW interpolation function under geostatistical analyst tools in ArcGIS, uses the measured values surrounding the prediction location to predict a value for any un sampled location, based on the assumption that things that are close to one another are more alike than those that are farther apart. For this study, fire assembly sample points were picked using GPS. Owing to the extent of the study area and restrictions of access to some places. Using IDW tool, interpolation was done to ascertain the general distribution pattern of fire assembly points. Interpolation Contours lines were used as the symbology of the interpolated surface. It was chosen because of its simplicity in interpretation.

3.4.3 Proximity Analysis
The Proximity analysis tools in Arc GIS are used to determine how close a feature is from another point of interest feature. This is applied in the assessment of optimal locations of facilities under investigation. In this study, Generate near table tool was employed. The generate_near_table tool determines the distances from each feature in the input features to one or more nearby features in the target features, within a search radius. The results are recorded in the output table. In this study, the input feature from which the distances were taken was the buildings data, while the near features to where the measurements were made to was; fire hydrants, fire assembly points, open grounds, roads and health facilities. The search radius was left open to ensure that the search is done throughout the study area. After generation of the near_table, the summary of the table and the statistical summary were generated. This enabled the analysis fire preparedness within the area of study.

3.4.4 Network Analysis
Network analysis process was achieved by the help of Network Analyst toolbox in Arc GIS which contains tools that perform network analysis and network dataset maintenance. Tools in this toolbox, can be used to maintain network datasets that model transportation networks and perform route analysis, closest facility, service area, origin-destination cost matrix, vehicle routing problem, and location-allocation network analyses on transportation networks. For this study, the latter two analysis was not done as they were out of the project scope.
The process of network analysis begun with the creation of road network topology using road network datasets in the personal geodatabase created within Arc Catalogue module of Arc GIS. A Topology is a dataset that enables implementation of a set of geometric rules (positional, translational etc.) on the network feature classes to correct for errors and enable the input elements to maintain specific geometric relationships. Using Merge tool from data management tools, road network polylines were merged, topology was built, made to run, errors corrected, and saved in the personal geodatabase

3.4.4.0 Network Analysis Procedure.

*Figure 3.3* A flow chart of road Network analysis process

Source: Author
3.4.4.1 Polygon to Point Conversion

This tool creates a feature class containing points generated from the representative locations of input polygon features. The software computes the centroids of each polygon. The interest of this study was not the actual size of the buildings but general location. The study focused on firefighting facilities in the external environment which needed to be conspicuous on the map. To reduce congestion on the map, the polygons were converted to points. In addition, network analysis process does not allow polygons hence the necessity for the conversion. The summary process is shown below:

Figure 3.4. The figure showing conversion of polygon buildings to building centroids using ArcGIS software.

Polygon building dataset                       ArcGIS conversion wizard                                Point building dataset

Source: Author

The figure 3.3 above is a flow chart outlining the systematic process that was followed in carrying out the analysis of road network connections within CBD and its environs as well as creation of optimal routes, directions and graphic layers, to a fire incident from a fire station.

3.4.4.2 The Network Dataset creation

The network dataset defines a network’s connectivity, turns, attributes and direction of travel. Network dataset was built from Arc Catalogue which allowed for the creation of analysis layers which yielded routes, directions and graphics within the network in the study area. In the process of network creation, connectivity was defined to ensure the streets link up at the end points. Global turns default feature which contains universal rules on network turns was used. Network attribute were set. These were; Drive time, restrictions (one-way roads and restricted junctions). An impedance of Travel time was used as a factor that determines the ‘cost’ of negotiating the network. The attributes included in the creation of network dataset were; the travel time and travel distance,
the reason being the study was restricted to time taken by fire engine to arrive at the fire scene and
the optimum routes as per the time of the response.

The global turn rules for global turns that is, time taken for a fire engine to maneuver a straight
reverse, right or left turn were set. The settings were as below;

Table 3.2. Global turns network settings

<table>
<thead>
<tr>
<th>TURN</th>
<th>ANGLE (degrees)</th>
<th>TIME (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>Reverse</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>Right</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: ESRI Tutorial

The settings enabled the network analyst to calculate and find the optimal routes with the least cost
of impedance between points as well as searching facilities in the proximity to fire incident scenes.
The directions were set to use streets and road names.

3.4.4.3 Creating Network analysis Layer

The network analysis layers in ArcGIS include; route layer, closest facility layer, service area layer,
Origin Destination (OD) layer and vehicle routing problem layer. This study did not perform vehicle
routing problem layer. The closest facility layer gives the optimum route to a fire incident or
accident. It was also used to search for nearest hospitals within 100meters radius from the fire station.
A network service area is a region that encompasses all streets that can be accessed within a given
distance or travel time from one or more facilities. Service areas are commonly used to visualize and
measure accessibility. The service area within from a fire station was computed for 3minutes,
5minutes, and 10minutes and beyond 10 minutes were computed using network analyst tool. For the
study, the Origin Destination (OD) layer was not necessary because it produces similar results as
that produced by closest facility layer. The only advantage of OD matrix is that it is faster and solves
large problems; measures the least-cost paths along the network from multiple origins to multiple
destinations.
3.4.4.4 Model Building
This the process of automating a process in ArcGIS such that the tools needed to perform certain processes can be sequenced to perform all the required tasks and yield results at once. It is suitable for repetitive tasks to avoid carrying out the same processes every time a need arises. The model that was developed for this project was to automate the process of network analysis and creation of network analysis layers which were closest facility layer, route layer and service area layer. Example of route layer network analysis model is shown below in figure 3.5;

Figure 3.5 .Network analysis route model

3.5 Administering Questionnaires
The questionnaires were administered to two categories of respondents. These were the Nairobi county fire station experts (fire men and fire women) and the general public (university of Nairobi students and workers). The study sought to establish the awareness of the public to general causes of fires in all buildings categories, as well as to establish the most to the least cause of fire within the study area. The questionnaires was also to establish the percentage of public involvement in fire drills, awareness of fire evacuation procedures, fire signs and equipment within buildings. Administration of questionnaires enabled the general assessment of fire preparedness within the University of Nairobi, CBD and its environs as well as establish lapses in fire responsiveness by the public.
CHAPTER 4: RESULTS AND ANALYSIS

4.1 Overview
This chapter focuses on presentation of the results that were produced and analyses that were carried out during the implementation of this project. As stated earlier, the overall objective of the study was to apply Geographic information systems (GIS) in mapping and evaluation of fire preparedness.

4.2 Results
Consistent with the set objective, the following results were obtained;
   a) A geodatabase populated with various data elements for this project
   b) A map of distribution of fire stations in Nairobi County and their particular location
   c) A map showing land use within the CBD and its environs
   d) Streets and road network map
   e) Fire assembly points distribution map
   f) Fire hydrants distribution map
   g) Fire hydrants 70Meters buffer map
   h) Proximity table showing average distance from buildings to roads, water hydrants, fire assembly points and open grounds
   i) Network analysis dataset.
   j) Service area map; 3minutes, 5minutes, 10 minutes and >10minutes service areas.
   k) Route layer (dynamic map); optimal routes from a fire station to a point of fire incident at uchumi Supermarket.
   l) A map showing health facilities within 2kilometers radius from the study area.
   m) Questionnaire study results and analysis.
4.2.0 A geodatabase populated with various data elements for the project

Figure 31. A personal Geodatabase and the datasets that are stored

The corrected and processed data were stored in the geodatabase created by using Arc Catalogue module of ArcGIS, to ensure optimum data management and prevent datasets duplication. The Created Geodatabase named *Nairobi fire preparedness* as shown on Figure 4.1 above.

4.2.1 A land use map of the CBD and its environs

Figure 4.2. Land Use Map of Part of CBD and its environs

*Source: Author*
Figure 4.2 above is a land use map showing various land use within the area of study, which was found to be; transportation, residential, recreational, open spaces, mixed commercial and institutional, institutional and commercial. This is vital information to indicate possible fire risk zones, the type of fire causative agents and the level of damage that can be incurred in case of fire break out. The map also shows open spaces and recreational areas within the study area that can acts as evacuation grounds in case of fire.

**Table 4.1: Statistical analysis of land use within the study area**

<table>
<thead>
<tr>
<th>LANDUSE</th>
<th>Count_LANDUSE</th>
<th>Sum_BUILDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>commercial</td>
<td>45</td>
<td>89</td>
</tr>
<tr>
<td>institutional</td>
<td>77</td>
<td>416</td>
</tr>
<tr>
<td>mixed CI</td>
<td>91</td>
<td>613</td>
</tr>
<tr>
<td>no_structures</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>open space</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>recreational</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>res_slum</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>residential</td>
<td>25</td>
<td>151</td>
</tr>
<tr>
<td>transportation</td>
<td>24</td>
<td>87</td>
</tr>
<tr>
<td>unknown</td>
<td>8</td>
<td>116</td>
</tr>
</tbody>
</table>

Source: Author

The table 4.1 above shows the quantity of each land use within the area of study and the building count within respective land use region. From the table, the number of buildings within the zone of Mixed commercial and industrial land uses are higher- proportional to the size covered by *mixed commercial and industrial* land use (mixed CI), than the buildings within open spaces, indicating congestion which is one of the predisposing factors for fire Breakout and difficulty in accessing fire disaster scenes as well as huge loses in case of fire occurring. The CBD and its environs have high rise buildings with huge investments as implied by land uses on the table, and so, any successful fire occurring in the area results to huge loses in monetary value and business dreams shuttering.
Figure 4.3. A Bar graph of land use within the CBD and its environs

Source: Author

Figure 4.3 above gives graphical representation of table 4.1, showing different levels of land uses within the area of study. From the graph in figure 4.3 above, it is evident that Nairobi CBD is full of mixed commercial and industrial land uses, followed by institutional, commercial, residential, transportation and others as shown on the legend in figure 4.3.

Figure 4.4. A graph indicating number of buildings in respective land use zone

Source: Author
Figure 4.4 above is a bar graph showing number of buildings found within each land use zone in the study area indicated on land use map, (figure 4.2). Comparing this graph and the graph of Land use in figure 4.2, it can be deduced that the number of land uses within the study area is proportional to the number of buildings found in the respective land use zones. Given that fire cannot happen in open grounds unless it is a bomb, then it can be concluded that the fire risks and huge loses are high in zones with many buildings than those with low number of buildings.

Table 4.2: possible fire sources within the study area.

<table>
<thead>
<tr>
<th>Possible Fire Source</th>
<th>Number of landuse</th>
<th>Sum of Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>apartments</td>
<td>6</td>
<td>32</td>
</tr>
<tr>
<td>car park</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>club</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>guest house</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>hotel</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>market</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>petrol station</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>restaurant</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>staff quarters</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>student housing</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>supermarket</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Author

The table 4.2 above outlines possible sources of fire within the area of study. Fire can be caused by cooking using gas within apartments, guest houses, hotels, restaurants, staff and student housing. Electrical faults can also start fire in these places. Engine fires from car parks and garages can be devastating. Petrol stations are also a risky source of fire. From the table, the number of hotels are more, followed by car parks, petrol stations then others as shown on table 4.2 above. The table also indicates the total number of buildings in each possible fire source. The apartments was leading on the list of sum of buildings, followed by hotels and staff and students’ housing which implies that the contribution to average fire Breakout within the study area take the same hierarchy. Petrol stations can be a major contributor to fire within the study area.
Figure 4.5. A bar graph of possible fire sources within CBD and its environment.

The graph in figure 4.5 above shows a summary of possible sources of fire within the CBD and its environs drawing comparisons between the land uses in terms of quantity coverage within the area of study.

4.2.2 A map of distribution of fire stations in Nairobi County and their particular location

Figure 4.6. The map of distribution of public fire station within Nairobi County

Source: Author
The map in figure 4.6 shows the distribution of fire public fire stations that serve the entire Nairobi County. From the map, there are only two fire stations and one fire staff quarters. According to Nairobi county council fire station head office, there is one more fire station, not shown on the map, at Ruaraka area. This makes it only a total of three fire stations within Nairobi County.

Table 4.3. Population projection estimates of Nairobi County from 2009 to 2030

<table>
<thead>
<tr>
<th>City</th>
<th>2009</th>
<th>2013</th>
<th>2018</th>
<th>2023</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nairobi City</td>
<td>3,138,372</td>
<td>3,601,351</td>
<td>4,174,952</td>
<td>4,677,677</td>
<td>5,212,500</td>
</tr>
</tbody>
</table>

Source: JICA Study Team (JST) and Census 2009 data

From table 4.3 above showing population projection from 2009 to 2030, at such a time, the total population in Nairobi County is over 3 million. It is hard to imagine that only three fire stations can serve such a population. In other words, one fire station serves over one million people.

Figure 4.7. Locations of Existing Fire stations in Nairobi County

Source: JICA Study Team (JST) and Census 2009 data

The Figure 4.7 above shows Nairobi county inset map that gives exact locations of fire stations existing within Nairobi County. The coordinate grid on the inset enables exact location of these important facilities.
According to Nairobi county council fire Station, there are other fire response teams in private sector for example; KK, G4S, SECUREX, RADAR and others. There are also those from other government institutions like National Youth Service (NYS), Kenya Defense Forces (KDF) and Kenya Wildlife Service (KWS). This alternative fire response teams do not respond to public fires unless invited by the Nairobi County Council fire station head office. However, they take long to respond because of long protocols in their institutions, before dispatch of their fire rescue teams, especially those from discipline forces such as KDF and NYS. This paints other agencies unreliable.

4.2.3 Fire assembly points distribution and Prediction map

_Figure 4.8. Map showing the distribution of fire assembly points and prediction by interpolation contours._

Source: Author

The map in figure 4.8 above shows the distribution of marked fire assembly points within the study area. The assembly points were not picked to detail and hence inverse distance weighting (IDW) interpolation was used to predict the general distribution of the assembly points. The symbology used was the contour lines. From the map, it is evident that the fire assembly points are concentrated.
to the northern part of the study area and sparse to the southern part which is also depicted by the interpolation contours shown on the map.

4.2.4 Fire hydrants distribution map

*Figure 4.9: Distribution of fire hydrants within the area of study*

Source: Author

The map in figure 4.9 above shows the distribution of fire hydrants within the study area. From the map, fire hydrants are highly concentrated the Centre of the map which is the Centre of Nairobi Central Business District. This place is full of a mixture of commercial and institutional buildings as revealed by the land use map (figure 4.2). Most of this buildings are high-rise. This highly mixed land use at the core of the city implies high risk of fire breakout and huge losses associated with fire disasters. Furthermore, extinguishment of fire within the Centre of the city is difficult due to high rise buildings and high traffic congestion during the day, (both pedestrian and motorists) Therefore, it was established that concentration of fire hydrants was directly proportional to buildings congestion.
4.2.5 Fire hydrants 70M buffer map

The standard recommended radius serviced by one fire hydrants is approximately 70Meters. The reason being that one horse pipe from a fire engine is 30meters long and several horses can be linked, although two liked horse length is more convenient. (From questionnaire results of Nairobi county council fire station, fire experts).

*Figure 4.10.* Fire hydrants buffer map of 70 meters divided in 30m, 50m, and 70m radii from each hydrant

The map in figure 4.10 above, indicates the service area by each fire hydrant (70Meters Euclidean buffer zones). The 70 meter buffer is divided into three zones; 30 meter radius, 50 meter radius and 70meter radius. The Building facilities indicated by small green dots (building centroids created by conversion of building polygons into point features using ArcGIS software), that are found within 30 meters radius are well serviced with fire hydrants while those found to the extreme region of 70 meters radius from the fire hydrants are a little bit strenuous to be reached, since it would be required to join more horse pipes from the fire engine in order to be reached. One standard horse pipe is 30Meters long. (From questionnaire results of Nairobi county council fire station’s fire experts). On the map, it is evident that more buildings on the north-western region of the study area are outside the recommended radius from a fire hydrants.
4.2.6 Streets and road network map

Figure 4.11: Distribution of road networks and major streets within the area of study, map

The figure 4.11 above is a map showing major streets and road network within the area of study and the environs, which are essential in terms of accessibility of the area. Under ideal conditions with other factors such as traffic jams, in case of fire breakout, the fire engines would respond within the shortest time possible to the fire scenes. From the map, it is evident that the study area is highly accessible. This map supplements information of proximity of buildings to roads shown in table 4.5. Therefore it can be said that the area is well prepared in terms of accessibility to fire disaster scenes in case of any fire occurrence within the extents of the study area.

Source: Author
4.2.7 Network analysis dataset.

*Figure 4.12.* A map of road network connectivity done by network analyst tools in ArcGIS software

The map in figure 4.12 above shows road network connectivity. The network analysis was carried out using road network dataset and it was established that the entire study area had roads which connect. There was no unconnected roads within the study area. Green nodes on the map indicates junctions of road connections. The analysis was done by network analyst tools in ArcGIS software. Therefore, it was established that accessibility within the area of study by ambulances and fire engines in case of fire break out was good, due to absence of dead end roads. This network datasets was used to create other layers that was used to assess the preparedness of the study area against fire. The example of this layers were; service area map, and optimal route layer.
4.2.8 Health facilities within an approximate 2 kilometers Radius from Uhuru highway-Kenyatta Avenue Round-about.

Figure 4.13. A map of health facilities within 2 kilometers radius from Uhuru highway-Kenyatta avenue roundabout.

Source: Author

Fire disaster is associated with many injuries including loss of life. Therefore, while assessing the fire preparedness of Nairobi CBD and its environs, it was vital to map health facilities within 2 kilometers radius in the study area as shown in figure 4.13 above.

Table 4.4: number of healthy facilities within neighbouring county wards in 2KM radius from study area

<table>
<thead>
<tr>
<th>County Ward</th>
<th>Number Of Health Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CITY CENTRE</td>
<td>7</td>
</tr>
<tr>
<td>CITY SQUARE</td>
<td>7</td>
</tr>
<tr>
<td>HIGHRIDGE</td>
<td>3</td>
</tr>
<tr>
<td>KENYATTA</td>
<td>3</td>
</tr>
<tr>
<td>KILIMANI(NAIROBI)</td>
<td>7</td>
</tr>
<tr>
<td>LANDI MAWE</td>
<td>2</td>
</tr>
<tr>
<td>NGARA WEST</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Author
The total number of the facilities were thirty, hence it is deduced that the area of study is well prepared in terms of medical emergencies that may arise in case of fire Breakout. The table 4.4 above was generated by ArcGIS software.

4.3.0 Proximity table showing average distance from buildings to roads, Fire hydrants, fire assembly points and open grounds.

The assessment of how the city is ready to deal with fire prevention and breakouts, the proximity analysis was carried out to establish average distance to existing fire facilities from buildings.

Table 4.5: a proximity table indicating approximate distances each building is from the firefighting facilities

<table>
<thead>
<tr>
<th>Fire preparedness Facility</th>
<th>Minimum Proximity Distance (Meters)</th>
<th>Maximum Proximity distance (Meters)</th>
<th>Average proximity distance (Meters)</th>
<th>Standard deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire assembly points</td>
<td>0</td>
<td>62</td>
<td>21.8</td>
<td>17.4</td>
<td>304.0</td>
</tr>
<tr>
<td>Fire hydrants</td>
<td>0</td>
<td>57</td>
<td>12.9</td>
<td>15.3</td>
<td>233.7</td>
</tr>
<tr>
<td>Health facilities</td>
<td>0</td>
<td>19</td>
<td>4.1</td>
<td>7.1</td>
<td>49.8</td>
</tr>
<tr>
<td>Open grounds</td>
<td>0</td>
<td>49</td>
<td>9.4</td>
<td>11.8</td>
<td>138.2</td>
</tr>
<tr>
<td>Roads</td>
<td>0</td>
<td>96</td>
<td>11.2</td>
<td>15.6</td>
<td>243.8</td>
</tr>
</tbody>
</table>

Source: Author

The table 4.5 shows proximity of buildings to the listed fire rescue and emergency facilities within the study area. The table was generated by proximity tool in ArcGIS software. The table shows minimum, maximum and average distance each building in the study area is, from facilities that boosts fire extinguishment, accessibility to disaster scenes, medical emergency to fire casualties and evacuations. From the table, for example, the furthest building to a fire assembly point is 62 meters and minimum distance is Zero meters, however, on average, every building is 21.8 meters from each assembly point. The results therefore, implies that the study area in terms of fire preparedness facilities, it is fairly prepared. The table also shows standard deviation and variance.
4.2.9 Service area map; 3minutes, 5minutes, 10 minutes and >10minutes service areas

Figure 4.14 A map of zones of time taken to respond to a fire, from Nairobi county council fire station head office.

Source: Author

The map in figure 4.14 shows response time zones to an incident in part of the area of study, this map can be used by fire department to strategically come up with a response plan for the zones owing to the limited resources compared to the area of coverage. The map was created through road network analysis process. On the map it is also possible to dynamically solve for the optimum route to a fire incident depending on the time of the day as shown by the optimum route (point 1 to point 2 route) on the map. The factors that are input in the analysis of the network are restrictions like one-way routes, historical information of traffic jams on specific routes at different times of the day and roundabouts. These factors are used by the ArcGIS software to solve the network for optimal response route to a fire incident.

From the map, it can be deduced that; if it takes close to 10minutes to respond to a fire incident within the central business district of Nairobi, then it will be difficult to cover a wide area before significant fire damages. Noting that fire growth from ignition to destructive stage, takes seconds.
4.3.0 Route layer (dynamic map); optimal routes from a fire station to a point of fire incident at Uchumi Supermarket.

Figure 4.15. A dynamic map showing an example of optimal fire response route determination using GIS

Source: Author

Figure 4.15 above was a dynamic map created as a route layer by road network analysis, using ArcGIS software. It indicates the optimal route to a fire incident at Uchumi Supermarket, from Nairobi county council fire station. The softwares considers factors mentioned earlier in figure 4.14 (Traffic jams, one-way routes, roundabouts).the directions in terms of streets and road names was displayed immediately after solving the network from point 1 (Fire Station) and point 2(Uchumi Supermarket) as shown on the map. The displayed direction text for the route established in figure 4.15 is as shown in figure 4.16 below;

Figure 4.16. Textual direction display of optimal route shown in figure 4.15 above.

Source: Author
4.3.1 Questionnaire study results and analysis.

The questionnaires were analyzed by a statistical methods and the results was as shown below:

1) Major Causes of fire within CBD and its Environs

   a) Nairobi County Council fire station Respondents results

   Figure 4.17. Most to least likely cause of fire in the CBD and its environs (fire expert’s response)

<table>
<thead>
<tr>
<th>Fire Cause</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faulty Electrical installation</td>
<td>19.70%</td>
</tr>
<tr>
<td>Human Carelessness</td>
<td>30.03%</td>
</tr>
<tr>
<td>Gas Leakages</td>
<td>20.33%</td>
</tr>
<tr>
<td>Flammable Liquids</td>
<td>13.15%</td>
</tr>
<tr>
<td>Arson</td>
<td>16.79%</td>
</tr>
</tbody>
</table>

   b) General Public Response results (University of Nairobi Students and Workers)

   Figure 4.18. Most to least likely cause of fire in the CBD and its environs (general public’s response)

<table>
<thead>
<tr>
<th>Fire Cause</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faulty Electrical installation</td>
<td>26.30%</td>
</tr>
<tr>
<td>Human Carelessness</td>
<td>21.00%</td>
</tr>
<tr>
<td>Gas Leakages</td>
<td>18%</td>
</tr>
<tr>
<td>Flammable Liquids</td>
<td>12.90%</td>
</tr>
<tr>
<td>Arson</td>
<td>21.80%</td>
</tr>
</tbody>
</table>

The comparison between response of the fire experts and the general public indicates a sharp ignorance of the public on matters of fire. The fire experts that responded to questionnaires had work experience of 1 year to 34 years. This implies that there response was as good as standard, which was used to evaluate the general public response.
2) Fire Drill involvement

Figure 4.19. Public participation in fire drills and trainings

<table>
<thead>
<tr>
<th>Participation in fire drills</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever participated</td>
<td>30%</td>
</tr>
<tr>
<td>Never participated</td>
<td>70%</td>
</tr>
</tbody>
</table>

3) Awareness of evacuation procedures and presence of fire signs and equipment in buildings

Figure 4.20. Public awareness of presence of fire evacuation procedures, signs and equipment in buildings

<table>
<thead>
<tr>
<th>Aware/Not aware</th>
<th>Percentage Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aware</td>
<td>80%</td>
</tr>
<tr>
<td>Not Aware</td>
<td>20%</td>
</tr>
</tbody>
</table>

4) General fire preparedness rating by respondents in the University of Nairobi

Figure 4.21. General rating of fire preparedness within the University of Nairobi

<table>
<thead>
<tr>
<th>Level</th>
<th>Percentage response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>0%</td>
</tr>
<tr>
<td>Very Good</td>
<td>0%</td>
</tr>
<tr>
<td>Good</td>
<td>60%</td>
</tr>
<tr>
<td>Poor</td>
<td>40%</td>
</tr>
<tr>
<td>Worst</td>
<td>0%</td>
</tr>
</tbody>
</table>

Source: The graphs and pie charts were generated from the questionnaire results which were designed administered and analyzed by the author.
Figure 4.17 shows the response results of Nairobi fire station experts. The results shows that the major cause of fire within the CBD and its environs was human carelessness and the least was flammable liquids. Owing to fire experts’ work experiences at the fire station of between 1 years to 34 years, their response was treated as standard. On the other hand, the general public represented by the University of Nairobi Students and workers (Figure 4.18), indicated the major cause of fire within the CBD and its environment was faulty electrical installations and the least cause was flammable liquids. The response of the general public (represented by university of Nairobi students and workers) on the causes of fire within the study area, compared to the fire experts response, indicates a sharp ignorance of the public on issues of fire.

Figure 4.19 shows that only 30 percent of the general public have participated in fire drills. Figure 4.20 indicates that 70 percent of the general public are aware of evacuation procedures and the presence of firefighting equipment within buildings. Figure 4.21 reveals that according to University of Nairobi students and workers, the general preparedness of the University of Nairobi against fire was between good and poor, 60 percent believing that the level of preparedness was good.

According to fire experts at the Nairobi fire stations, the challenges that are encountered by fire personnel during fire extinguishment are; ignorant public on responding to fire emergencies such as using lifts in high rise buildings as opposed to using stairways and use of cars to escape fire, congestion especially during the day both onlookers and traffic jams, rowdy members of the public especially if the fire cause was arsonist, inadequate serviced equipment ,few fire personnel as compared to the area of coverage and media misreporting on fire escapades.

4.4 General Analysis
The study area was found to be a base for residential apartments, commercial land use, recreational, open spaces and a mixture of commercial and institutional. The commercial land use was composed of hotels, restaurants, petrol stations and recreational facility such as clubs among others. This land use mentioned have proven to be possible sources of fire within the CBD and its environs from previous fire breakout history. (Figure 4.2, Figure 4.3, Figure 4.4)

From the results, the Nairobi central business districts (CBD) and part of its environs, is fairly prepared in terms of installations of fire facilities such as water hydrants, fire assembly points, open spaces and recreational facilities (can be used as evacuation grounds) and in-house fire equipment installations as well as fire signs (Figures 4.8,4.9,4.10,4.12) . The area of study is highly connected
in terms of road network implying that the area is highly accessible (Figures 27, 28). Within a radius of 2 kilometers, it was established to be having thirty health facilities, fairly distributed and well connected to roads (Figure 4.13, Table 4.4). Proximity analysis of individual buildings to each fire preparedness facility resulted to be fairly good, with average proximity distances ranging from 4 meters to 21 meters (Table 4.5).

However, there have been fire occurrences in the recent past within the study area that have caused loss of property worth millions of shillings! (Mutungi and Maingi 2010). It was established from the results that there was only three public fire stations within the whole Nairobi County! (Figure 4.6). A county with a population of over 3 million people (JICA, 2009, census projections, table 4.3). Other fire rescue agencies such as private firms for example G4S and government agencies for example; Kenya Defense Forces (KDF), National Youth Service (NYS), Kenya Wildlife Service (KWS), follow long protocols before dispatching their fire rescue teams to a public fire breakout. This leads to delay therefore loss of significant properties and lives. (Nairobi County Council fire experts)

According to Nairobi County Council fire experts, although, the fire breakout occur as a result of electricity failures, gas leakages, petrol ignitions and other causes, they are mostly attributed to human carelessness in handling electrical equipment and fuels (Figure 4.17). Despite of the public being aware of the presence of fire evacuation procedures, signs and firefighting equipment within buildings, (Figure 4.20), the public is less involved in fire drills of how to respond to fire breakouts, and the use of in-house installed fire equipment to put off fire at its initial stages (Figure 4.19). This contributes significantly to fire damages in case of fire breakout. Traffic jams have reached chronic stage in Nairobi CBD, according to fire experts, these traffic jams cause a lot of delay of fire engines during response to fire disasters. From the questionnaires administered it was found that the three fire station within Nairobi county are further stretched in terms of number of fire engines (Head station had only six fire engines, with only two operational at the time of this study) and inadequate fire response personnel.
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion
The specific objectives of this study were achieved to a tremendous extent which finally led to achieving the main objective of this project. The mapping of fire facilities was achieved and the evaluation of their suitability in location and distribution done using Geographic Information System (GIS) technology. The major findings of the study was that; within the study area, external measures put in place such as fire hydrants, fire assembly points, were fairly satisfactory. The distribution of health facilities within a radius of 2 kilometers was quite good with a total of thirty health facilities that are well connected to roads.

The road network was extremely well connected implying the high accessibility of the study area. However, the well connected road network experience traffic congestions, which delay movement of fire engines to fire scenes. Shockingly, the number of fire stations within the whole Nairobi County, leave alone the study area, was alarming; with only one main fire station at Nairobi CBD and two other substations at Viwandani area and Ruaraka area (figure 4.7). These few fire stations serve close to four million people within the city (JICA population projection, 2009 census), with strained personnel and equipment. It was also noted that the public is not sensitized on the use of in-house firefighting installations and how to respond to fire breakout.

From the findings, it can be said authoritatively that the major fire damages occur due to;

i) Traffic congestions (both human traffic and motorists), especially during the day.
ii) Very low number of fire stations to population ratio.
iii) Poorly equipped fire stations in terms of fire engines and personnel (fire men and women)
iv) Inadequate public sensitization on how to respond to fire breakouts and how to use in-house fire equipment installations and on which extinguishing agent to use on different fire types.
v) Long protocols followed by other government agencies like NYS and KDF before responding to assist in public fire extinguishment when called upon by public fire response teams.

Therefore, it can be concluded that the area is partially prepared for major fire disasters.
5.2 Recommendations

The activities and measures that should be undertaken to ensure the Central Business Districts (CBD) and its environs is well prepared to deal with major fire disasters when they occur as well as prevention of the avoidable fires, include:

1. **Number of fire Stations**: more substations should be installed in area where they are urgently required across the whole county of Nairobi. These can be done by using previous report’s findings for example a study done by JICA, 2009 which recommended that Nairobi County needs a minimum of 35 fire stations. The Fire stations should be well equipped in terms of modern fire engines and firefighting personnel, including fire expert’s spokesperson to avert media misreporting on fire escapades.

2. **Creating Public awareness and sensitization**: by conducting fire drills in learning and government institutions at all levels within the study area and the surroundings, to teach the public on how to respond to fire breakout. How, when and where to use in-house fire equipment and installations, and the use of media adverts to relay fire response skills to the general public. Firefighting life skills should be incorporated in the curriculum of learning institutions.

3. **Partnerships of public fire rescue and private fire agencies**: the public fire stations should enter into contract with private fire rescue teams in the sense that the private agencies can respond to public fires at any time and bill it on the government.

4. **Decongestion of roads**: by rerouting public service vehicles (PSV) outside the CBD and proper control and coordination of traffic by enforcing traffic rules and regulations by the authorities. Introduction of emergency lanes

5. **Legislations**: Revision of fire policy 2010 to conform to the current demand of the city in terms of fire safeguarding, prevention and mitigation, and enforcement of risk reduction rules 2007, by Nairobi County Council.
REFERENCES


6. Disasters in Kenya: A major public health concern, a full length research paper by Marion W. Mutugi* and Samuel G. Maingi

7. GIS For Fire Station Location and Response Protocol, An ESRI white paper, 2007

8. Fire Lane Standards, City of Mercer Island, Washington
APPENDIX: QUESTIONNAIRE SURVEY

UNIVERSITY OF NAIROBI
DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY
QUESTIONNAIRES FOR INVESTIGATION OF FIRE PREPAREDNESS
CASE STUDY: NAIROBI CBD AND ENVIRONS

Dear sir/madam,

The researcher is a fifth year geospatial engineering student carrying out a study on **application of GIS in mapping and evaluation of fire preparedness** within urban centers, among residents, building occupants, fire department management and the general public with the case study, Nairobi CBD and its environs.

Questionnaire number…………………………………………………………

Date of administration…………………………………………………………

Section A

1. Have you ever witnessed/experienced/heard off a fire outbreak
   - Yes □ No □
   - How many incidences have you witnessed/experienced or heard off?
     ………………………………………………………………………………………………………..

2. If Yes to the above question, which step did you take towards extinguishing the fire?
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………

3. Are you aware of any preparations towards fire by the institution you are in or working in?
   - Yes □ No □

4. If yes to the above question, what are the preparedness measures that you have encountered?
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………

5. Are you conversant with fire evacuation procedures in buildings/library/lecture halls as well as fire signs?
   - Yes □ No □
   - If No to the number 5 above, what is your reason?
     ……………………………………………………………………………………………………………
     ……………………………………………………………………………………………………………

6. From the above mentioned measures, have you ever participated in the trainings and awareness of how to use in house fire equipment installations in case of fire?
   - Yes □ No □
If NO to the above question, what do you think are the reasons?

…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

7. With the knowledge of various measures of fire preparedness in your environment, in case of fire, are you willing to follow or use the measures in assisting in fire extinguishment?

Yes ☐ No ☐

What is your reason for your answer above?

…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

8. According to you, what are the causes of fire that you know of?

Rank from the most common to the least common (1-Most common to 5-Least common)

a) Faulty electric installation ☐
b) Gas leakages ☐
c) Human carelessness e.g. cigarette disposal ☐
d) Flammable liquids ☐
e) Arson ☐
f) Any other (specify)………………………………………………………………..

9. From the general causes named in number 5 above, rank in chances of occurrence, the most likely cause of fire in Nairobi Central Business District (CBD) and the University of Nairobi. Use the following criteria to rank the cause:

1-Highest, 2-High 3-Moderate 4-Low 5-Lowest

g) Faulty electric installation ☐
h) Gas leakages ☐
i) Human carelessness e.g. cigarette disposal ☐
j) Flammable liquids ☐
k) Arson ☐
l) Any other (specify)………………………………………………………………..

10. How would rate the level of fire preparedness of your institution?

Excellent ☐ Very good ☐ Good ☐ Poor ☐ Worst ☐

11. In your opinion, what are your recommendations to relevant bodies or persons in terms of fire preparedness within your locality/institution?

…………………………………………………………………………………………………………
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

50