Development of Utility Information System for Management of Electricity Distribution of Iyaji Residential Layout, Oyo, Oyo State, Nigeria

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Abstract-Utilities are infrastructures such as electricity, water, telephone etc that provide a common good for individual and the society. Utility networks in a country are vital for the proper and smooth functioning of the modern society. A breakdown of the services of these networks can cause serious economic damage. This study focuses on proper working of electricity distribution infrastructure that can only be assessed and monitored by using Geographic Information System. To accomplish this, geometric data on electricity distribution network in the study area was acquired which involved updating the existing map of the area with GPS observation, georeferencing and digitizing the map. Attribute data was acquired through questionnaire and oral interview. Designing and creation of database for electricity distribution in the study area was then carried out using relational database management approach. Spatial analyses were used to solve spatial problems such as getting the locations of the transformers and the electricity poles, identifying where faults are which aid in decision making and in proper keeping of records. Geometric and Attribute databases were linked using the ArcGIS 9.3 which was also used for Spatial Analyses and information presentation. The result of the analyses revealed that 113 and 359 buildings are connected to transformers 1 and 2 respectively. 64 buildings use prepaid meter while 121 buildings use analog meter. Buffering operation was also utilized in this project to determine buildings that contravene the setback rule of 6m. Only one of such buildings exists within the study area. Best route analysis was also performed from a building to transformer 2 in case of any fault or fire outbreak that affects electrical facility or buildings. It was recommended that Ibadan Electricity Distribution Company (IBEDC) should establish GIS departments in all its sections and divisions to be handled by competent personnel who are versatile in using GIS software. Training and retraining of IBEDC staff working in the department of Geoinformation should also be encouraged especially in areas of computer knowledge and in the use of GIS software.

Index Terms: Utility, GIS, Electricity, Information

1. INTRODUCTION

Utilities are organized large scale public services such as electricity, water, oil and gas supplies. Utility mapping system is concerned with the description and mapping of physical network of distribution lines and the associated facilities that ensure their effective performance. They are also concerned with the provision of spatially referenced information used in the management of these very complex networks that extend over large areas. Their efficient management is highly desirable for the economic and social well-being of the individuals in the society.

At the moment, most utility maps in Nigeria are in the analogue medium (paper maps) in fixed scales and forms. The obvious disadvantages of this form of record keeping are many. Too many features or too few of them may be available in an existing unit, making such unfit or inadequate for many purposes. The production, as well as updating of such records are expensive and time consuming. There is little or no flexibility in handling the information on such medium (Ezeigbo, 1998)

Complexity of electrical distribution power system is a good reason for introducing new information technology. Geographic information system (GIS) can carry out complex power system analysis e.g. fault analysis, optimization of networks and load forecasting in acceptable amount of time. By using GIS in conjunction with its own in-house developed software, in less time and more accurately, the utility engineer is able to design and analyze electrical distribution network. The introduction of a GIS allows the mains to be represented as it really is, to show where lines have been put up, which lines connect which customers as well as background information like plots, houses etc. It allows a user to attach information to each object in a table and refer to this table whenever required. It becomes even easier, if this digital database is a spatial digital database or a Geographic information system.

Above all, the greatest supremacy of GIS is visualization. The entire electrical network can be visualized as it is laid on the ground. Just by looking at the map and clicking at a particular feature (say a transformer), all the information (both location and engineering information) is displayed. This provides a more flexible understanding of the network and hence a faster approach to the solution. The electricity provider has to ensure that the entire network is operational at all times, regulate connection for operations as well as billing purposes. It is necessary to model the spatial distribution of the electricity consumption in order to predict the future trend for the purpose of planning for management of electricity generation to minimize time for power restoration.

2. MATERIALS AND METHODS USED

2.1 Study Area

The study area is Iyaji residential layout Oyo. Iyaji residential layout is in Iyaji (ward 5) of Oyo West Local Government Area covering about 71.5 hectares of land. Oyo West Local Government Area is one of the three local councils carved out of Old Oyo Local Government Area of Oyo state of Nigeria. It is located between latitudes 07° 40′N and 07°51′N and between longitudes 03°50′E and 03°57′E (see fig.1a, b and c). It is bounded in the North by Atiba Local Government Area, in the west by Iseyin and Ifedapo Local Government Areas, in the east by Oyo East Local Government area and in the South by Akinyele Local Government Area. The population is about 100,000 People (1991 census).

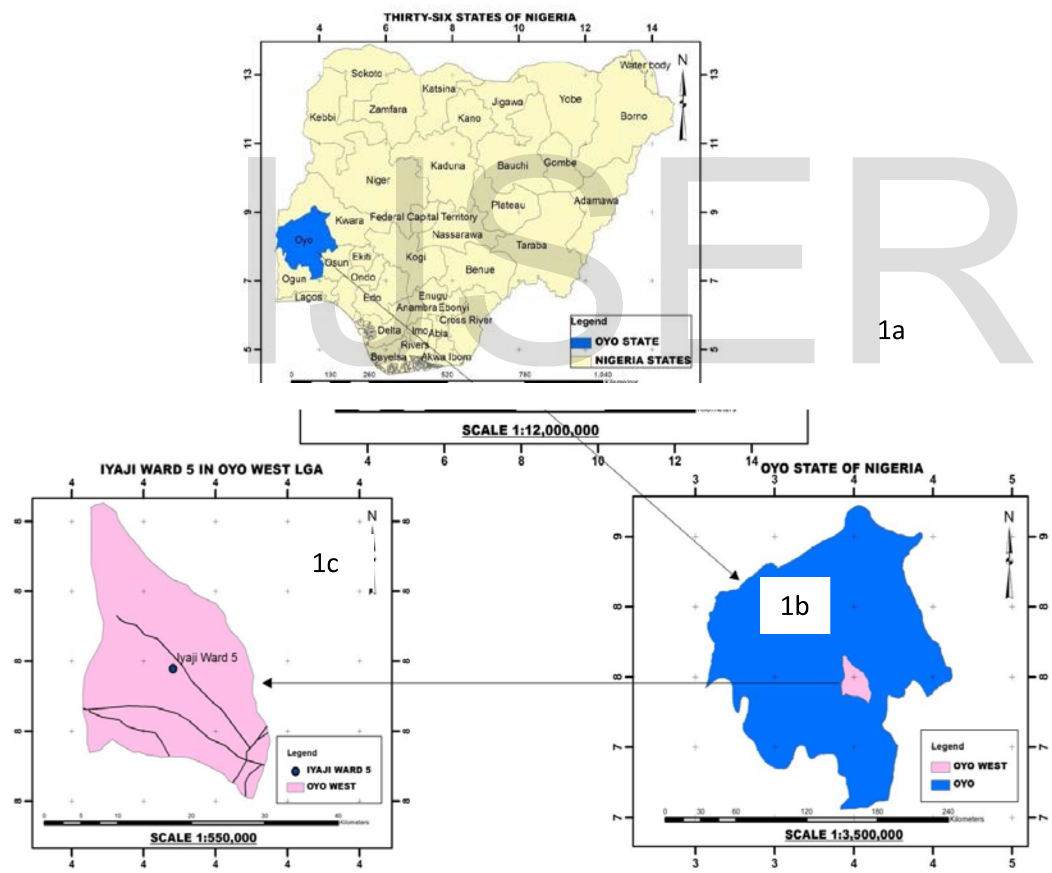

Fig.1a: Map of Nigeria Showing Oyo State; Fig. 1b: Map of Oyo State Showing Oyo West and Fig.1c: Map of Oyo West Showing Iyaji Ward 5 (the Study area)

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2.2 Methods

The methodology adopted for this research work is subdivided into the following steps:
i. Office Planning/Reconnaissance
ii. Database Design
iii. Data Acquisition
iv. Data Processing
v. Database Creation
vi. Geospatial Analysis/Generation of Queries
vii. Information Presentation and Discussion

Office planning involves adequate preparations and taking decisions that will aid the realization of the set objective in order to achieve the aim of the project. Users requirement survey was carried out and all necessary information that helped in the execution of the project were collected from the end users. It also guided in knowing the configuration of the hardware and software system required for the work and in the choice of appropriate model and structure to be used. The study area was visited with a view to having an overall picture of the area and noting the features that exist in the area and all information available including the challenges that would be faced in the course of executing the project work.
The data collected using the Garmin Handheld GPS was downloaded into the computer system to obtain the X, Y coordinates of the electric poles, transformer and other feature of interest which were not on the existing map. The coordinates obtained using the GPS was in WGS 84 coordinate system. The coordinates were transformed into the Nigerian Transverse Mercator Coordinate System (Minna Datum) using Geocal software. The data was later imported into ArcGIS 9.3 through notepad software for updating the map.

In the design of database for this work, four basic steps were taken. These include: articulation of reality, translation of reality to conceptual model, translation of conceptual model to logical model and physical design. The real world entities and their relationships were analysed and modeled in such a way that maximum benefits would be derived while utilizing a minimum amount of data. Figure 2 shows the entity-relationship (E-R) diagram used in modeling the database.

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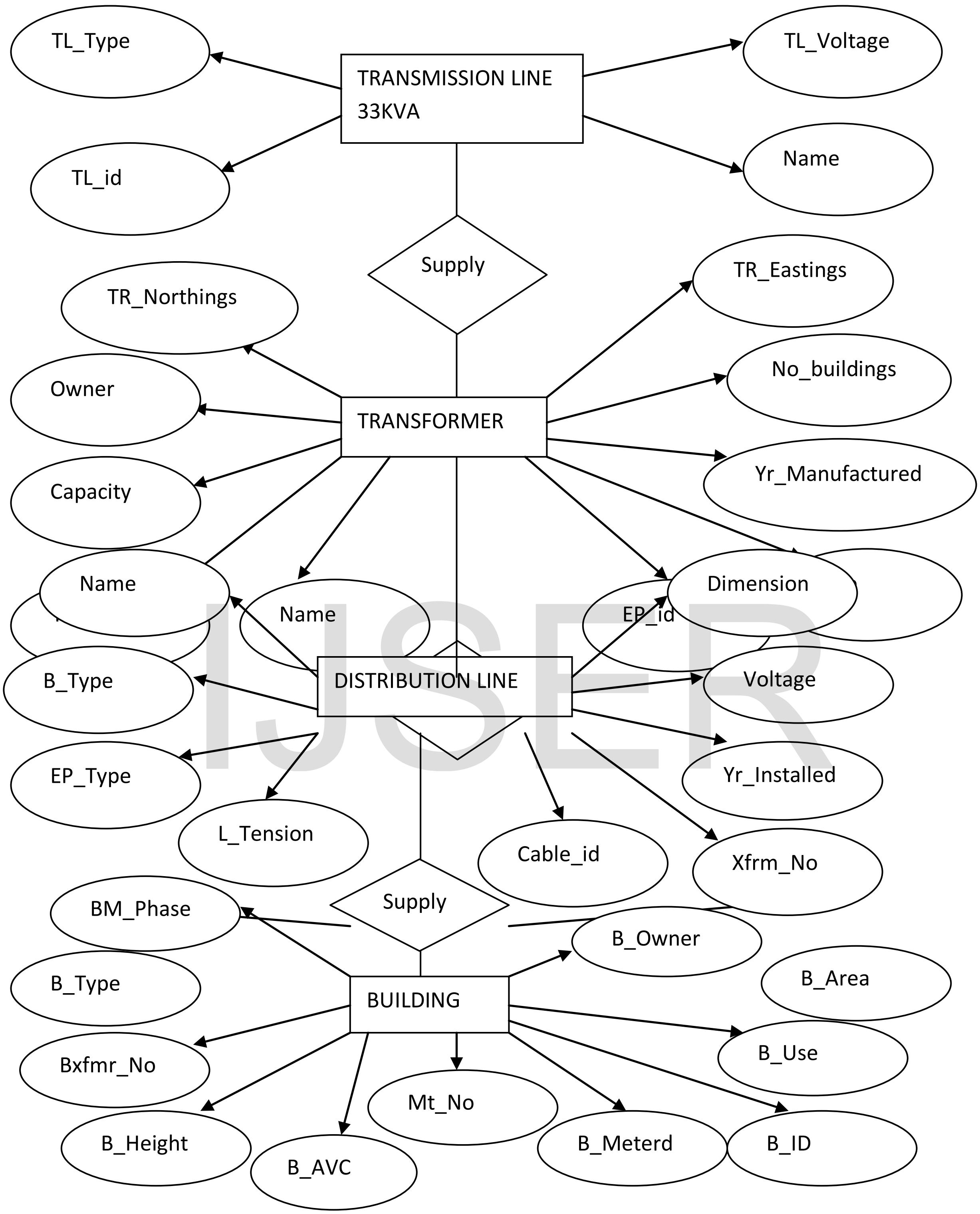

Figure 2: Entity-Relationship diagram (Electricity Network of Study Area)

From the ER diagram (fig 2), transmission line feeds many distribution transformers, while transformer step down the high voltage (low voltage) and serves the distribution lines which in turn gives the voltage to service lines and service lines connect the building as the end user.

However, the conceptual model in fig 2 was translated into a logical data structure and the following relation tables were created for the study area.

ELECTRIC POLE TABLE (EP_ Id, EP_ Height, EP_ easting, EP_ Northing, Xfrm_ NOL_Tension, H_ Tension, EP_ type, EP_ Image);

BUILDING TABLE (Bd_ Id, B_ owner, B_ type, B_ use, BM_ phase, M_ No, B_ Xfrm-S, B_ height, B_AVC, B_ metered);

TANSFORMERS TABLE (TR_ Id,Ht, East_ co, North_ co, Tr_ image, Tr_ Capacity);

CABLES (LINE) TABLE (line_ Id, str_ name, xfrm_no and distr_ line) and

ROAD TABLE (Rd_ id, str_ name, xfrm_no and Distr_ line)

BLOCK TABLE (B_ id, B_ name, B_ no) See Table 1-6 for description of the Attribute Name.

Table 1: Electric Pole Entity and its Attributes

Attribute Name	**Description**
EP_Id	Electric Pole Identifier
EP_Height	Electric Pole Height
EP_Easting	Electric Pole Easting Coordinate
EP_Northing	Electric Pole Northing Coordinate
No_Building	Number of building serving
Xfrm_No	Transformer No Source
V_Type	Low/High Voltage tension
EP_Type	Electric Pole Type
EP_Condition	Electric Pole condition
EP_Owner	Electric Pole Owner
EP_Life Span	Electric Pole Life Span
EP_Image	Electric Pole Image

Table 2: Building Entity and its Attributes

Attribute Name	**Description**
B_Id	Building Identifier
B_Owner	Building Owner
B_Type	Building Type
B_Use	Building Use
BM_Phase	Building Meter Phase
ME_Type	Meter Type
B_Xfrm_S	Building Transformer Source
B_AV_Consumption	Building Average Consumption
B_Road	Building Road
B_Av Amt/mth	Building Average amount/Month
B_Date Connected	Building Date Connected
B_Billing	Building Billing

Table 3: Transformer Entity and its Attributes

Attributes Name	**Description**
TR_Id	Transformer Identifier
TR_Type	Transformer Type
East_Co	Easting Coordinates
Northing_Co	Northing Coordinates
TR_Yr of manufac	Transformer Year of Manufacture
TR_Date of install	Transformer Date of installation

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TR_Owner	Transformer Owner
TR_Capacity	Transformer Capacity
TR_Lifespan	Transformer Lifespan
TR_Location	Transformer Location
TR_Voltage	Transformer Voltage
TR_Condition	Transformer condition
TR_Image	Transformer Image

Table 4: Line Entity and its Attributes

Attributes Name	**Description**
LN_Id	Line Identifier
LN_Name	Line Name
LN_Type	Line Type
LN_Condition	Line Condition
LN_Dimension	Line Dimension
LN_Voltage	Line Voltage

Table 5: Road Entity and its Attributes

Attributes Name	**Description**
RD_ID	Road identifier
RD_Name	Road Name
RD_Xfrm No	Road Transformer Number
RD_Distri Line	Road Distribution Line
RD_Building Avail	Road Building Available
RD_Pole Att	Road Pole Attached

Table 6: Block Entity and its Attributes

Attributes Name	**Description**
B_Id	Block identifier
B_name	Block Name
B_no	Block Number

3. RESULTS AND DISCUSSION

Results of the database queries were presented in digital maps and attribute tables. The result of Sample queries performed on the databases and their results are discussed below

Query 1: Select by attribute from Electric Poles, Electric Pole type that are concrete Syntax [EP_TYPE] = 'Concrete'

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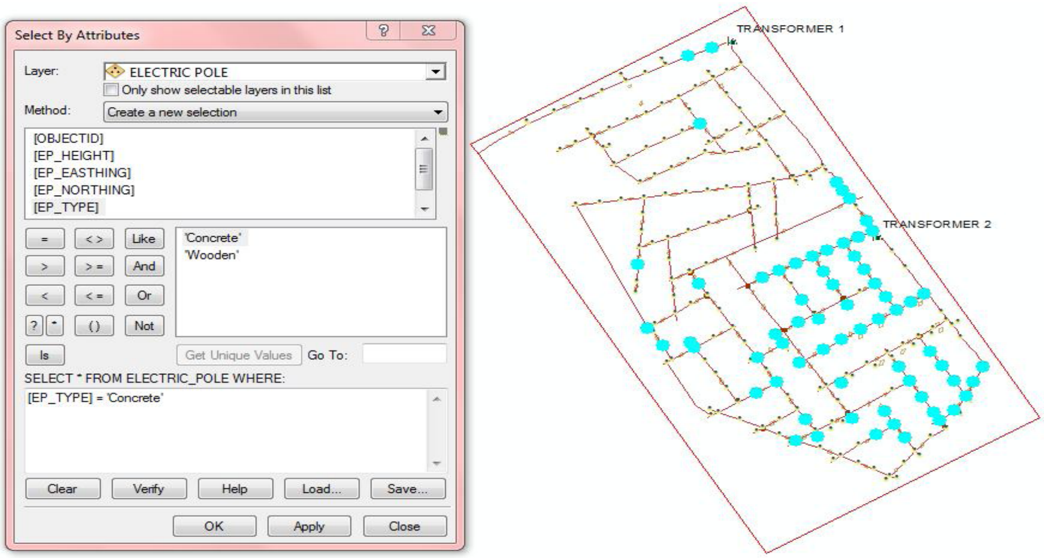

Figure 3.1: Query result showing Electric poles that are concrete

Query 2: Select by attribute from Electric Poles, Electric Pole type that are wooden Syntax [EP_TYPE] = 'Wooden'

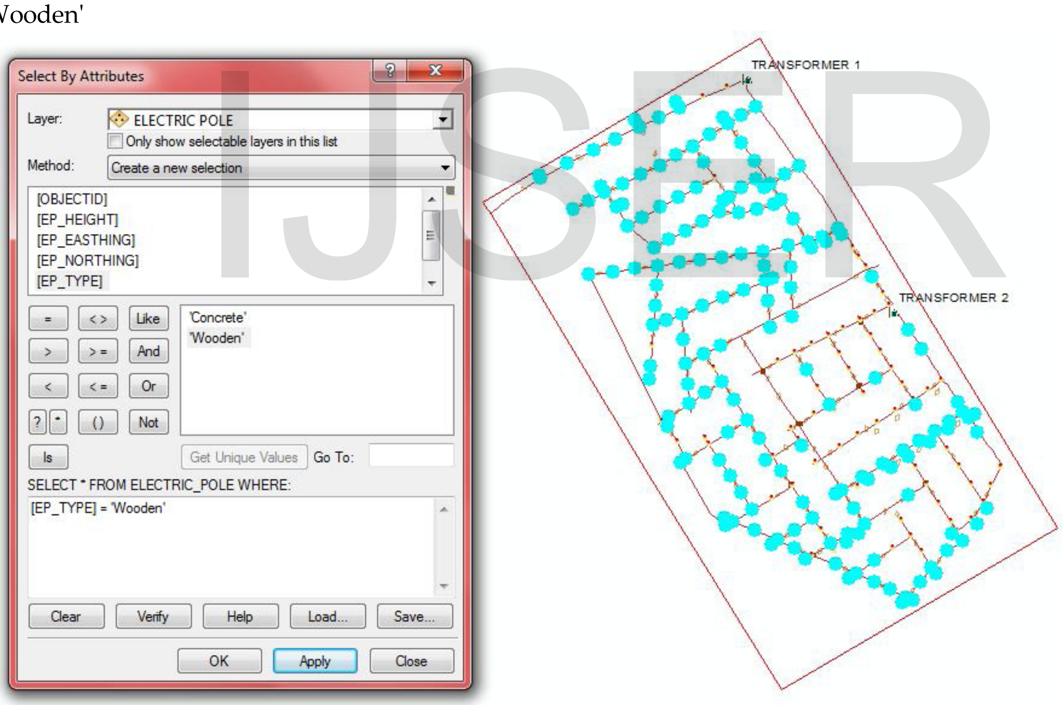

Figure 3.2: Query result showing Electric poles that are wooden.

There are 235 numbers of electric poles within the study area as at the period of study. 69 of them are concrete poles where 166 of them are wooden poles. The disadvantage of the wooden poles is that they can be eaten by termites and can be easily destroyed when hit by a vehicle. It is not as durable as the concrete poles. The query result can assist the IBEDC to know the number of wooden electric poles that need to be replaced to ensure stability and safety.

Query 3: Select by attribute from buildings, transformer name that are connected to transformer 1 Syntax [TR_NAME] = 'TRANSFORMER 1

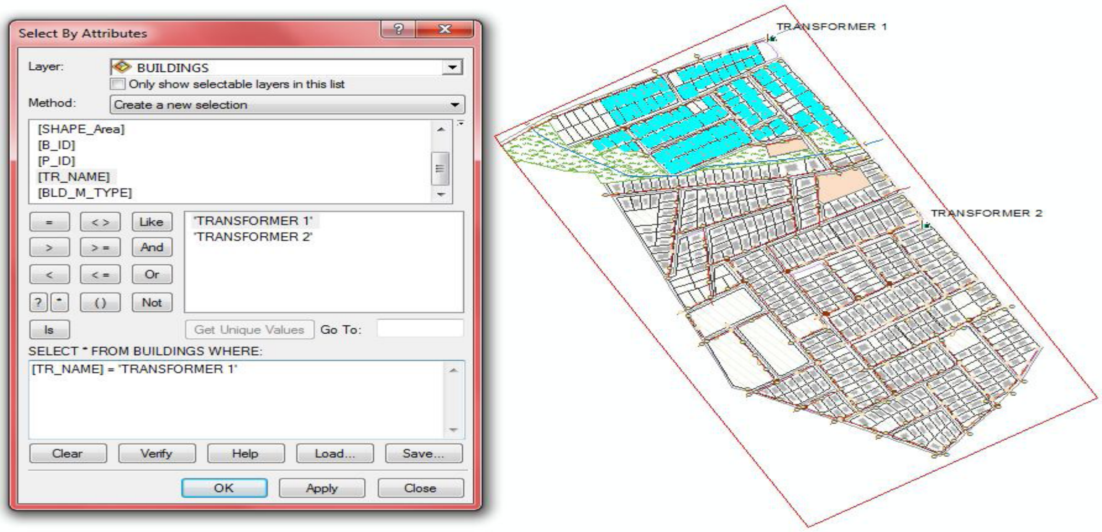

Figure 3.3: Query result showing buildings that are connected to Transformer 1.

Query 4: Select by attribute from buildings, transformer name that are connected to transformer 2 Syntax [TR_NAME] = 'TRANSFORMER 2

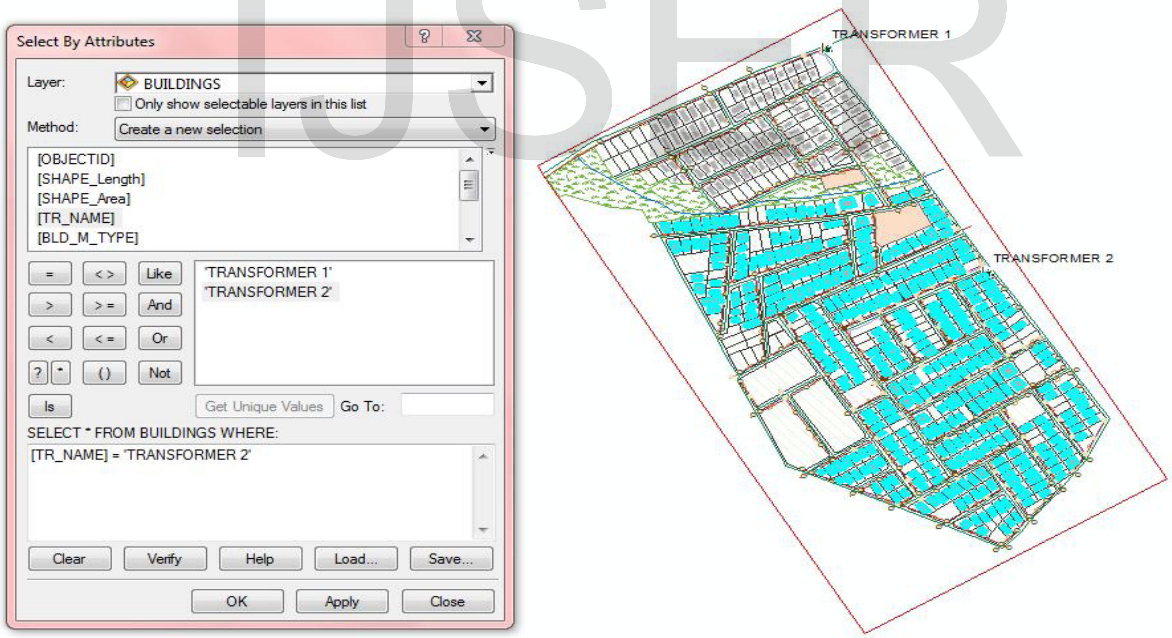

Figure 3.4: Query result showing buildings that are connected to Transformer 2

From the results of the analyses, the study area consists of 472 completed Buildings, which are already being utilized. Other plots are either yet to be developed or occupied by uncompleted buildings. There are two numbers of transformers in use in the area. Transformer 1 was installed in 2001 and has been there to serve other areas apart from the study area. Only 113 buildings from the study area are attached to transformer 1 and this forms 23.9% of the total buildings in use. Transformer 2 was installed in 2006. 359 buildings are attached to transformer 2 which forms 76.1% of the total buildings in use in the area. This information will help the IBEDC in fault clearing and in proper billing system for each building.

Query 5: Select by attribute from buildings, defaulters of bill after July, 2012 billing Syntax [AFTER_JULY_BILL] = 'DEFAULTER'

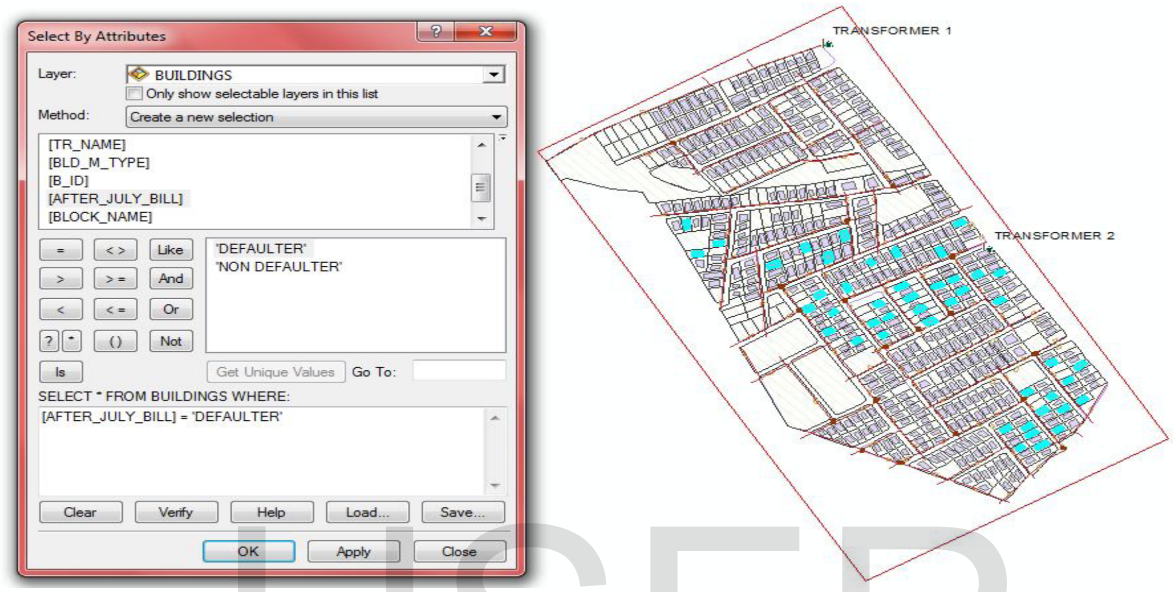

Figure 3.5: Query result showing defaulters of bill after July 2012 billing.

Query 6: Select by attribute from buildings, buildings that made payment after July 2012 billing Syntax [AFTER_JULY_BILL] = 'NON DEFAULTER'

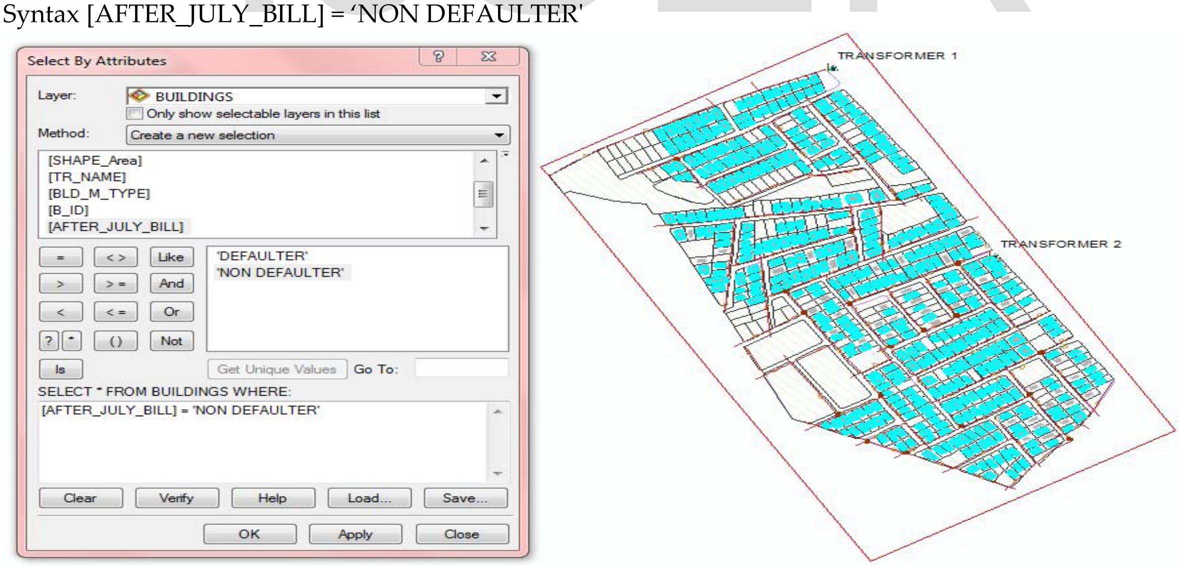

Figure 3.6: Query result showing Non-defaulters of bill after July 2012 billing.

The query result in figure 3.5 and 3.6 reveals buildings that fail to pay their electric bill after July 2012 billing and those that pay their electric bill after July 2012 billing respectively. The query result can also be performed for other months and the results used to deduce buildings that have consecutively fails to pay their electric bills and possibly disconnected.

Query 7: Select by attribute from buildings, buildings with no meter
Syntax [BLD_M_TYPE] = 'NO METER'

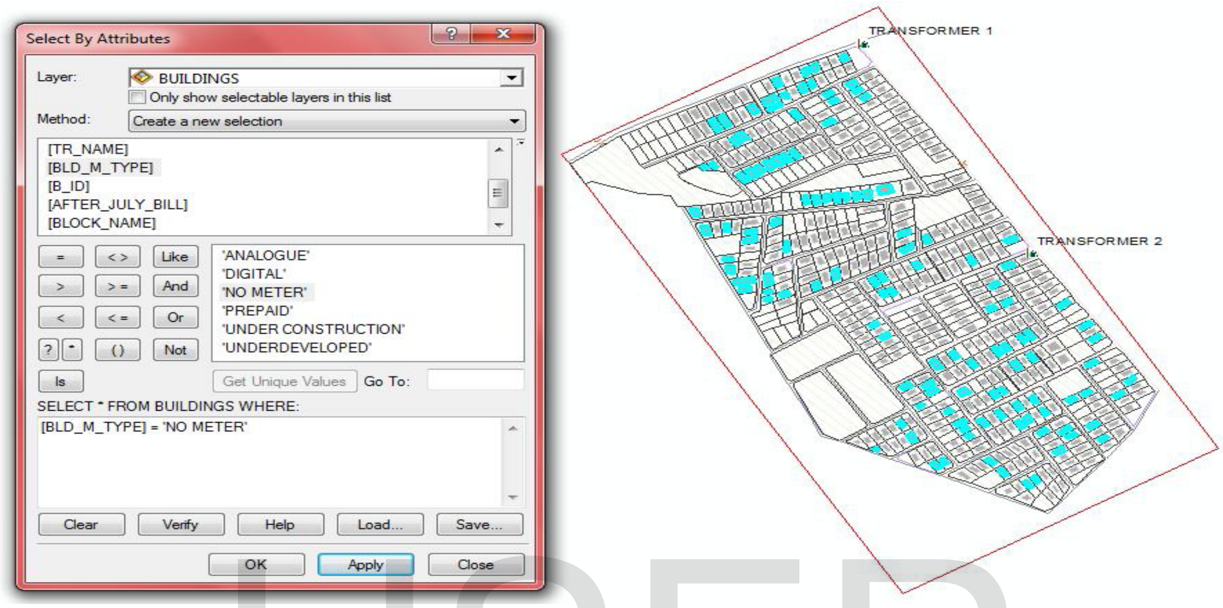

Figure 3.7: Query result showing buildings with no meter

Query 8: Select by attribute from buildings, buildings with prepaid meter
Syntax [BLD_M_TYPE] = 'PREPAID METER'

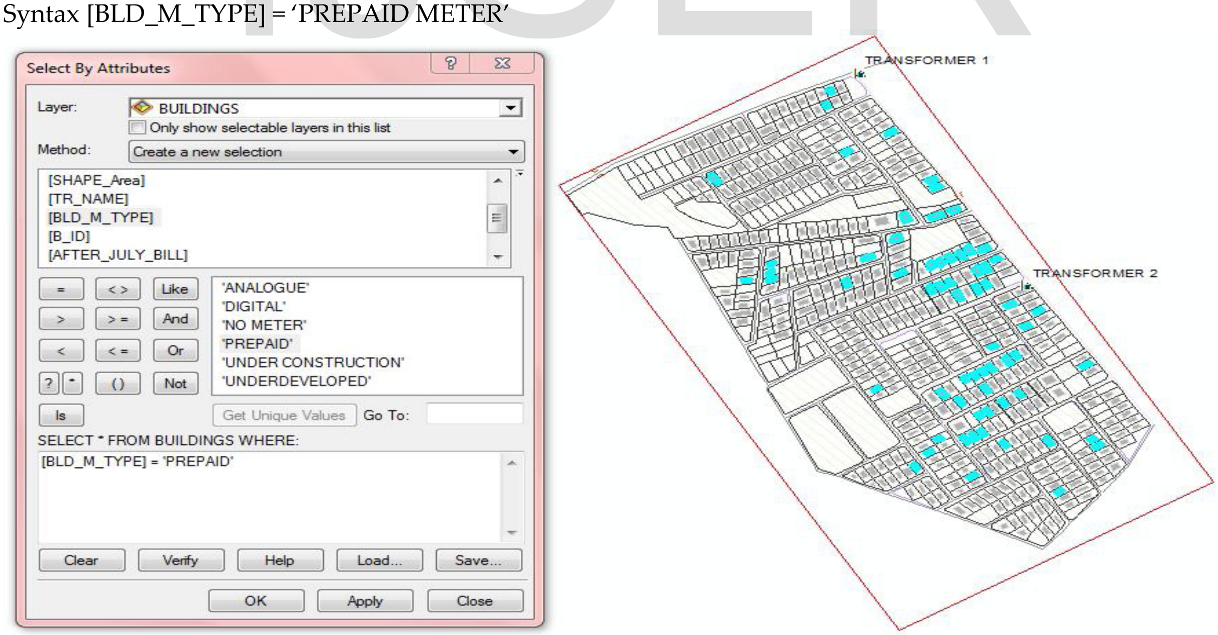

Figure 3.8: Query result showing buildings with prepaid meter.

The whole residential layout is covered by low tension lines that run through the streets from where electricity was tapped from each building. Out of the 472 buildings in the study area, 64

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buildings make use of prepaid meters while 121 buildings make use of analogue meters. The remaining 287 buildings have no meters at all but use planks with fixed cut-out connected with electricity from the poles. In this case, billing is based on just mere estimation by the officials of the IBEDC every month.

Query 9: What is the best route from a building on lane 13 to transformer 2?

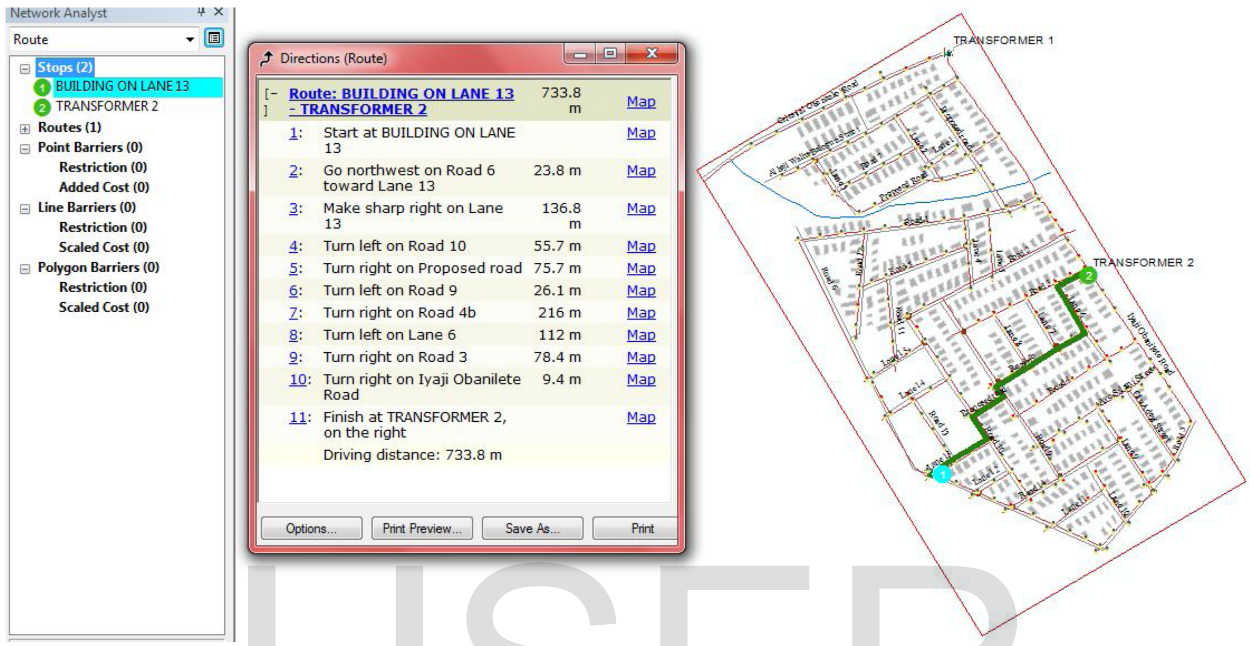

Figure 3.9: Best route analyses from a building on lane 13 to transformer 2.

Best route analysis was performed from a building on lane 13 to transformer 2. The best route covers a distance of 733.8meters. The result of this analysis is very important. For instance, In case of fire outbreak or any fault that affects a building or a transformer or any other electrical facility, the best route provides the shortest route to the scene from the IBEDC office or from fire brigade office.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The discussions so far on development of electricity distribution has come with a lot of findings. Considering the benefits of the developed system, IBEDC would be able to know the spatial relationships which exist among their facilities as the system revealed the spatial distributions and locations of electricity distribution facilities within the study area such as the 11kv line, the distribution transformers, the electric poles and the buildings connected to the transformers.

It will also guide them to know the areas that need new installation or where they could extend or improve their services. The system would also help them in fault management, improved billing system, planning of routine maintenance, easy handling of customers inquiries, data update and sharing among various users and in speedy and easy retrieval of information.

The type of meter a particular building is using can also be determined while the buildings without meters at all are indicated. This will greatly help the IBEDC in carrying out the facility (meter) check and supply meters to the buildings without meter when they are available. The type of electric pole can also be easily determined. The wooden poles are termed temporary poles, and these can be changed to concrete poles in near future as the locations of concrete and wooden poles are known. Considering the above information and others contained in this research, the benefits of managing information using Geographic

Information System (GIS) for electricity distribution cannot be overemphasized
Therefore, for IBEDC to perform to the expectation of customers there is the need for the analogue data to be converted to digital format which will aid information acquisition quickly and faster in order to yield quality services and ensure prompt and accurate decision making.

4.2 Recommendations

1. The ugly situation of erratic power supply coupled with non-availability of Utility Information System to effectively monitor and manage the distribution network in Iyaji Residential Layout, Oyo, Oyo state by the concerned authority i.e the Ibadan Electricity Distribution company (IBEDC) is not peculiar to the residential layout alone but also to many areas in the country. Therefore, government should include the issue of managing the generation, transmission and distribution of electricity in the country using Geographic Information System (GIS) to enhance sustainable power supply.

2. IBEDC should establish GIS departments in all its sections and divisions to be handled by competent personnel who understand the principles behind the process of electricity distribution and are versatile in the use of GIS software.

3. Training and retraining of IBEDC staff working in the department of Geoinformation should be encouraged especially in areas of electricity distribution principles, computer knowledge and in the use of GIS software.

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