



UNIVERSITY OF NAIROBI
SCHOOL OF ENGINEERING

**MULTIMODE NETWORK FOR LOCATING NEAREST
PETROL STATION**

(A case study of petrol stations within Nairobi CBD)

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**A project submitted to the Department of Geospatial and Space Technology in
partial fulfillment of the requirements for the degree of
Master of Science in GIS**

DECLARATION

I declare that this Project report is the result of my research except as cited in the references. This report is not concurrently submitted in candidature of any other degree.

Signature _____ Date _____

Titus M. Ng'ang'a

This project has been presented for examination with my approval as the University supervisor.

Signature _____ Date _____

Professor R. S. Rostom

DEDICATION

Dedicated to my family

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ABSTRACT

Many times, tourists face a situation where they are lost in a new place and do not know how to reach their desired destination. Sometimes they face an emergency situation like running out of petrol but don't know the locality of the nearest petrol station. There is therefore need for route guided interactive maps.

The interactive map allows the tourist to find the nearest petrol station. Searching is by the way of incidences. The incidence is shown by computer guided Global Positioning System. The tourist clicks on the current position/incidence and then chooses the number of nearest petrol stations of interest for viewing.

The interactive map provides visual analysis. A tourist can identify the nearest petrol station and the availability of a service, among other things.

The queries performed on the multimode road network dataset are evident that mapping of petrol stations and network analysis can lead to informed decision making. Similar decisions could be achieved through the same concept eg locating the nearest hospital by ambulances in case of emergencies and whether such facilities such as Intensive Care Unit are offered.

LIST OF ACRONYMS

CARS	Computer-Aided Routing System
CBD	Central Business District
ERC	Energy Regulatory Commission
GIS	Geographic Information System
GIS-T	Geographic Information Systems for Transportation
GPS	Global Positioning System
IT	Information Technology
JKIA	Jomo Kenyatta International Airport
KEBS	Kenya Bureau of Standards
KPC	Kenya Pipeline Company
KPRL	Kenya Petroleum Refineries Ltd
NCBD	Nairobi Central Business District
NEMA	National Environmental Management Authority
NOCK	National Oil Corporation of Kenya
PIEA	Petroleum Institute of East Africa
UFTAA	Universal Federation of Travel Agents Association
IATA	International Air Transport Association
ICU	Intensive Care Unit
UTM	Universal Transverse Mercator

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1.0 INTRODUCTION

1.1 Background Information

Diesel and Unleaded Petrol

Diesel is generally easier to refine than unleaded fuel and contains a slightly higher calorific value (around 17% higher than unleaded). Diesel engines are more efficient than petrol engines as they can obtain higher compression ratios and still do not suffer from 'engine knock' whereby the fuel ignites at the wrong time in the cycle (PIEA, 2009).

Unleaded fuel was born out of the health concerns associated with leaded petrol. The lead in fuel was used as an anti-knock agent that prevented the engine from misfiring. Instead of the lead the fuel contains a number of hydrocarbons. These compounds also have health concerns and are sometimes linked to causes of cancer (PIEA, 2009).

The Kenya Pipeline Company (KPC)

KPC was incorporated on 6th September 1973 under the Companies Act (Cap 486) and started commercial operations in 1978. KPC operates a pipeline system for transportation of refined petroleum products from Mombasa to Nairobi and western Kenya towns of Nakuru, Kisumu and Eldoret.

The overall objective of setting up KPC was to provide the economy with the most efficient, reliable and least cost means of transporting petroleum products from Mombasa to the rest of the country.

In collaboration with the government, KPC facilitates the implementation of Government policies, acts as a government agent in specific projects as directed through the Ministry of Energy, assists in the fight against fuel adulteration and dumping, ensures efficient operation of petroleum sub-sector.

Unlike some state corporations, KPC does not depend on government subsidies but is a source of revenue to the Government in terms of dividends and taxes.

1.11 Petroleum regulatory framework for retail

The Energy Act, 2006 became operational on July 7th 2007. The main activities covered in the Act are road transportation, storage and Transportation by sea. It recognizes NEMA and KEBS in the petroleum sector, establishment of Energy Regulatory Commission (ERC) and establishment of the Energy Tribunal.

The functions of ERC includes regulation (importation, exportation, transportation, refining, storage, sale of petroleum and petroleum products), protecting interests (of consumers, investors and other stakeholders), maintaining list of accredited energy auditors and fair competition in the energy sector (PIEA, 2009).

1.12 Structure of the oil industry

Prior to liberalization in October 1994, the government owned substantial stake in supply, storage and transportation of petroleum products. The marketing aspect was exclusively in the hands of the private sector where marketing and distribution companies were responsible for importation and distribution of petroleum products.

The National Oil Corporation of Kenya (NOCK), a wholly owned government company, was mandated to supply 30% of all crude oil requirements to the country for processing at the Kenya Petroleum Refineries Ltd (KPRL).

During the liberalization process, a number of reforms were implemented in the petroleum industry with a view to improving the operational efficiency of the sector, attracting private investments and promoting competitive sourcing and pricing of petroleum products (Ministry of Energy, 2009).

Road Transport

The road transport is entirely in the hand of the private entrepreneurs, who use road tankers to distribute petroleum products from depots in major towns to bulk consumers and retailers, and also to the neighbouring countries. Road transport rates are negotiated between the marketing companies and road transporters (PIEA, 2009).

Road transport is ideal for direct customer deliveries. The main concerns are lack of professionalism by transporters, poor enforcement of standards, products security issues, e.g adulteration and theft, accidents and spills and damage to roads (Ministry of Energy, 2009).

OIL companies

Regional oil companies include Kobil, Engen, Petro, Gapco. Local oil companies include National, Triton, Metro, Galana. Independent service services stations buy products from cheapest supplier. About 30% of service stations are independent (Ministry of Energy, 2009).

Depots within Nairobi Area

Depots relating to petrol stations within NCBD include the Joint depot (Chevron Kenya Ltd, Kenol Kobil and Total), Shell depot, Libya Oil depot and National Oil depot.

Imports sources for Oil in Kenya

The Middle East is the main source of crude oil and refined products. It has the advantage of both distance and availability to the African market. On occasion, products are sourced from other areas.

Licensing of petroleum business

All importers, wholesalers and exporters are licensed by ERC after meeting defined criteria. Service stations are currently licensed by provincial administration (PIEA, Feb 2009).

1.13 Tourism sector

Tourism generates an estimated US\$500 million per year in hard currency earnings, making this sector the country's single largest source of foreign exchange (Crawley M, 2000).

Kenya is a country with a well structured and organized transport system. For the vehicles to run smoothly the government is taking efforts to improve the roads and national highways of Kenya. The national highways run long distances connecting important points and cities of Kenya. Presently the conditions of the highways have been improved. There are petrol stations on most national highways. Restaurants, bars and lodges are also present along the highways for the convenience of the travelers and drivers

(<http://www.mapsofworld.com/kenya/transportation/national-highways-of-kenya>).

Kenya's tourism sector is a thriving growth industry, and presents many excellent opportunities for investment. We encourage both local and foreign investment in tourism, as means of encouraging development and alleviating poverty.

Tourist businesses include hotels, restaurants, tour operators and other businesses. Most Tourism Businesses in Kenya pay a Catering and Tourism Development Levy. These funds are utilized by levy, which is charged with the mandate of developing the Kenyan tourism industry through sponsorship of marketing and development of standards (<http://www.tourism.go.ke/ministry>).

Tourism associations

Kenya's well established Tourism sector is strengthened and united by several public and private sector associations. The following organizations can provide a great deal of useful information and resources on Kenyan tourism (<http://www.tourism.go.ke/ministry>):

Kenya Association of Tour Operators

The Kenya Association of Tour Operators is Kenya's leading tourism trade association, representing the interests of some 200 experienced professional tour operators (<http://www.tourism.go.ke/ministry>).

Kenya Association of Travel Agents

The Kenya Association of Travel Agents is a national organization comprising of mainly International Air Transport Association (IATA) agents. The association is a member of UFTAA, the Universal Federation of Travel Agents' Association representing 84 countries with its headquarters in Brussels (<http://www.tourism.go.ke/ministry>).

The Eco-Tourism Society of Kenya

Ecotourism Kenya is a civil society organization that promotes ecotourism and sustainable tourism practices in Kenya. Founded with enormous industry support, the society is charged with the responsibility of providing the required support for the development of ecotourism and sustainable tourism in the country (<http://www.tourism.go.ke/ministry>).

Kenya Association of Hotelkeepers and Caterers

The Kenya Association of Hotelkeepers and Caterers is a company with no share capital. The Association hosts and celebrates diversity. It is the principal umbrella organization bringing together hotels, lodges, restaurants, membership clubs and prominent airline caterers whose all common theme is to render services in the hospitality industry (<http://www.tourism.go.ke/ministry>).



Photo 1 : A giraffe in Nairobi National Park, with Nairobi's skyline in the background
(http://en.wikipedia.org/wiki/Nairobi_National_Park).

1.13 Multimode Transport Network

A network is often defined as a graph that has at least one real-valued attribute or weight (e.g. length) associated with every edge (De Smith, Goodchild & Longley, 2009). Networks are the interconnected features that are used for transportation and include highways, avenues and city

streets. Networks are an important part of everyday lives and analysis of these networks improves the movement of people, goods, services and the flow of resources (Nancy E, 2003).

Multimodal Transport is the door-to-door movement of goods (non-interrupted flow of goods from origin to destination). It is an integrating factor or a chain that interconnects different links or into one complete process that ensures an efficient transport (<http://r0.unctad.org/en/subsites>).

Multimodal networks allow organizations in both the public and private sectors to better perform transportation planning analysis (<http://www.esri.com/software/arcgis/extensions/networkanalyst>).

In this project, highways, avenues and streets have been integrated to form the multimode transport network.

1.14 Shortest path in networks

A path between two vertices that minimizes a pre-defined metric such as the total number of steps, total distance or time, is called a shortest path. Hence this term (shortest path) is relative to the metric applied and even then may not be unique for any given network. Determination of shortest paths is often described as shortest path analysis (De Smith, Goodchild & Longley, 2009).

In order to make the output more meaningful, the highlighted route is also described with regard to details like the road to start, the roads to traversed, turns to left or right and distance of travel along each road (<http://www.gisdevelopment.net/application/Utility/transport>).

Finding the best way to a particular location is usually referred to as shortest path analysis. To determine the best way one needs at a minimum an origin and a destination. (Jochen A, 2007). The problem of identifying the shortest path along a road network is a fundamental problem in network analysis, ranging from route guidance in a navigation system to solving spatial allocation problems (Zeng W & Church R, 2009).

1.15 GIS and GIS-T

Geographic Information System (GIS)

GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (<http://www.gis.com/whatisgis>). Geographical

Information System (GIS) is a tool which has been employed for integration of spatial and non-spatial data. GIS is a specific integrated system of hardware, software and procedure designed to support capture, management, manipulation, analysis and display of spatially referenced data for solving complex planning and management problems (Mukti A, Srirama B & Pathan S, 2005).

Traditional approaches are no longer adequate for analyzing network flows and conducting minimum cost routing. GIS provides effective decision support through its database management capabilities, graphical user interfaces and cartographic visualization (<http://www.geog.utah.edu/~hmilller/papers/Wu-Miller-Hung>).

Geographic Information Systems for Transportation (GIS-T)

GIS-T refers to the principles and applications of applying geographic information technologies to transportation problems (Miller H & Shaw S, 2001). Bus companies can find the best routes by integrating GIS technology with GPS. Bus drivers can use GPS to find locations. Integration of GIS technology with GPS allows trucking companies to reach locations quickly. (Hosseini B, 2003). A country's transportation system represents development stage of that country (Mukti A, Srirama B & Pathan S, 2005).

Finding an efficient route is difficult problem for many drivers. Car Navigation Systems are sometimes offered as a special feature on new cars. These systems are capable of performing some of the tasks traditionally performed by driver, such as determining the best route to the destination. This process of finding shortest path from one point to another is called routing (Nazari S, Meybodi M, Salehigh A & Taghipour S, 2008).

Transportation infrastructure represents one of the largest and most critical investments made in any nation, at any stage of development. The movement of people and goods either domestically or internationally is vital to every aspect of that economy. GIS can be used to determine the location of an event or asset and its relationship or proximity to another event or asset. Information on bus routes, current location, subway stop location, emergency situations and locations, track condition, demographic changes, and employment centers are all factors that can be used to improve transit performance (Syed A, 2004).

For Kenya's tourism sector to remain dynamic, developing and in line with the changing needs of the international market, existing tourist businesses need to be flexible and adaptable to change. This not only means maintaining, upgrading and developing infrastructure and services, but also being aware of market changes and ensuring that products and services suit the interests, budgets and needs of the appropriate market. This requires continual reinvestment in business as well as the flexibility to make informed decisions to adapt business to market demands (<http://www.tourism.go.ke/ministry>).

1.2 Problem statement

Nairobi is a hub in the Eastern African countries and a tourist global destination. At times, motorists face an emergency situation like running out of petrol in the city but do not know where the nearest petrol station could be. However, there is lack of interactive maps for motorists.

1.3 Justification

There is need for route guided interactive maps to be made available. The study is significant for those organizations that wish to deploy spatially enabled location-based services in general as a platform for improved services.

1.4 Objectives of the study

1.41 General Objectives

The study demonstrates how GIS application (mapping of assets and linkage to datasets) could lead to decision making.

1.42 Specific Objectives

- (i) To generate a digital data of petrol stations consisting of a map indicating location, products and other services.
- (ii) Finding the nearest petrol station from a location, referred to as an incidence in ArcGIS.
- (iii) Making a digital map intelligent by linking it to attribute data.

1.5 Scope and limitations of the study

The study is limited to conspicuous company and independent stations. It excludes private stations that could exist even within private premises.

The price information was not accurate due to the ever changing prices of petroleum products.

Traffic data was not included in the study even though it would add value to the most effective route to a petrol station.

There are not enough vehicles fitted with GPS receivers in Kenya.

2.0 LITERATURE REVIEW

2.1 Global Positioning System (GPS)

GPS technology allows accurate determination of location (Dommety & Jain1998). The NAVSTAR system, operated by the Defence department of US, is the first such system commonly available to civilian users. The Russian system, GLObal NAVigation SatelliteSystem (GLONASS), is alike in operation to the NAVSTAR system (Dommety.R& Jain.R 1998).

Twenty-four satellites are in orbit, of which twenty to twenty-one are in operation. Four from these 21 satellites are visible at any time from any station on earth. The vertical and horizontal position for each specific station is feasible to be obtained in the form of X, Y, Z coordinates.

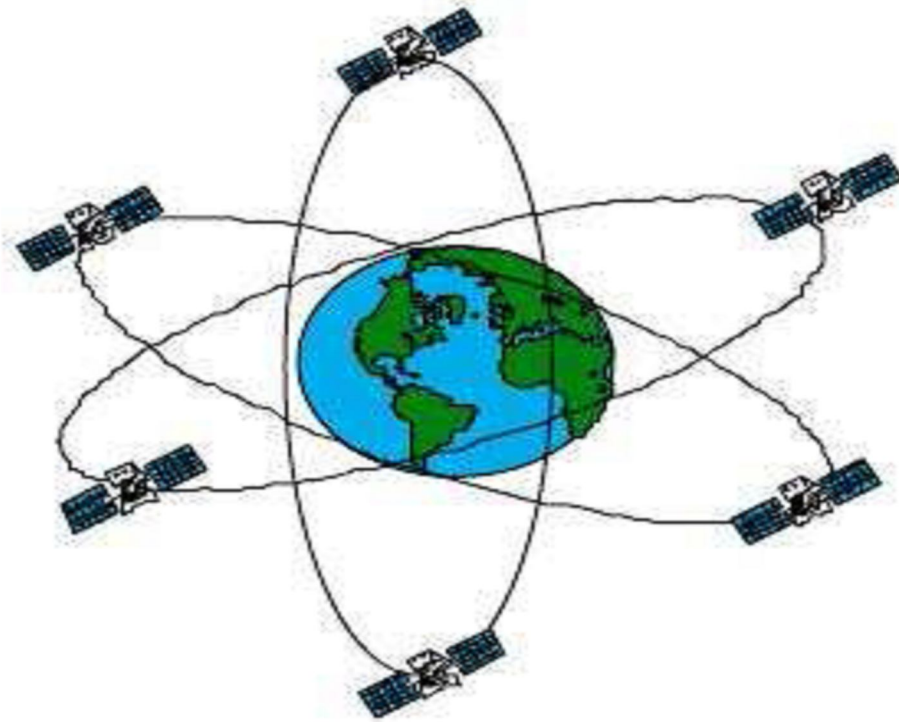


Fig 1: Global Positioning System

(GPS Information Technology Resource Management Guideline, 1994).

2.11 Limitations of GPS

GPS signals pass through charged particles in the ionosphere and water vapour in the troposphere. The signals may bounce off various local obstructions before getting to the receiver causing multipath errors. Minute time differences can occur within onboard atomic clocks.

GPS accuracy can be increased by differential mode, i.e simultaneously using data from two receivers provided that one of them is accurately known.

Receivers will attempt to correct the ionospheric and tropospheric errors bases on mathematical models which are very limited in their accuracy. They have no way of correcting for orbit errors, multipath or receiver noise.

GPS signals reception requires line of sight intervisibility between the satellites and the receiving antenna. GPS signals may be obstructed around skyscrapers, in tunnels and in city canyons. The GPS signal can be totally blocked (Nils H, 2007).

In order to get an accurate measurement from a GPS satellite, it is necessary that the signal from the GPS satellite travels directly from the satellite to the GPS antenna. If the signal has been reflected off of another surface prior to being received at the antenna, its length will be greater than was anticipated and will result in positioning error.

In this study, the handheld Garmin GPSmap 60cx GPS receiver was used to pick the locations of the petrol stations and had an accuracy of between 3-5 meters.

2.13 GIS Software

A network is a collection of linear features that are inter-connected such as highways, railways and city streets. When the linear features are joined together to form a single transportation network they are regarded as a multimode infrastructure.

Networks give the means for the movement of people, the flow of resources and energy and the communication of information (Haggett & Chorley, 1969) Network analysis in GIS provides good

decision support for users interested in finding the nearest facility and determining the service area (Pahlavani. P & Samadzadegan. F, 2006).

The ArcGIS Network Analyst extension allows you to build a network dataset and perform analysis on a network dataset. This extension is composed of a number of parts: a wizard to create a network dataset (in ArcCatalog), a dockable Network Analyst window (in ArcMap), a Network Analyst toolbar (in ArcMap), and a number of geoprocessing tools contained within ArcToolbox.

The Network Analyst Window helps you manage inputs to analysis and results. It displays objects, such as barriers, stops, and routes.

The Network Analyst toolbar is a combination of menus and buttons for adding and modifying network locations, generating directions, identifying network features, building networks, and performing analysis on network datasets.

The Network Analyst extension also supports the use and creation of layers in ArcMap, including the network dataset layer and the network analysis layer. The network dataset layer allows you to display and query the underlying network dataset.

The network analysis layer is the layer created through one of the Network Analysis operations. This layer can be used in further analysis, both within the ArcMap user interface and within the geoprocessing framework. It can also be saved as a permanent layer.

Network data structures must store the edge and vertex features that populate the network datasets, the attributes of those features, and most importantly for network analysis, the topological relationships among the features (<http://www.goliath.ecnext.com/Network-analysis-in-geographic-information.html>).

Labeling

ArcGIS, labeling refers specifically to the process of automatically generating and placing descriptive text for map features. A label is a piece of text on the map that is dynamically placed.

In ArcGIS:

- Label positions are generated automatically
- Labels are not selectable
- Display properties of individual labels can not be edited

Labeling can be a fast way to add text to your map, and it avoids you having to add text for each feature manually. In addition, ArcMap labeling dynamically generates and places text for you.

To control where labels are placed, the label placement properties were used. Label placement properties made it possible to specify where each label was placed on the map with respect to the feature being labeled.

2.14 Customization and Query

ArcGIS Spatial Analyst provides new functionality for advanced customization and interoperability. A key component of ArcGIS Spatial Analyst is the ability to perform queries. The query functionality gives the analyst the ability to leverage existing data and to make more informed decisions (ESRI White Paper, 2001).

2.2 Networks

Elements of geometric Networks used in the project

Nodes - A network is a system of linear features connected at nodes eg nodes could be where three or more street segments intersect.

Arc - The linear feature connecting any given pair of nodes is called an arc, or network link.

Direction - Each arc on a network is represented as an ordered pair of nodes

Shortest path - Is the shortest (or least 'cost' path) from a source node (origin) to a destination node. In practice, pathfinding seeks the shortest or most efficient way to visit a sequence of locations.

A turn on a network is the transition from one arc to another arc on a network.

Edges - An edge is a feature which has a length through which some travels along. Edges are created from line feature classes in a feature dataset.

Junctions - A junction is a feature that allows two or more edges to connect and facilitates the transfer of commodity between edges. Junctions are created from point feature classes in a feature dataset. Edges must connect to other edges at junctions.

Events or locations may be viewed as collection points e.g. origins or destinations. The events in the project are also regarded as Incidences and Facilities.

Representation of Network Attributes

- The key to network representation is to represent nodes, arcs and network topology efficiently.
- Once the nodes, arcs, and network topology are efficiently represented, other data and information associated with nodes, arcs, stops and turns can be represented as attributes either associated with nodes or arcs (Benjamin F, 2008).

The logical network

When a geometric network is created ArcGIS also creates a corresponding logical network, which is used to represent and model connectivity relationships between features. The logical network is the connectivity graph used for route analysis. In the project, the route analysis operation was finding the shortest route from an incidence in terms of distance (Impedance). All connectivity between edges and junctions is maintained in the logical network.

The logical network is managed as a collection of tables that are created and maintained by ArcGIS. These tables record how the features involved in a geometric network are connected to one another. The logical network allows ArcGIS to quickly discover and model the connectivity relationships between connected edges and junctions in a geometric network during editing and analysis. This allows for fast network tracing and facilitates the generation of on-the-fly connectivity while editing (Benjamin F, 2008).

When edges and junctions are edited or updated in the geometric network the corresponding logical network is automatically updated and maintained as well.

Sources and sinks

Networks are often used to model real-world systems where the direction of movement through the network is well-defined. Junctions in geometric networks can act as sources or sinks.

Geometric network features store various mechanisms and behaviors that maintain the topological connectivity between them. ArcMap editing capabilities can be used to create new network edges and junctions. By using the ArcMap snapping environment, one can create these features while maintaining network connectivity on the fly.

2.21 GIS and Networks

GIS contain data related to location points, lines (commonly roadway links and corridors), and polygons. Analysis tools that are part of GIS software packages can be used to relate these data. The use of GIS to manage data can simplify the analysis of transport systems and can enhance the decision-making process (<http://www.worldbank.org/transport/roads>).

In recent years, we have witnessed an increasing popularity of transportation related decision analysis within a GIS environment. In this type of analysis, the computation of shortest paths is often a central task because shortest path distances are often needed as input for "higher level" models in many transportation analysis problems such as facility location, network flows, vehicle routing and product delivery, just to name a few. With the advancement of GIS technology and the availability of high quality road network data, it is possible to conduct transportation analysis concerning large geographic regions within a GIS environment (<http://www.publish.uwo.ca/~jmalczew>).

GIS is being used to integrate, analyze and display spatial data. Because of the spatial nature of most transportation data, transportation professionals found GIS to be a powerful tool to construct and analyze transportation networks and to conduct impact assessment of transportation facilities. (Zhong-Ren P & Edward A, 1998).

The GIS capability of displaying graphics, while linking features to attribute tables has become a valuable tool for maintaining and updating roadway network files. Displaying the road network on a computer monitor is a very effective and efficient tool in observing the relationship between the spatial and physical attributes of roadway facilities. The ability of GIS to produce coloured maps has provided a visual dimension for travel demand analysis (Mezyad A, 2001). The application of GIS to a diverse range of problems in Transportation engineering is now well established. It is a powerful tool for the analysis of both spatial and non-spatial data and for solving important problems of networking (Mukti A, Srirama B & Pathan S, 2005).

GIS can be used as an effective tool in Managing and Planning transportation (Siddeswar P, 2003). Transportation professionals can integrate GIS as a decision support tool for applications such as network planning, vehicle routing, inventory tracking, and route planning and analysis (<http://www.urisa.org/node>). GIS is successfully used for Route planning and analysis, Bus dispatch and emergency response, Automatic vehicle location and tracking, Paratransit scheduling and routing, Bus stop and facility inventory, Accident reporting and analysis, Demographic analysis and route restructuring and Transportation planning and modeling, among others (http://www.mvcommission.org/GIS_for_transportation).

GIS has been recognised for many years now as an invaluable tool for managing, planning, evaluating, and maintaining transportation systems. As the gateway to economic development and, subsequently, a healthy economy, transportation infrastructure represents one of the largest and most critical investments made in any nation, at whatever stage of development. Similarly, for many firms in the transportation industry, profitability and a strong competitive position depend on a safe and reliable system. Roads are the main arteries of a modern society's infrastructure, contributing heavily to the distribution of goods and persons. GIS provides many helpful applications for ensuring a smooth transportation flow. Efficient operations require accurate, and timely, decision making. GIS can provide this critical information. Customer satisfaction, competitive position, timely response, effective deployment, and profitability are all positively affected (GISDATA Group, 2009).

2.22 Case Studies

The results of application of similar projects case studies depict numerous benefits including minimizing travel time, minimizing driving distances, reducing fuel consumption, providing driving directions to new drivers, estimating drive time and increasing the number of trips.

Riyadh's Municipality, Kingdom of Saudi Arabia

Riyadh's Municipality has adopted various GIS engines (software) regardless of vendors since they feature a so-called open system, GIS via localised database. Due to its compatibility, this certainly enabled various planning departments to use it. In GIS, a links attribute table, which contains links, characterised is attached to the network map. Using the GIS capability of displaying the network attribute table along with a graphic display, link attributes can be corrected and updated. In addition, results of travel demand analysis are attached and stored in the network attribute tables, such as a link's modelled volume, speed, and impedance. As needed, coloured maps of the roadway network displaying the different kinds of information are developed illustrating spatial relationships, temporal changes in travel needs, or locating facilities based on class, number of lanes, congestion and speed (Mezyad A, 2001).

Sears Holdings Corporation, USA

Sears Holdings Corporation is a megastore in the United States with nearly 900 full-line stores and 1,100 specialty stores and more than 48 million active customer households. It manages one of the largest home appliance repair businesses in the world, with six distinct geographic regions. More than 10,000 technicians throughout the United States complete approximately 11,000,000 in-home service orders each year. The business of supporting a mobile workforce requires good management, and Sears knew that GIS technology was the answer to routing. Sears teamed with ESRI Professional Services to build the Computer-Aided Routing System (CARS). CARS provide nationwide street-level geocoding and optimized routing for more than 10,000 mobile service technicians daily. The mobile Sears Smart Toolbox application contains a GIS module provided by ESRI for mobile mapping and routing, which gives in-vehicle navigation capabilities to assist in finding service locations and minimizing travel time (<http://www.esri.com/library/fliers/pdfs/cs-sears>).

Before using GIS, Sears manually managed the number of calls taken and routed them by hand.

With the GIS-based CARS system, the travel time has been reduced on average by approximately four minutes per call, which adds another one-half call per day completed on each technician's daily schedule. This addition increased the productivity of the technicians by more than 10 percent. Sears has found that the IT costs incurred to support the GIS are more than made up by the savings the technology provides (<http://www.esri.com/library/fliers/pdfs/cs-sears>).

Ivan Smith Furniture, USA

Ivan Smith Furniture retailer has 48 stores in Louisiana, Arkansas, and Texas and runs up to 23 delivery routes per day. Ivan Smith Furniture was using an outdated routing software product to create its routes. The older, less sophisticated tool required a dispatcher to manually assign stops to a particular driver and sequence the stops in what appeared to be the most logical order. The old software did not have the capability to accurately estimate drive times and sequence stops correctly over a real street network by taking into account the actual roads used, bridges, natural barriers, one-way streets, and so forth. Like many less sophisticated programs, it simply estimated drive times and suggested sequences (sometimes erroneously) based on straight-line distances. (http://www.esri.com/library/casestudies/ivan_smith_furniture).

Ivan Smith Furniture contacted ESRI, to help identify and implement a routing and scheduling solution that would give the company confidence that it was building optimal routes that reduced miles driven and fuel consumption. Esri's application ArcLogistics helps dispatchers quickly create route summary reports for detailed information on the cost of each route as well as provide maps and driving directions for drivers (http://www.esri.com/library/casestudies/ivan_smith_furniture).

DHL Express, Europe

DHL Express employs 550,000 people and manages the shipment of packages and goods in 220 countries. Staff members use ArcGIS Server to manage routes and stops, as well as edit geographic data when necessary. First, data entry staff enters the information for the next day's deliveries into the main computer system. The information is automatically loaded into ArcGIS Server, where shipment addresses are geocoded and checked against a map to determine the zone to which each shipment belongs. The zones are created based on routes and drivers. These zones are then clustered and optimized into tours based on allocation rules. All data is accessible to staff via handheld

computers. Being able to optimize the number of tours per terminal helps DHL minimize its fleet and the driving distances of each vehicle. Routes are optimized daily, which greatly reduces the effort and resources needed during peak shipment periods such as the winter holiday season (<http://www.esri.com/library/casestudies/dhl-express-europe>).

GreyHawk Technologies Inc, Washington, USA

GIS-based technology also helps increase driver productivity with the use of color touch- screen Mobile Data Computers installed in vehicle cabs. GreyHawk Technologies Inc., a systems Integration Company specializes in Mobile Data Computers for paratransit drivers who use specialized vehicles with wheelchair lifts to pick up and drop off elderly and disabled people. The onboard GPS is used to show on the touch- screen map exactly where the vehicle is located. With the touch of a button, the touch-screen system calculates turn-by-turn directions to get to the next stop and graphically displays the suggested path with blue colour highlighting on a map. This is ideal for newly hired drivers or substitutes because all they have to do is follow the blue line. To help drivers safely follow the blue line, Grey- Hawk developed the Follow Function. In this mode, the vehicle icon remains stationary in the middle of the map screen and always faces toward the top of the screen (straight ahead). As the vehicle moves along the streets represented by the blue line, the map rotates underneath. That way, if the blue line shows a left turn, the driver turns left and the map rotates underneath. This allows drivers to glance at the map to see upcoming turns in the same perspective as the view through the windshield, thus eliminating any confusion about which way to turn. The chances of making a wrong turn in the Follow Function mode are slim (Karl T and Susan H, 2006).

3.0 METHODOLOGY

Schematic Presentation – Flowchart of methodology

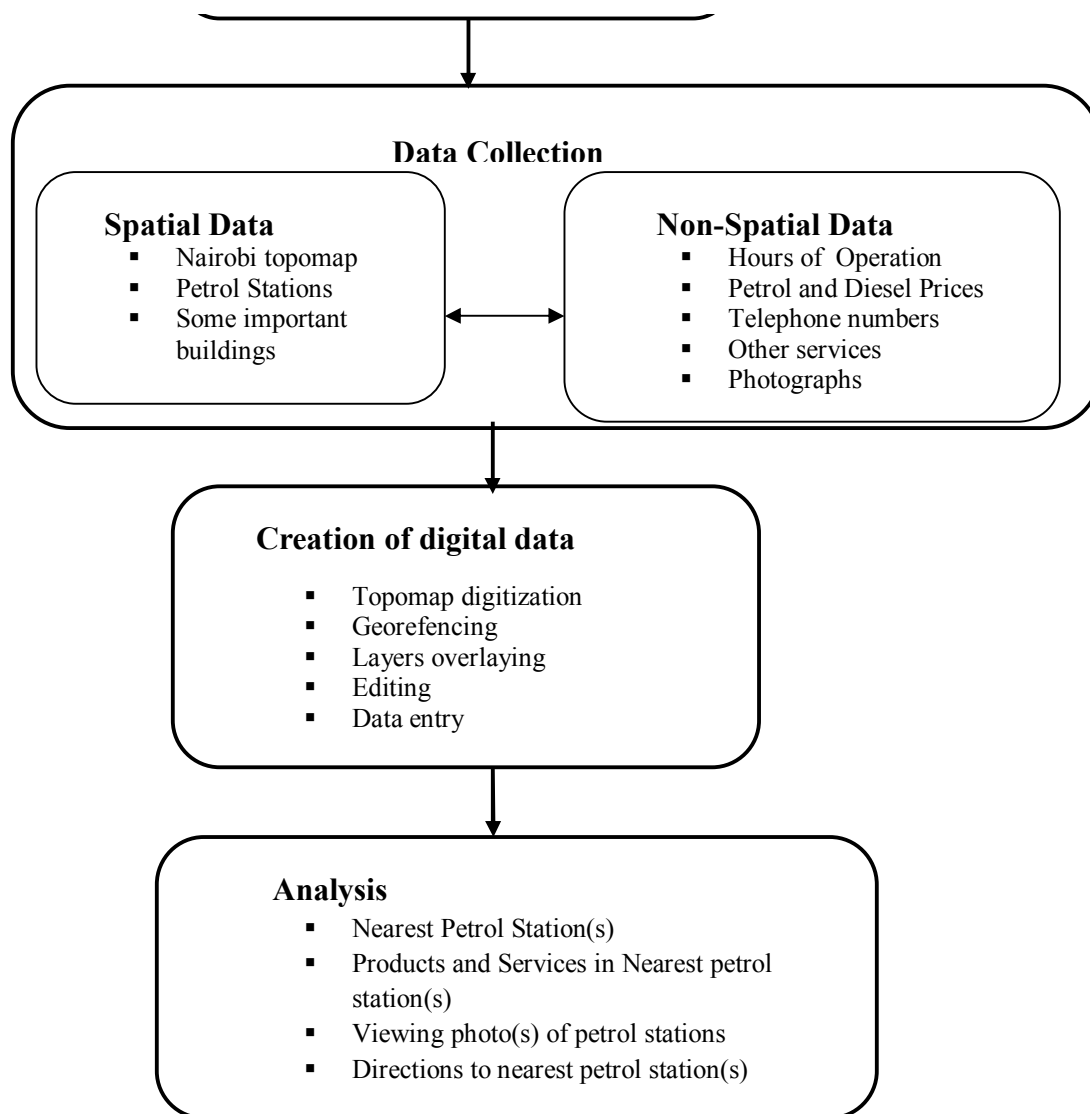


Fig 2: Schematic overview of the project approach

3.1 Area of study

The CBD takes a rectangular shape, around the Uhuru Highway, Haille Selassie Avenue, Moi Avenue and University Way. It includes many of Nairobi's important buildings, including the City Hall and Parliament Building. However, some of the surrounding areas were included in order to support easier analysis and interpretation (Fig 3).

3.2 Tools and Equipment

The equipment used included hand held GPS receiver, GIS hardware and software.

3.21 GIS hardware

These included a laptop (Pentium IV, 80 GB hard disk), Inkjet printer, flash disk, Epson scanner and optical disks.

The handheld Garmin GPSmap 60cx GPS receiver with an accuracy of between 3-5 meters was used to pick the locations of the petrol stations. The data consisted of grid coordinates referenced by the UTM WGS 84 Zone 37⁰ S projection. Once the location of a petrol station was observed, it was stored within the GPS and downloaded later.

3.22 ArcGIS 9.2

In the study, the major software used was ArcGIS version 9.2 including its extension Network Analyst. The three main applications of interest in ArcGIS 9.2 were ArcToolbox, ArcMap and ArcCatalog.

ArMap was used to display spatial data. It was used to create, edit, query and analyse the maps. It offered many ways to interact with maps such as exploring, analyzing and present the results.

ArcCatalog was used for accessing and managing data. It was also used to move, rename and copy datasets as well as preview geographic and attribute data.

ArcToolbox provided access to advanced geoprocessing functionality and was also used for data management, data conversion and geocoding the petrol stations.

3.3 Data Collection and Preparation

The study involved fieldwork in which the petrol stations were visited and their geographic coordinates picked using hand held GPS. Attribute data were obtained from the petrol stations attendants. The directions of the one way roads/streets were obtained from google maps.

The primary data collected required editing. ArcGIS suite application ArcMap was used for editing the data.

Data Capture

The map of Nairobi district analogue was scanned into soft copy so as to result into a portion of it, the CBD. The georeferenced CBD map was created. Before scanning, the document was well prepared to ensure that line widths are resolvable and unwanted data was cropped out.

All the physical locations of the CBD, including roads (linear feature) were digitized. The end result was a digitized map of Nairobi CBD that contained roads network and buildings.

Data Editing

The primary data collected required to be edited. ArcGIS suite application ArcMap was used for editing the data. Digitizing introduced errors eg undershoots and overshoots. Linear features for network analysis required thorough editing to close gaps and disseminate orphaned junctions.

Editing errors involved error correction such as closing gaps. Broken road network lines were connected using line snapping by specifying gap threshold value to connect lines that match the snapping criteria. Line smoothing was done using the generalization technique to remove artifacts caused image scanning.

The line editor was used to add missing lines manually. It was also used for line merging and splitting, node editing, and line labeling functions.

Spatial and attribute data linkage

Secondary data obtained from the petrol station attendants (attribute data) was stored in Microsoft Excel spread sheets from where they were imported to ArcGIS 9.2 for analysis. Though the main product under interest by the motorist was fuel, other services were found to be offered by the petrol

stations including wheel balancing, cafeteria, minor repair, and washroom facilities. Other information available included telephone contact, data on time of opening and closing and the mode of payment acceptable.

3.4 Finding the nearest Petrol Station(s)

Finding the nearest facility is a multimode infrastructure network dataset query type of analysis. A tourist in a hired GPS fitted vehicle may need to locate the nearest petrol stations and compare the cost of fuel as well as know what other services are offered, e.g cafeteria and washrooms. The GPS fitted vehicle shows the right position (Incidence) of the tourist. The tourist enters the incidence within a click of the mouse and enters the number of petrol stations he/she would like to view.

4.0 RESULTS AND ANALYSIS

The main objective of the study was to demonstrate how GIS application could lead to decision making. In order to achieve that objective the facilities considered were petrol stations within the Nairobi CBD. A road network dataset was generated. The dataset contains all the relevant information require by the tourists to enable querying. The analysis of the results was done through spatial queries into the road dataset.

The analysis involved the following;

- Identifying the closest facility from a location
- Tracing the best route between a location and a facility
- Tracing the best route between a location and a facility satisfying certain conditions
- Step-by-step directions along an identified route

Using ArcGIS 9.2, a map showing conspicuous and independent petrol stations within the NCBD was generated (Fig 4). A tourist at Hilton hotel was considered a route to the nearest petrol station was generated through running network analysis (Fig 5).

Clicking on the position of the nearest petrol station, Shell Latema Road, generate a window with information on the facilities and services available (Fig 6). The window contains a hyperlink/hotlink record. Clicking on the hyperlink generates a picture of the particular petrol station together with some of the surrounding environment (Fig 7).

ArcGIS 9.2 Extension 9.2 contains a button used to view the directions from the origin to the deatination. Fig 8 shows the directions from Hilton hotel to Shell, Latema Road, the closet petrol station.

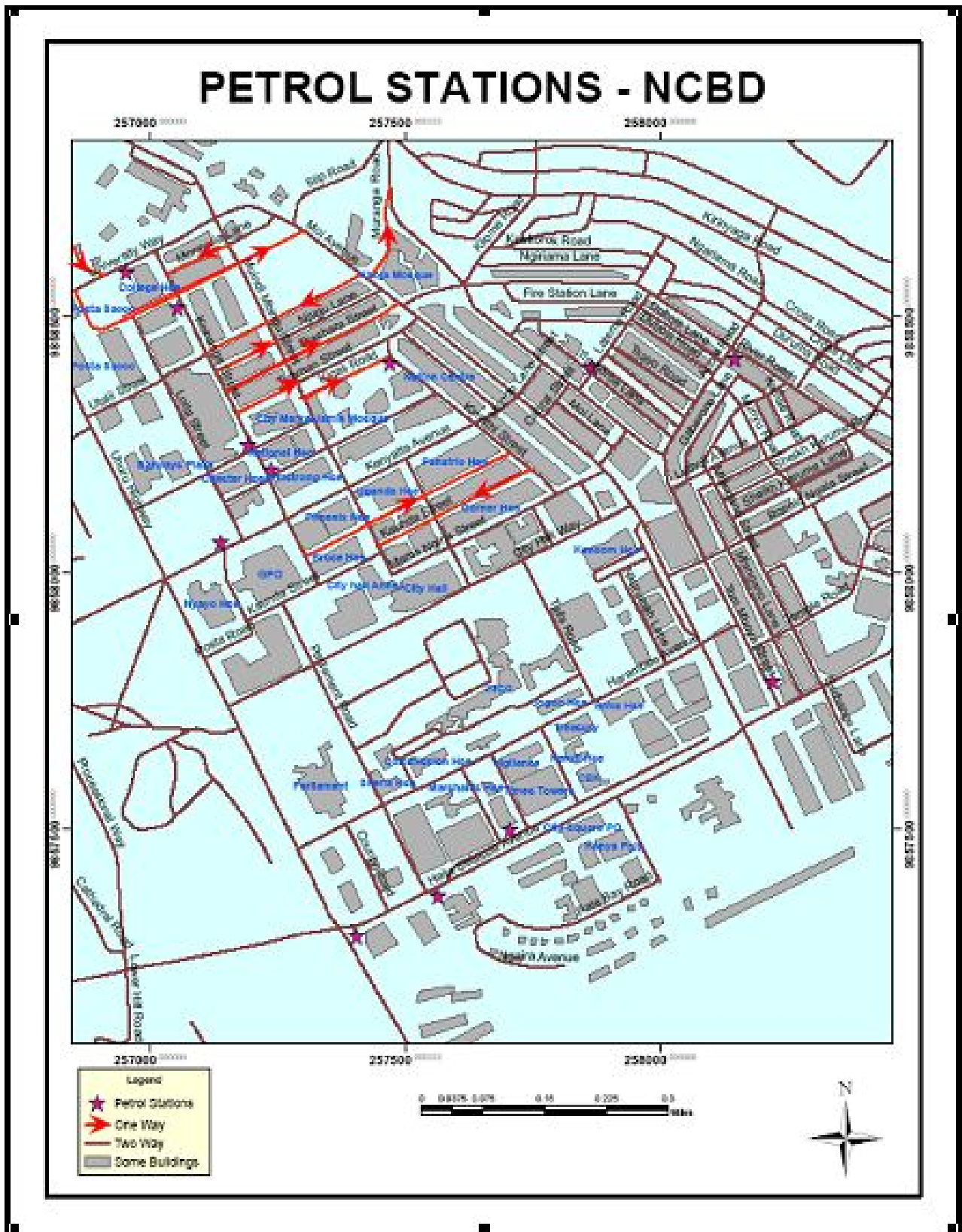


Fig 4: Petrol stations within NCBD

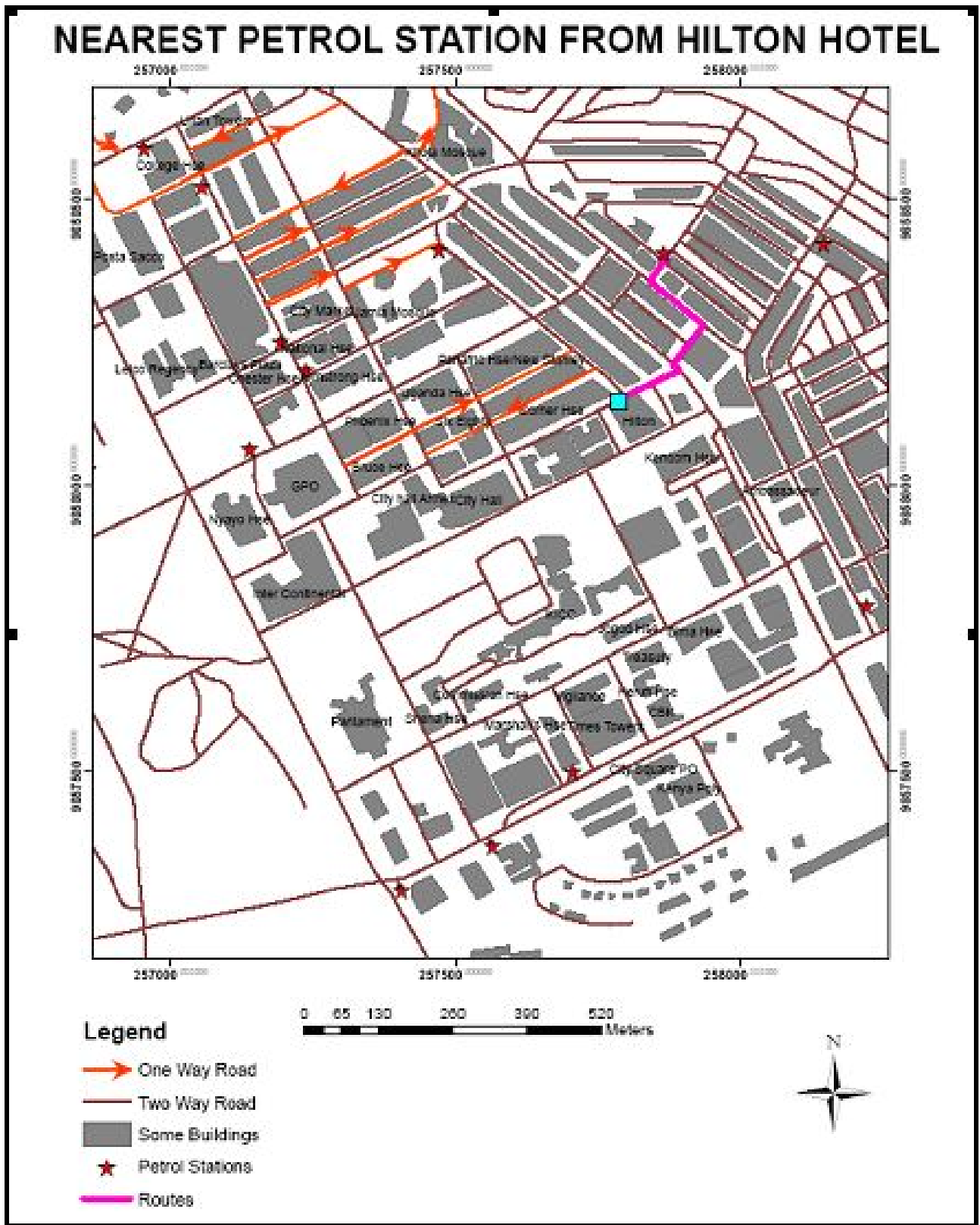


Fig 5: Map showing nearest petrol station from Hilton hotel

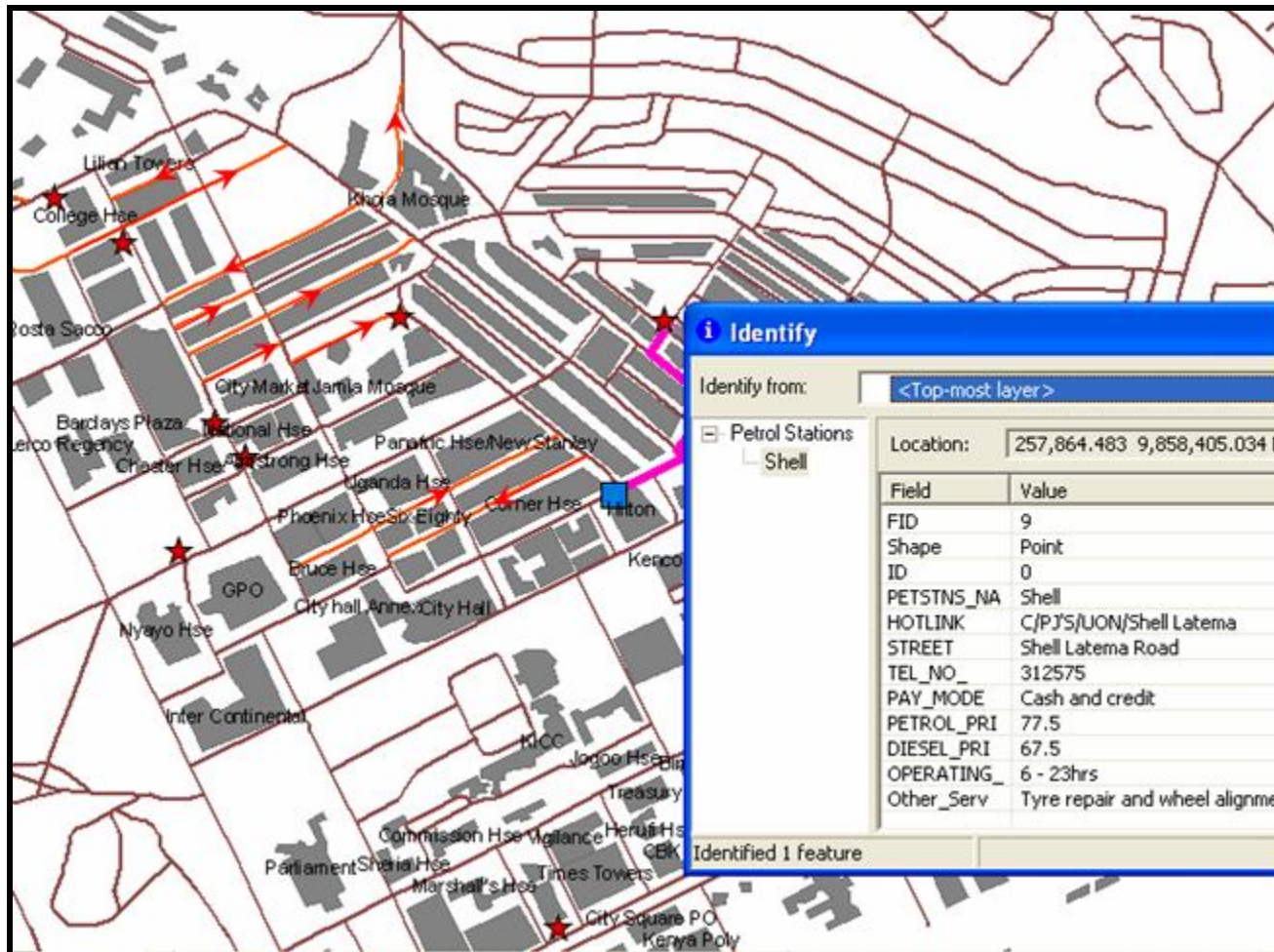


Fig 6: Details of Products and Services at Shell, Latema Road

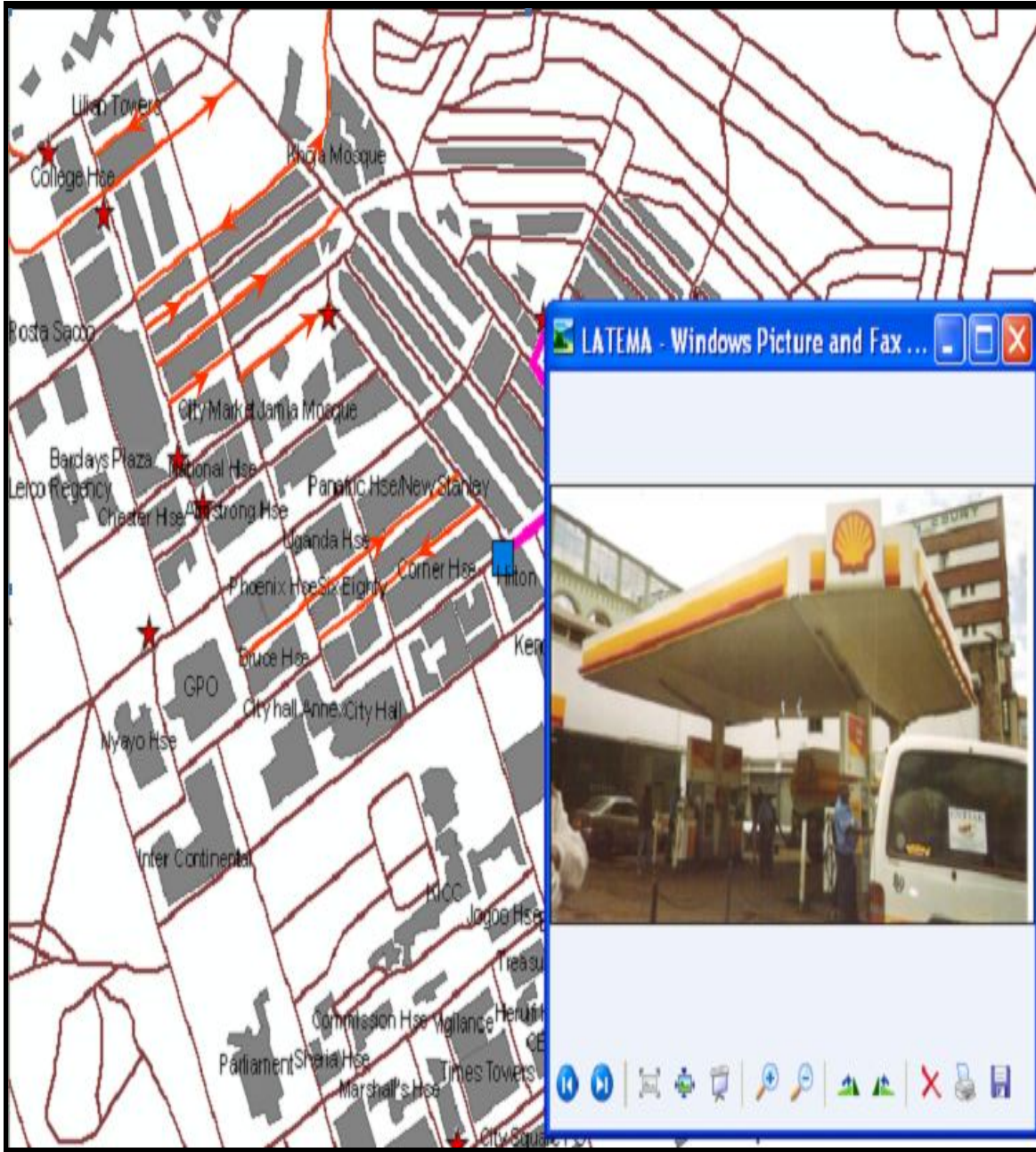


Fig 7: Shell Latema Road photograph as viewed by the tourist on a hyperlink

Driving Directions

Route: Hotel - Petrol Station	368.4 m
1: Start at Hotel	
2: Go North East on Mama Ngina Street toward Watalii StreetWatalii Street	90.9 m
3: Make sharp left on Moi Avenue	15.7 m
4: Turn right on Maragua Lane	87 m
5: Turn left on Tom Mboya Street	122.1 m
6: Turn right on Latema Road	52.7 m
7: Finish at Petrol Station	
Total distance: 368.4 m	

Fig 8: Directions from Hilton hotel to Shell, Latema Road

The following customized window provides the tourist with information on a petrol station with specific services according to his/her needs (Fig 9).



The image shows a software window titled "Search for a Petrol Station" with a close button in the top right corner. The window contains several filter options, each with a dropdown menu:

- Repairs:** Set to "Yes".
- Cafeteria:** Set to "Yes".
- Operating Hrs:** Set to "24 HR".
- Washrooms:** Set to "Yes".
- Where Petrol Price:** A section with a dropdown menu set to "Less Than" and a text input field containing "80".

At the bottom center of the window is a button labeled "Search Petrol Station".

Fig 9: A window showing the specific needs of a tourist

A map highlighting the petrol station satisfying the above requirements was generated (Fig 10). The tourist then makes a first 'stop' at the current location and a second 'stop' at the highlighted petrol station and clicks on the run button.

A route to the petrol station is generated (Fig 11). Clicking on the petrol station thus highlighted gives the details of products and services available (Fig 12). The window contains a hyperlink/hotlink record. Clicking on the hyperlink generates a picture of the petrol station together with some of the surrounding environment (Fig 13).

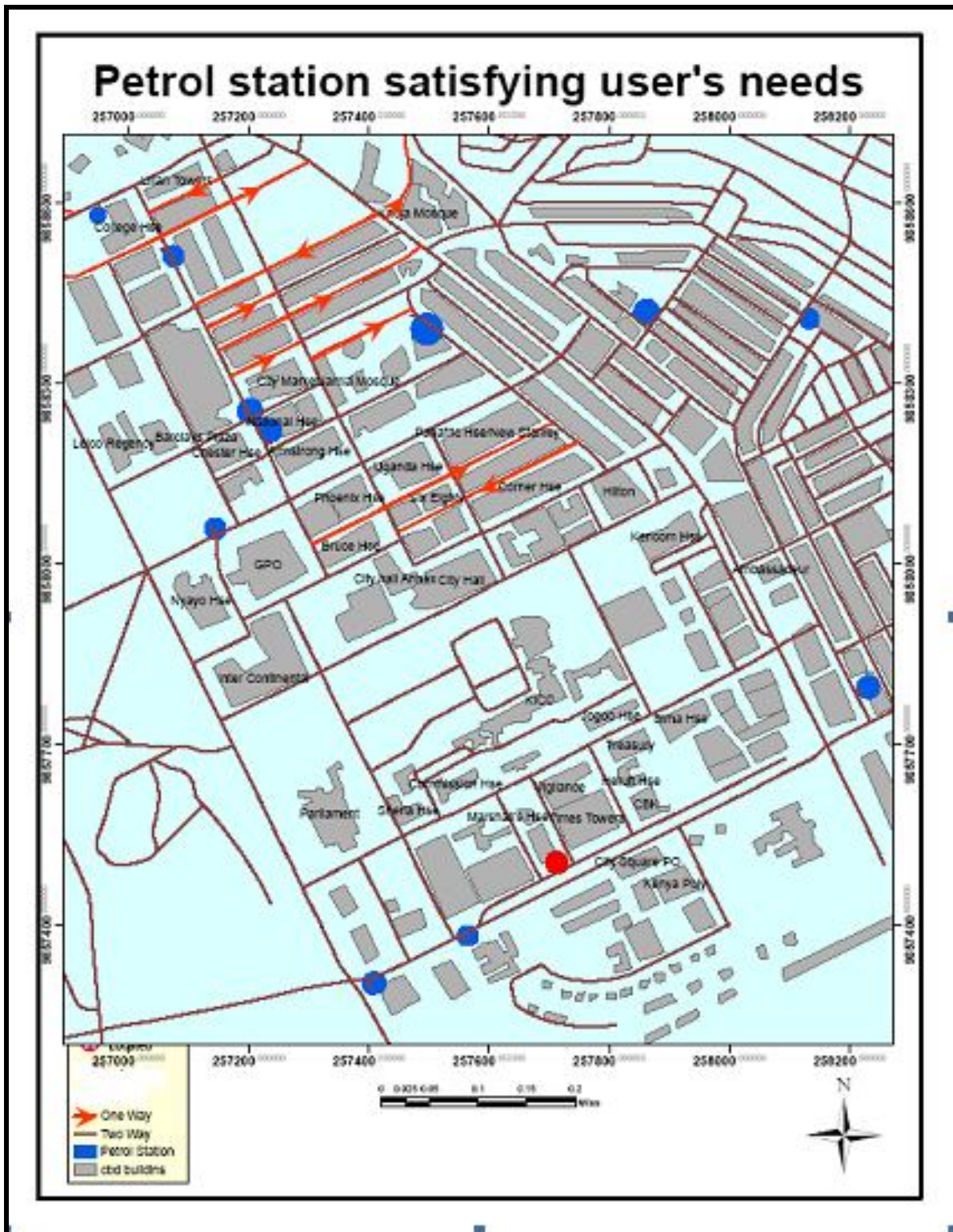


Fig 10: A map highlighting the petrol station satisfying tourist's needs

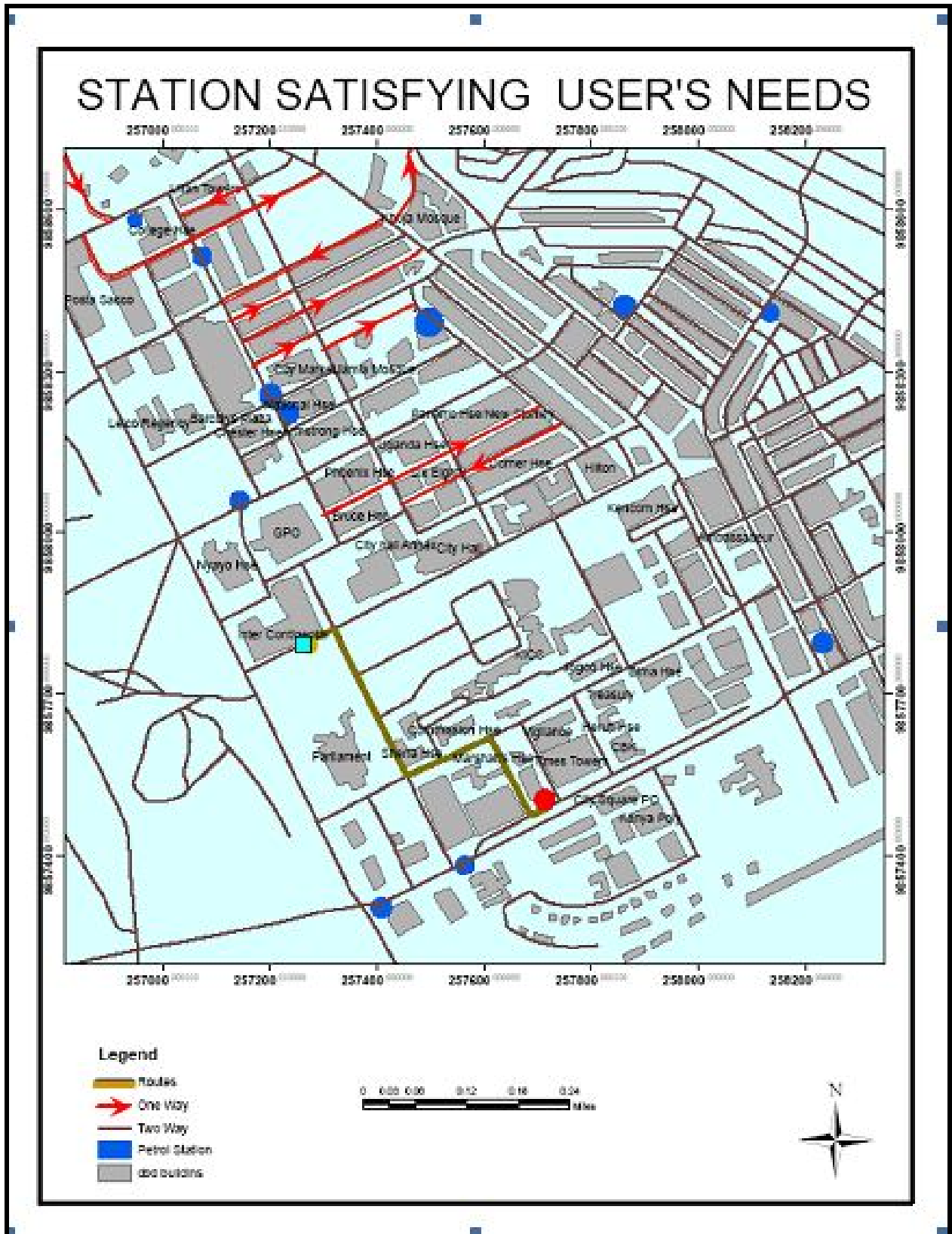


Fig 11: A map showing the route to the petrol station satisfying tourist's needs

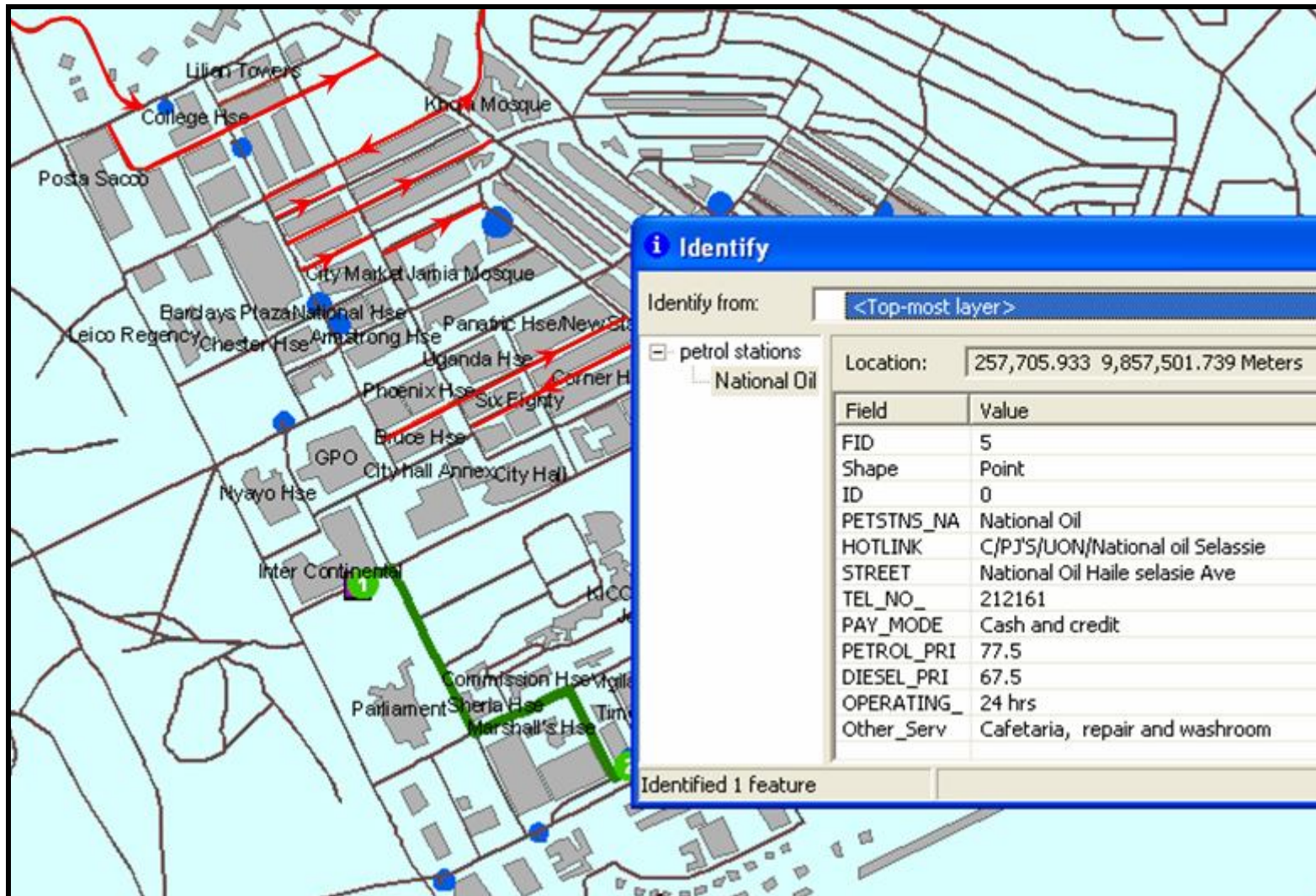


Fig 12: Details of Products and Services at National Oil petrol station



Fig 14: Photograph showing National Oil petrol station as viewed on hyperlink

Driving Directions

Route: Hotel - Petrol	723.6 m
1: Start at Hotel	
2: Go North East on City Hall Way toward Parliament Road	53.1 m
3: Turn right on Parliament Road	304.8 m
4: Turn left on Harambee Avenue	170 m
5: Turn right on Haile Selassie Lane	164.2 m
6: Turn left	31.5 m
7: Finish at Petrol, on the left	
Total distance: 723.6 m	

Fig 15: Directions from Intercontinental hotel to National Oil petrol station

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results of the study were based on the data collected and the analysis undertaken. The analysis mainly involved multimode infrastructure network dataset query for tourists. The results showed a successful completion of spatial and attribute data manipulation. The graphical output is in form of maps indicating the route to be traversed along with the distances and directions to be traversed along each road segment.

The queries performed on the multimode road network dataset were satisfactory and they demonstrated how mapping of petrol stations and network analysis can lead to informed decision making. The study illustrated the application of GIS in finding the optimal route between the given origin and destination.

5.2 Recommendations and Future Work

The study demonstrated that similar decisions could be achieved through the same concept, e.g ambulances locating the nearest hospital in case of emergencies and whether such services such as Intensive Care Unit (ICU) are available.

This concept as well applies to planes that would need to take an emergency landing on the nearest airport/airstrip during times of emergencies thereby avoiding crash landing in which case the services offered need to be included as attribute data.

For the purpose of updating digital maps and the attribute data, it is necessary that web based mapping is applied through the National Spatial Data Infrastructure.

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APPENDIX

APPENDIX I: FIELD NOTES

Petrol Station (i) Name _____
(ii) Street _____

GPS Coordinates (N) _____
(E) _____

Gasoline Prices

- i) Petrol (KSh)** _____
- ii) Diesel (KSh)** _____
- iii) Mode of payment** _____

Other Services

- (i)** _____
- (ii)** _____
- (iii)** _____
- (iv)** _____
- (v)** _____

Telephone Contact _____

Working hours (24 Hr Format)

- (i) Opening** _____
- (ii) Closing** _____

APPENDIX II: FINDINGS

Attributes of petrol stations							
PETSTHS_IA	STREET	TEL_NO_	PAY_MODE	PETROL	DIESEL	OPERATING_	Other_Serv
▶ Shell	Shell University way	227899	Cash and credit	77.5	67.5	6 - 23hrs	Vehicle repair , washroom, lubrication and car park
Total	Total Koinange Street	2249544	Cash and credit	78.5	68.5	24 hrs	Tyre repair and washroom
Kobil	Kobil Koinange Street	221882	Cash and credit	78.5	68.5	24 hrs	washroom
Shell	Shell Kenyatta Avenue	227849	Cash and credit	77	67	6 - 23hrs	repair ,washroom, wheel balancing and car wash
Kobil Haile	Kobil Haile Selasie Ave.	72283988	Cash and credit	78.5	68.5	24 hrs	washroom
National Oil	National Oil Haile selasie Av	212161	Cash and credit	77.5	67.5	24 hrs	Cafeteria, repair and washroom
Shell	Shell Haile Selasie Ave	224825	Cash and credit	77.5	67.5	6 - 23hrs	Cafeteria, repair and washroom
Oilibya	Oilibya Tom Mboya St	312568	Cash and credit	78.5	68.5	24 hrs	Car was, lubrication and washroom
Pop-in	Pop-in Accra Road	328796	Cash	76	66	24 hrs	Take away food services and washroom
Shell	Shell Latema Road	312575	Cash and credit	77.5	67.5	6 - 23hrs	Tyre repair and wheel alignment
Kenol	Kenol Koinange St	72280016	Cash and credit	78.5	68.5	24 hrs	Wash room and washroom
Caltex	Caltex Kigali St	3668000	Cash and credit	78.5	68.5	24 hrs	washroom

APPENDIX III: PETROL STATIONS



Photo 1: Caltex Kigali Street



Photo 2: Kenol, Koinange street



Photo 3: Kobil Haille Sellasie



Photo 4: Kobil, Koinange street



Photo 5: National oil, Haille Sellassie



Photo 6: Oil Libya Tom Mboya



Photo 7: Pop-In, Accra Road



Photo 8: Shell Haille Sellasie



Photo 9: Shell Kenyatta Avenue



Photo 10: Shell, Latema Road



Photo 11: Shell, University way



Photo 12: Total, Koinange Street

