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Development of a Geographic Information Systems Road Network Database for Emergency Response; A Case Study Of Oyo-Town, Oyo State, Nigeria

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ABSTRACT: *Recently, digital road network mapping has become important tool for prompt emergency responses. This paper briefly examines the use of digital road network for management of emergency services in Oyo Town through three major sets of objectives as follows; designing a database, spatial data acquisition, database creation and spatial analysis. A combination of spatial data acquired through the use of GPS with corresponding attributes and digital conversion of base maps were integrated into the database. However, query operations were used for analyses resulting in deferent maps for presentation. The research findings show the possibility of query for possible alternative routes in case of emergency and access to the nearest facility of interest. The proposed recommendation will serve emergency agencies adequately as both digital and hard copy maps could be made handy for emergency responses.*
Key Words: *GIS, Database, Road networks, Emergency response, Nigeria*

I. INTRODUCTION

This project is based on the development of a Geographic Information System (GIS) road network database for emergency response. The development of a GIS road network database management system will help in the conscious effort directed at improving the standard and the level of services of the transportation facilities available in a locality. The application of GIS to 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. In the write-up, concerted effort is being made to proffer solution to road problem during emergency situation by using digital road network. When there is an emergency situation such as fire outbreak, flooding, arm robbery etc. alternative route or road to the crime scene, hospital, or fire station has to be created. Hence, the need for a digital road network in the project area to facilitate easy access, and to eliminate delay in getting to such emergency spot by the concerned agency.

According to (Ehindero, 2006), protection of lives and property is a primary responsibility of government. However, this appears not being fulfilled in Nigeria in recent times as crime rate has not only surged but the crimes have taken much grievous dimensions. Law enforcement agencies are agencies set up by law to maintain internal security of the state. For law enforcement agencies to be as effective as possible when dealing with crime, they need to have the ability to understand and use their current incident data and the information generated by past crime incident responses to help protect against and prevent future incidents. Law enforcement agencies face a multitude of tasks and challenges in their daily responsibility of protecting life and property while keeping the peace in their communities. In Nigeria, there are several agencies saddled with the responsibility of law enforcement and these include among several others the Nigeria Police Force, The Nigeria Security and Civil Defense Corps etc.

(Esri 2005), revealed that virtually every task and challenge has a geographic component. These tasks require both strategic and tactical planning in rapidly changing social, economic, and political environments.

(Ajayi et al, 2015) opined that present road pavement condition could have a positive influence on traffic congestion rate, notable crime spots & accident hotspots. (Adulahi & Rabiu, 2014) in a study carried out in Gombe metropolis, noted that there is need to construct more road networks and also establish a GIS unit to aid future planning, maintenance and analysis of road network.

The increasing rate of crime incidences in Nigeria is an issue that cannot be over emphasized and it is no longer news that crime has become the order of the day in our contemporary society. In Oyo metropolis there are no digital road network maps that can solve the problem of emergency response. There is need to involve a system whereby law enforcement agencies can find the best or alternative road to crime incident hence GIS is being used in this study as a decision support to assist law enforcement agencies in tactical planning and emergency responses to crime incidences in Oyo metropolis. Therefore this paper is an attempt to deploy geospatial technology as a vital tool in emergency responses to crime incidences in Oyo Metropolis.

II. STUDY AREA

The study area is Oyo town, the ancient city in Oyo state. Oyo town is located approximately between latitude 7^0 53'14" and 7^0 48'55"north and longitude 3^0 58'5" and 3^0 58' 5" east of the Greenwich meridian. The general elevation of the town ranges between 250 to 340 meters above the mean sea level. Oyo town comprises of three Local Governments Areas namely, Oyo east, Oyo west and Atiba local Government Area. The population of the area was put at 428,799 during the 2006 census.

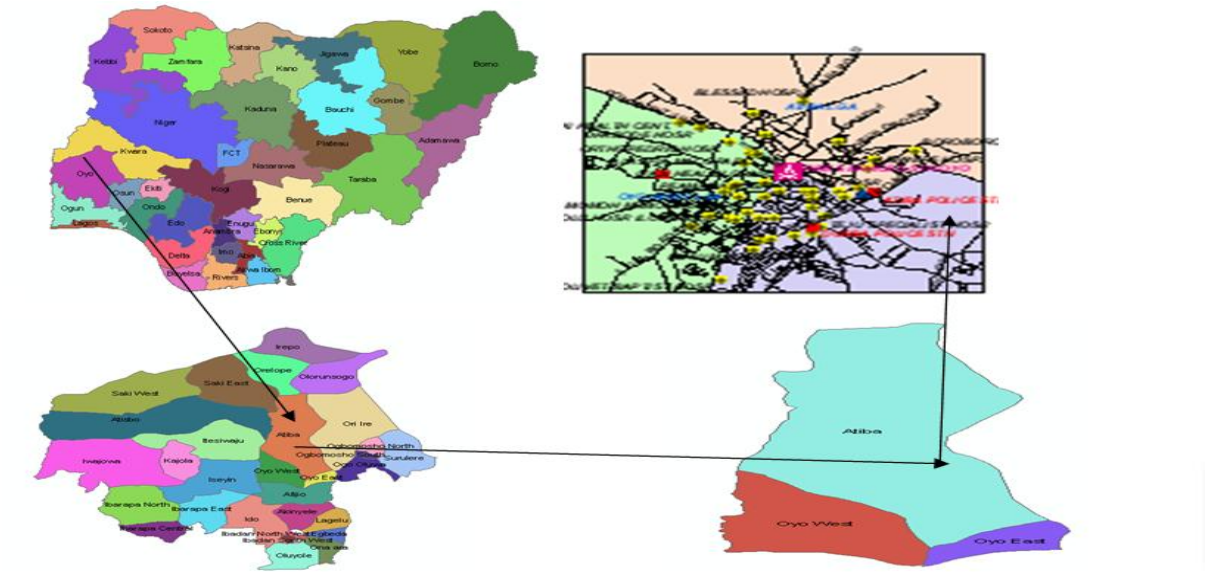


Fig 1.1 showing diagram of the study area

III. METHODOLOGY

Methodology involves the step by step approach employed for the execution of this project. It includes database design, data source, data acquisition and database creation

3.1 DATABASE DESIGN

This is the process by which the real world entities and their inter-relationship are analyzed and modeled in such a way that maximum benefit are derived while utilizing a minimum amount of data.(Kufoniyi 1998). At the heart of a GIS is database and the process of design such a database is called data modeling. GIS database consist of two phases and they are the design phase and construction phase or implementation phase. Kufoniyi further stated that, the design phase consists of four levels, namely, reality, conceptual design, logical design and physical design.

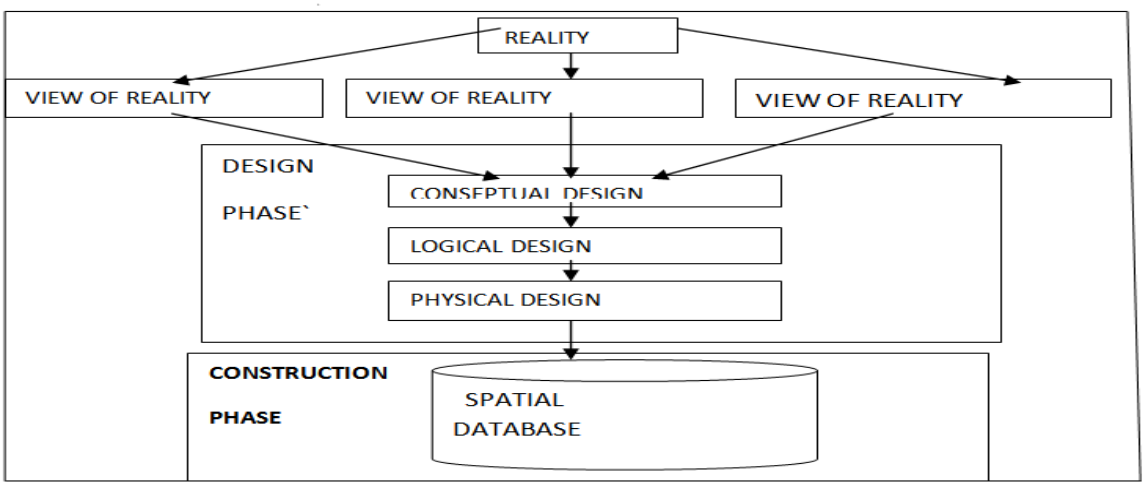


Fig 3.1 showing the design and construction phases of a spatial database (kufoniyi 1998)

3.1.1 VIEW OF REALITY

In this project, view of reality included road networks, police station, hospitals and fire service station. Reality refers to a phenomenon as it actually exist which includes all aspect that may or may not be perceived by an individual. The view of reality is the mental abstraction of the reality for a particular application or group of applications. Reality serves as needful input into the design phase.

3.1.2 CONCEPTUAL DESIGN

This is the representation of human conceptualization of reality (kufoniyi, 1998). In the conceptual data model, the area object, line object, and point object were the basic data set and they are represented by an entity relational diagram (fig 3.2). Each of the primary entity has a specific attribute. These attributes and their connecting lines represent the various relationship among them. Entity type is the abstraction that represents a class of similar object about which the system is given to contain information. One of the compelling and widely used approaches to forming a conceptual model of an information system was originally proposed by Chen (1979) and is known as the entity relationship (ER). This has been enlarged to extended entity relationship (EER) model (Wuboy, 1995). Generally, any of the three types of representation schema may be adopted in conceptual design (Kufoniyi, 1998) namely; Tessellation, Raster, vector and object oriented. Vector data model was used for this project.

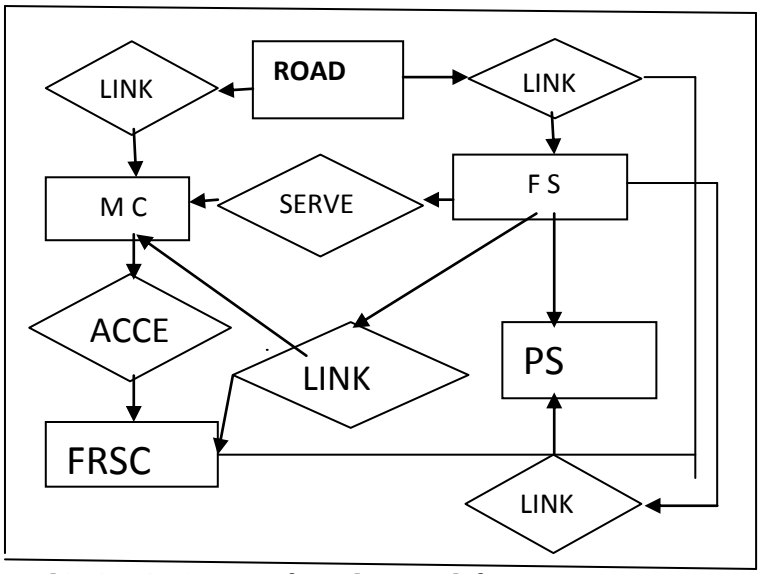


FIG 3.2 Entity Relationship (E-R) Diagram of Road Network for Emergency services

3.1.3 LOGICAL DESIGN

The second phase in database design in this research is the logical design. It is a representation of the data model which reflects the recoding of the data in computer system. In this case, entities, attributes and their relationship are represented in a single uniform manner in form of relations and in a manner such that there would be no information loss and at same no unnecessary duplication of data.

Table 3.1: Arc Entity and its Attributes

ROAD_Id	ROAD_NAME	ROAD_STATUS	ROAD_LENGTH

Table 3.2: Node entity and its Attribute

Point_Id	POINT_ADDRESS	POINT_NAME	POINT_TYPE

3.2 DATA ACQUISITION

This involved method of acquiring data required for the project using various data acquisition techniques such as land surveying, photogrammetric, digitizing etc.

3.2.1 RECONNAISSANCE

Reconnaissance was done to acquire necessary information about the project for proper and efficient execution of the project including costing and time measurement. Reconnaissance was divided into two and they are office and field reconnaissance.

3.2.2 OFFICE PLANNING

This involved sourcing for existing information about the project area. **:** At this stage the satellite imagery of Oyo was obtained. IKONOS image of 4m resolution taken in 2005 was used for the project.

3.2.3 FIELD RECONNAISSANCE

At this stage, the extent of the project area was determined. It was also carried out to identify the emergency outfit within the project site. With the printed copy of the satellite imagery covering the project area, the area was thoroughly examined for effective execution of the project.

3.3 GEOMETRIC DATA ACQUISITION

Data acquisition hardware such as the Garmin 76 CSX Hand held GPS was used to acquire data which was downloaded into the computer for processing and easy retrieval while cartographic digitizing of the satellite image was also employed.

3.3.1 PRIMARY DATA ACQUISITION

Land Surveying method was adopted by carrying out mobile mapping within the study area. This was achieved through the use of handheld GPS (Garmin 76CSX)

3.3.2 SECONDARY DATA ACQUISITION

This was achieved by making use of secondary data sources such as; IKONOS Satellite Imagery of 4m resolution taken in 2005 and an existing Basemap. Cartographic digitizing of the satellite image was employed. Layers were created for the features in arc catalogue of the Arc GIS and digitizing operation was employed.

3.3.3 ATTRIBUTE DATA ACQUISITION

Attribute data are observed facts about the features that has nothing to do with geometry. Attribute data were collected through personal interview carried out within the three local government area, medical centre, and along roads. Attributes acquired are street name, Id, name of the hospitals, etc.

3.4 DATA PROCESSING

As an effective management is measurement dependent, the data acquired were duly processed for further information presentation and analysis. Data was downloaded and plotted to produce the map of the study area.

3.5 PHYSICAL DESIGN

After designing a data structure and procuring the necessary hardware and software, the overall system model was defined to facilitate ease of data exchange. In addition to this, basic input data set were put in place. With these primary data in place, actual database implementation followed, starting with data acquisition. The created table was then populated with the impute data after carrying out all the necessary correction.

3.6 DATABASE IMPLEMENTATION

This involved the creation of both the necessary attribute relation and the graphical layers as set out by the design specification. Implementation involved linking of both the attribute and spatial data together and generating queries that can solve spatial problems. Arc GIS 9.3 was used for this database implementation. Database implementation involves the following steps:

1. Selection of hardware and software based on data to be stored and the format.
2. Physical database creation, to input data into the database
3. The graphical display of the spatial data content of the database

Attributes of MAJOR_ROAD_1

OBJECTID *	SHAPE *	SHAPE_Length	NAME *	ROAD_STATUS
64	Polyline	356.963898	OYO -OGBOMOSHO ROA	TARRED
65	Polyline	36.223407	OYO -OGBOMOSHO ROA	TARRED
66	Polyline	198.584667	OYO -OGBOMOSHO ROA	TARRED
67	Polyline	483.579572	OYO -OGBOMOSHO ROA	TARRED
68	Polyline	173.093735	OYO -OGBOMOSHO ROA	TARRED
69	Polyline	56.554995	OYO - ISEYIN ROAD	TARRED
70	Polyline	371.479836	OYO - ISEYIN ROAD	TARRED
71	Polyline	372.544687	<Null>	TARRED
72	Polyline	686.877461	OYO -OGBOMOSHO ROA	TARRED
73	Polyline	634.008326	OYO -OGBOMOSHO ROA	TARRED
74	Polyline	231.795586	OYO -OGBOMOSHO ROA	TARRED
75	Polyline	369.346147	OYO -OGBOMOSHO ROA	TARRED
76	Polyline	334.542847	OYO -OGBOMOSHO ROA	TARRED
77	Polyline	198.718276	OYO -OGBOMOSHO ROA	TARRED
78	Polyline	116.442945	OJONGBODU POLICE STN	TARRED
79	Polyline	124.028285	OYO - ISEYIN ROAD	TARRED
82	Polyline	348.869392	OYO -OGBOMOSHO ROA	TARRED
83	Polyline	101.809254	OYO -OGBOMOSHO ROA	TARRED
84	Polyline	22.288695	OYO -OGBOMOSHO ROA	TARRED

Fig3.3 Showing some part of database implementation.

3.7 SPATIAL ANALYSIS AND CAPABILITY

There is a wide range of function for data analysis available in most GIS packages; including measurement techniques, attribute queries, proximity analysis, overlay operation and analysis of surface and network analysis. What distinguishes GIS from other information systems is its ability to carry out spatial analysis. No meaningful GIS project can be said to have been completed, without carrying out spatial analysis. The following spatial analysis was carried out for this project.

(i) Spatial search (single and multiple criteria queries)
(ii) Network analysis (find the best route or closest facility and giving the direction)

3.7.1 SPATIAL SEARCH

This was made possible as a result of link between the graphic data and attribute data being acceptable to the implementing software for the purpose of this project. Analysis and queries were generated based on the composite map of the study area.

3.7.1.1 SINGLE CRITERIA

This is a situation where single condition is used to query the database. E.g. query showing Oyo – Ogbomosho road. Spatial search operations were used to demonstrate single criteria analysis. This is to answer questions like what is, where and where is what? The variants of queries involved are:

(i) Query by attribute.
(ii) Query by location.

Query by attribute: this was used to retrieve a geographical record from the information system by defining a certain criteria. It was implemented by building an SQL expression in the selected attribute dialogue box of arc-map label.

Query by location: was used to retrieve geographic records from the information system by defining a certain criteria. There two methods of retrieving geographic records by location i.e. by using identity tool to click on the feature or by defining a spatial query in the selected by location dialogue box. The result of using the identity tool to click at location displayed a description of the attributes of the feature at the location. This will enable rescue operation to be carried out.

3.7.1.2 MULTIPLE CRITERIA

This is a situation where more than one conditions is used to query on database. E.g. query for medical centers in Oyo west that has numbers of health workers greater than or equal to five.

3.8 NETWORK ANALYSIS

Network is a set of inter connected lines making up a set of features through which resources can flow. Rivers are one of the example but roads, pipelines and cable also formed network that can be modeled in GIS. There is a classic network problems , identifying the shortest route, the closet facilities and services are basically network problems the shortest route involves tracking all possible routes and presenting the one having the shortest path. Closet facility refers to features along the network that are designed as a facility in some ways.

IV. RESULT PRESENTATION AND DISCUSSION

Performing queries on a GIS database to retrieve data is an essential part of most projects. Queries offer a method of data retrieval and can be perform on data that are part of the GIS database or on a new data produced as a result of data and results obtained. The analysis performed in this project work is to test the system include spatial search (data retrieval). The analyses are considered within the precincts of single and multi-criteria analysis.

Single criteria analysis

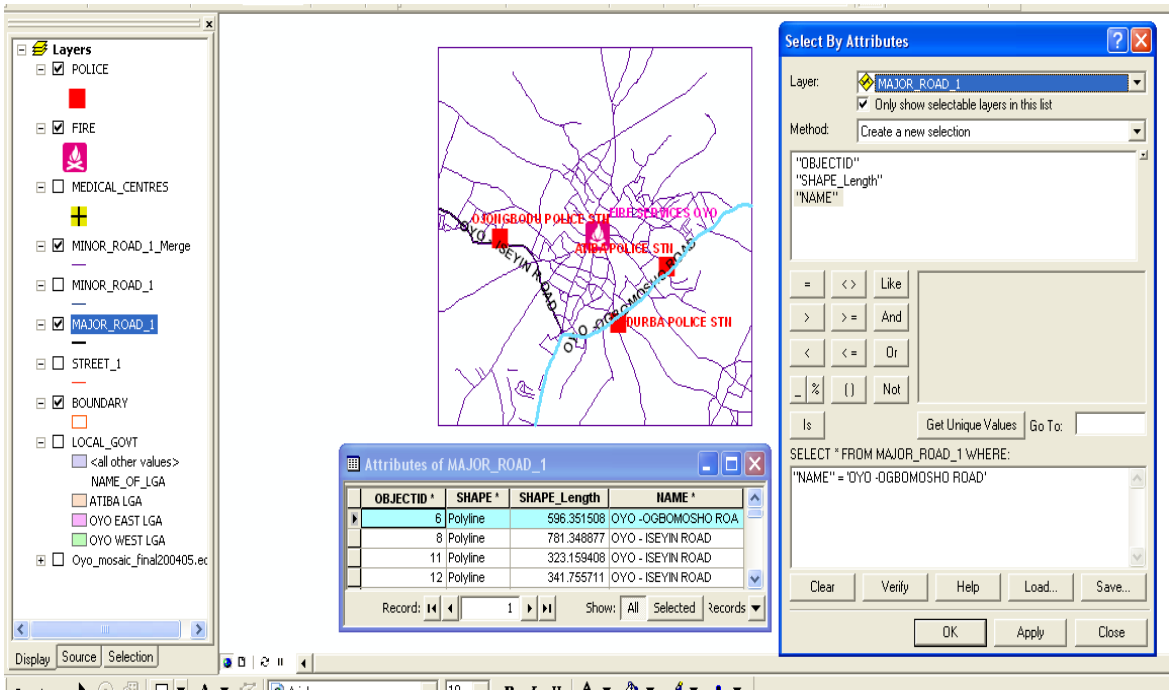


Fig 4.1 Query for Oyo - Ogbomosho road

Figure 4.1 above is a single criteria query analysis where a major and popular road was called up. This is an important query especially for road users that are relatively new in Oyo town. It does not take much time for the algorithm to highlight this road whose length totaled up to 596.351 meters from the city enter of Oyo to her outskirt. However, Oyo Iseyin road is also another very important but longest route connecting Iseyin to the city center of Oyo.

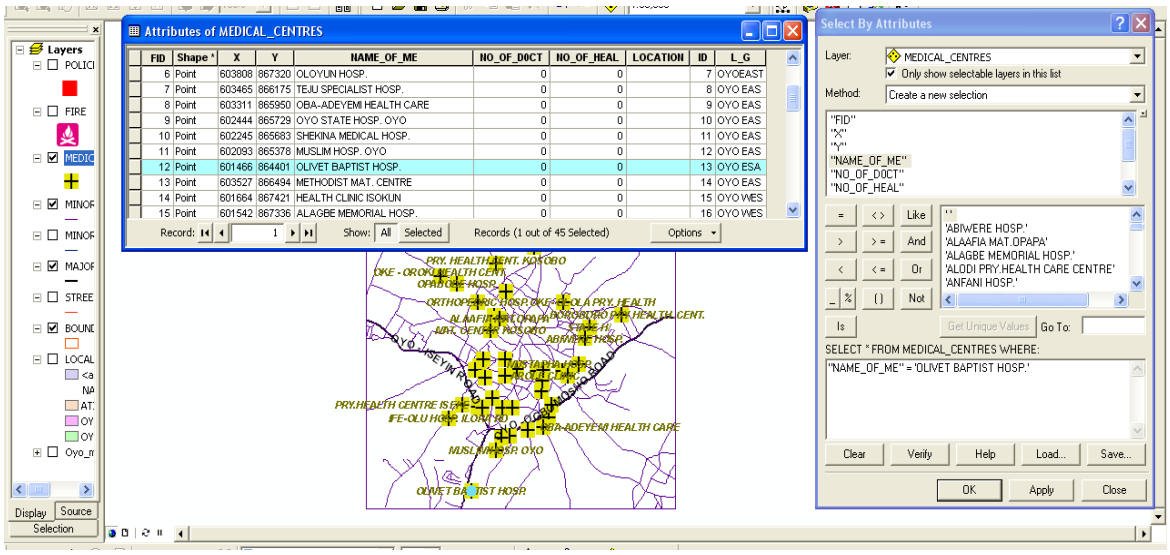
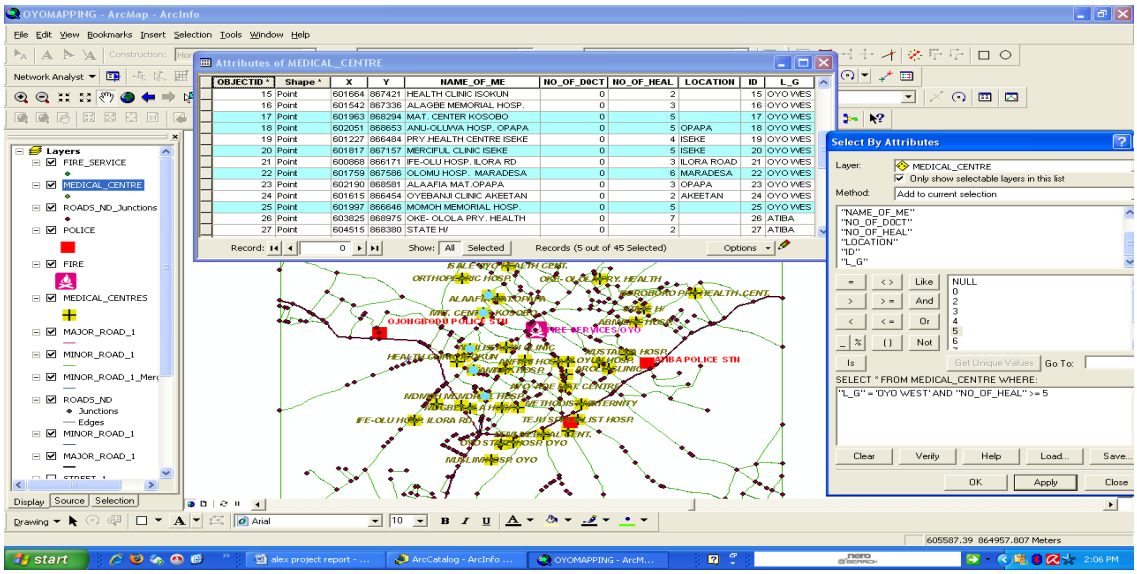


Fig 4.2 Query for Olivet Baptist hospital in Oyo town

The above figure analysis is a scenario where a particular Hospital of interest is queried. The analysis singled out Olivet Hospital in Oyo town, Oyo East Local Government Area.

MULTI CRITERIA



4.3 Query for medical centers in Oyo West that has numbers of health workers greater than or equal to five

In the above figure the multi criteria query analysis shows that the number of health staff in a given health facility determines the quality of the health facility. So that accident victims with the help of emergency workers an equally query for medical centers in oyo and also seek to know a medical facility that has numbers of health workers greater than or equal to five (5).

The result from this multi criteria query shows five deferent medical centers in oyo with workers greater than or equal to five.

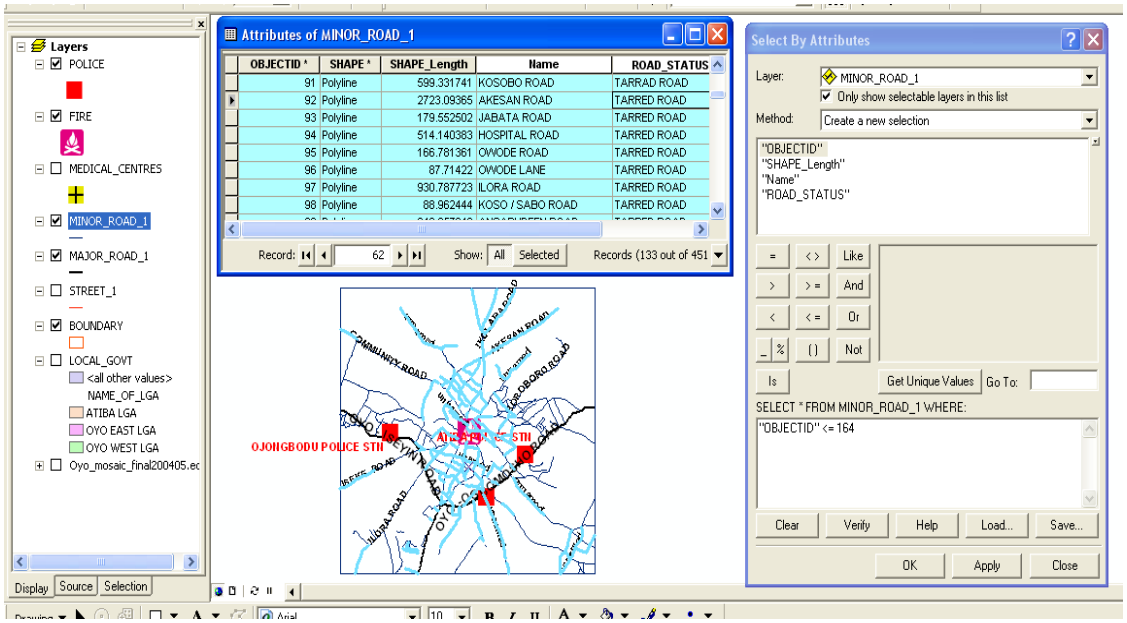


Fig 4.4 Query for minor roads which object ID is less than or equals (<=) 164

From figure 4.5 below, the operation carried out indicates a situation where there is an assumed accident around Owode area and the closest or best route to the nearest hospital and the direction to the facility was indicated. The area shaded in red indicates the accident spot while the closest hospital is shown in light green.

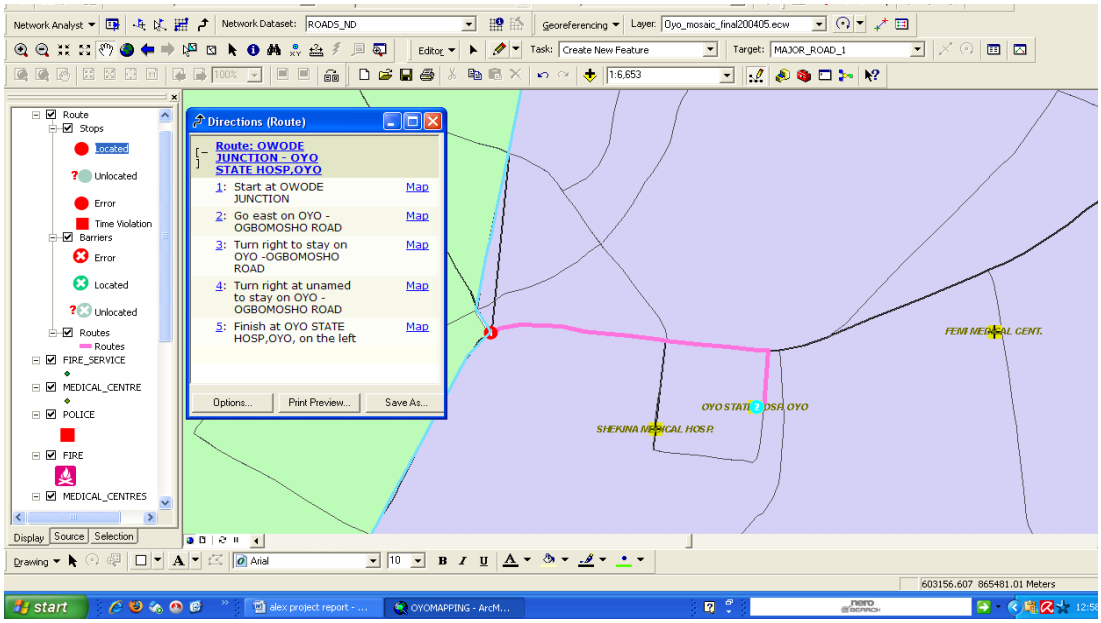


Fig 4.5 finds the best route and giving direction to the closet hospital from an accident scene

The figure above describes network analysis for the best route given direction to the closest hospital, In the result table the direction starts at Owode junction, goes east on Oyo - Ogbomosho road, turns right to stay on Oyo - Ogbomosho road, turn right at unnamed street to stay on Oyo – Ogbomosho road and finally finished at Oyo state hospital, Oyo on the left.

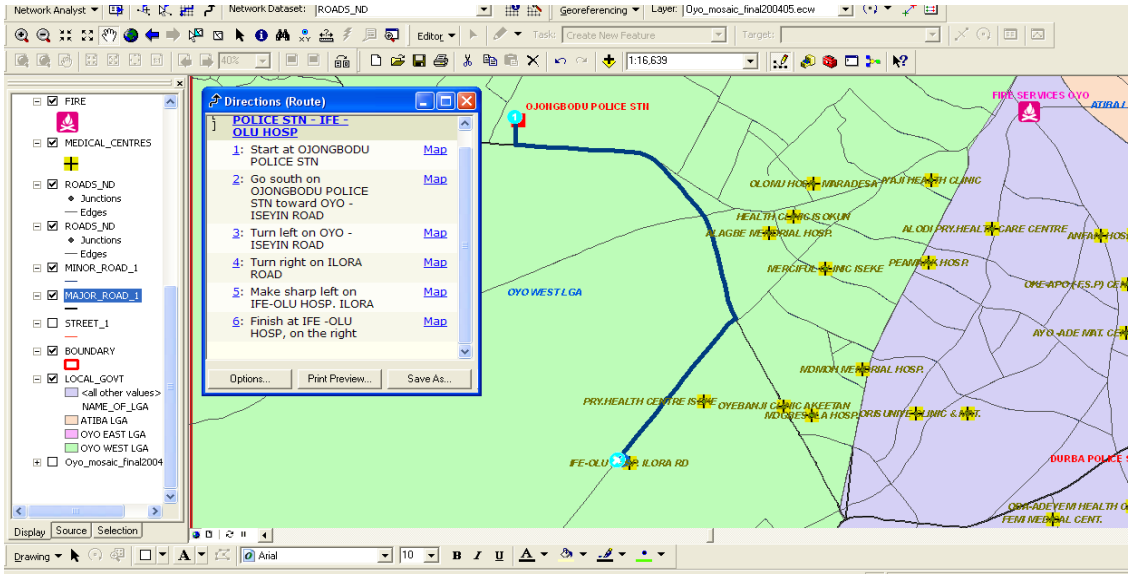


Fig 4.6 Location of the closest police station to an assumed armed robbery scene.

Figure 4.6 is closest route directional analysis to an assumed robbery scene within the Study area. Start at Ojongbodu police Station, go South on Ojongbodu Police Station toward Oyo – Iseyin, turn left on Oyo –Iiseyin Road, turn right on Ilora road, make sharp left on Ife – Olu Hospital. Ilora and finish at Ife – Olu Hospital on the right.

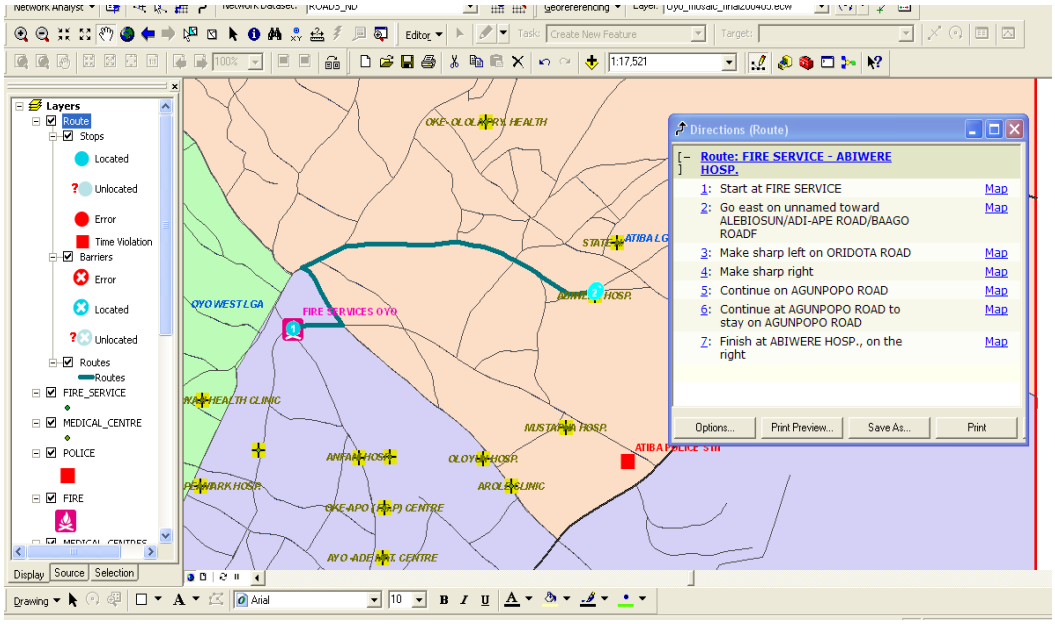


Fig 4.7 location of an assumed fire outbreak scene from fire service station

Finally, the analysis and result in figure 4.7 show a route directional analysis to a fire outbreak scene. A few network moves were made as follows. Start at fire service Station, go east on unnamed street towards Alebiosun/Adi Road/ Baago Road, make a sharp left on Oridota Road, make a sharp right, continue on Agunpopo Road, continue Agunpopo Road to stay on Agunpopo Road, then finish at Asiwere Hospital on the right.

V. CONCLUSIONS

The design and the creation of spatial database for digital road network for emergency services for Oyo town was carried out through the use of both primary and secondary data acquisition method by the use of GPS (handheld) and corresponding input through PC based on arc GIS software. Database was tested with some queries which generated expected result.

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