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Power Grid Corridor Modelling for Efficient Electricity Distribution in Communities of Damaturu Nigeria Using GIS

Bala-Geidam M.[1], Badema A.[2] and Shuaibu, M. A.[3]

[1]*Dept. of Basic Science, Yobe State College of Agriculture Gujba, Yobe State Nigeria*

[2]*Dept. of Geography, Yobe State University Damaturu, Yobe State, Nigeria*

[3]*Dept. of Surveying and Geoinformatics, Abubakar TafawaBalewa University Bauchi Nigeria*

ABSTRACT

This study focused on modelling of power grid corridor using geographic information system (GIS). The objectives are to map and evaluate the communities and existing Substations on national Grid with the aim of modelling new substations source for effective power distribution in the study area. The mapping of positions of the substations and communities around the grid was achieved using Etrex 10 handheld GPS receiver and the evaluation was carried out using the Location allocation analysis of ArcGIS 10.3. The result of the model reveals that ten (10) out of the thirty-two (32) communities found were on the national grid while eight (8) distribution substations out of the ten (10) communities were discovered during location-allocation analysis. Consequently, the pattern of distribution of the substations was found to be random but optimal and least cost. Hence, the result of this study will certainly make electricity distribution efficient in the study area and hence recommended for use by all stakeholders.

KEY WORDS: *Modelling, Location Allocation Analysis, GIS, Power Grid.*

1. INTRODUCTION

Electrical power generation, transmission and distribution are the three phases of supplying electricity to users at domestic, engineering, commercial, and governmental area. The supply of adequate and stable electricity to users is the back born of socioeconomic development of any nation. While inadequate and unstable supply of electricity to consumers in any nation would definitely lead that nation backward in terms ofits socio-economic growth. The physical structure of most power systems consists of generation facilities feeding bulk power into a high-voltage bulk transmission network that in turn serves any number of distribution substations. A typical distribution substation will serve from 1 to as many as 10 feeder circuits. A typical feeder circuit may serve numerous loads of all types. A light to medium industrial customer may take service from the distribution feeder circuit primary, while a large industrial load complex may take service directly from the bulk transmission system. All other customers, including residential and commercial, are typically served from the secondary of distribution transformers that are in turn connected to a distribution feeder circuit, Grigsby (2012).

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information. The geographic approach, through Environmental Systems Research Institute (ESRI) GIS technology, allows us to view, query, and understand data in many ways. We see relationships, patterns, and trends in the form of GIS-based maps, globes, reports, and charts. GIS helps you answer questions and solve problems. When viewed in the context of geography, your data is quickly understood and easily shared. GIS technology can be integrated into any enterprise information system framework.Utilities worldwide use GIS to manage and map the location of millions of miles of overhead and underground circuits. Within GIS, your utility's assets can be linked directly to your customer information system, allowing you to proactively monitor work orders, vegetation management, and outages.Therefore,GIS helps you determine the right location for new facilities and new technologysuch as smart grid sensors and smart meters, (ESRI).

1. 1 Aim and Objectives of the Study

The aim of the research is to evaluate some communities on national grid for effective power distribution andthis can be achieved via the following objectives

i. To mapped out the communities on national Grid.

ii. To evaluate the existing Substations.
iii. To suggest the new power substation source using Location allocate.

2. STUDY AREA

The Study area is Damaturulocal Government area of Yobe State, It is located between11° 44' 07"N and 11° 50' 00"N latitude with 11° 54' 08"E and 12° 02' 27"E longitude, it has an average altitude of 298m above Mean Sea Level.It is bounded between in North with Borno State, in South with Gujba, in East with Fune and in the North with Tarmuwa Local Government.

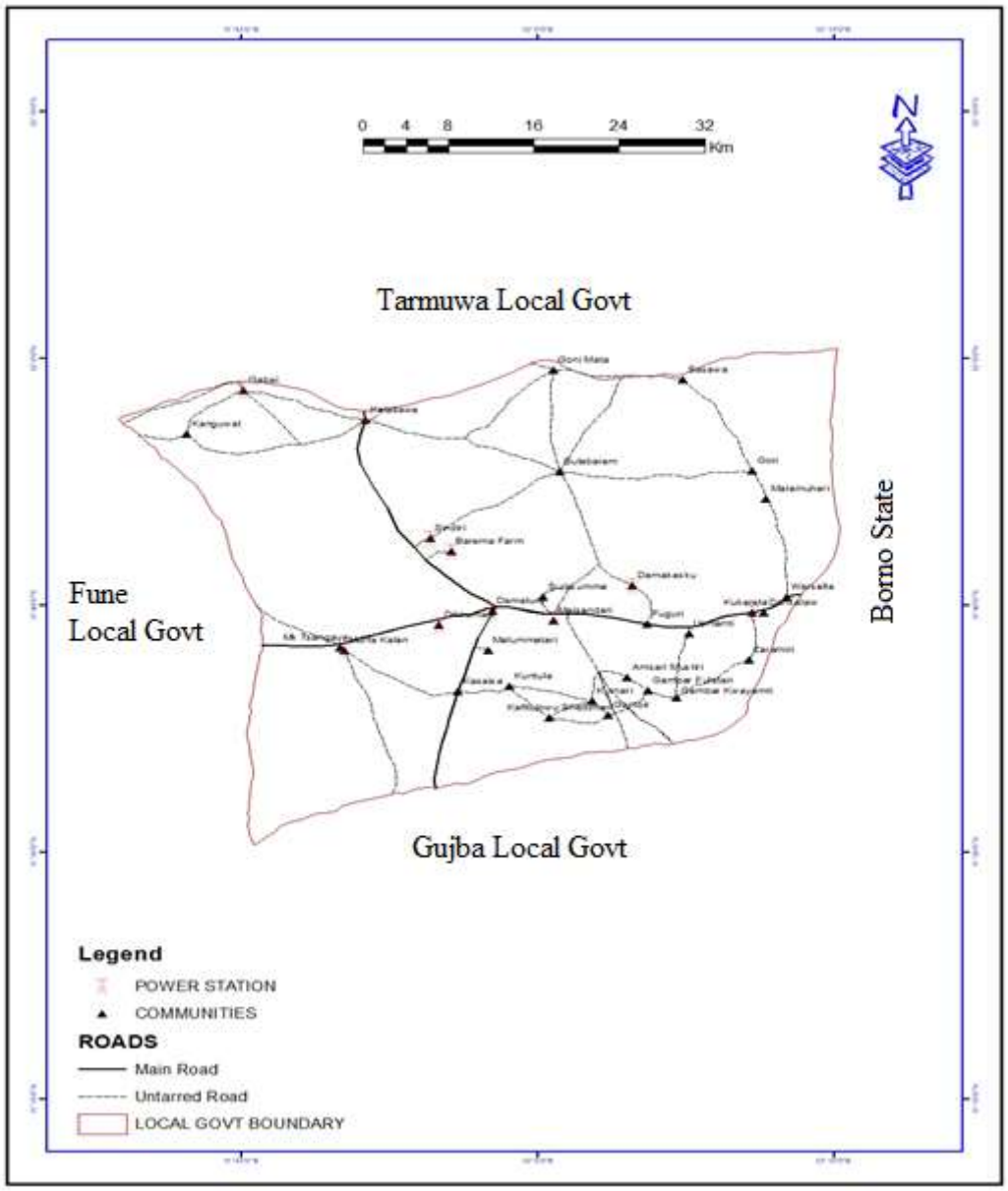

Figure 1.0: Map of Damaturu showing Road network and Power Substations

3. HISTORICAL BACKGROUND POWER IN NIGERIA

The history of electricity development in Nigeria can be traced back to the end of the 19th Century, when the first generating power plant was installed in Marina, Lagos, in 1898, fifteen years after its introduction in England. Its total capacity was 60kW. After the amalgamation of the Northern and Southern protectorates in 1914 to form modern Nigeria, other towns in the country started to develop electric power supply system on the individual scaleAwosope (2014).

The National Electric Power Authority (NEPA) was established by Decree No 24 of 1st April, 1972, with the amalgamation of Electricity Corporation of Nigeria (ECN) and Niger Dam Authority (NDA). NEPA was empowered to maintain an efficient, coordinated and economic system of electricity supply to all nooks and crannies of the nation.Major power stations namely: Ijora,

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Delta and Afam Thermal Power Stations and Kainji Hydro Power Station serving more than two million customers nationwide. That propelled the nation's technological and industrial growth. NEPA has become the fastest and biggest growing electricity industry in Africa and indeed the developing world with a customer population of about five million. NEPA has made giant stride in the production and marketing of electricity to the nation and beyond. A principal beneficiary of NEPA's extended electricity programme is the Republic of Niger under the agreement with NIGERLEC (Niger Electric Company), that country's electricity monopoly. Similarly, in September 1996, an undertaken was signed between NEPA and CummunauteElectrique Du Benin (CEB) which is responsible for the production of and transportation of electric energy in the Republic of Benin and Togo. NEPA has nine zones (Abuja, Benin, Enugu, Ibadan, Jos, Kaduna, Kano, Lagos, Yola) and 49 districts. With the present state of the technological advancement in Nigeria, much emphasis was placed on power generation through Hydroelectric and thermal sources. Nigeria has three hydroelectric stations and four thermal stations.In 2005, National Electric Power Authority (NEPA) change its name to Power Holding Company of Nigeria (PHCN), Plc with the aim and objectives of providing effective power supply to the nooks and crannies of the country(Olaniyi and Usman, 2006).

4.0 METHODOLOGY

This chapter worked out the research Material and Method for the present study. It explains the research purposes and appropriate methodology to achieve those objectives. The objectives of this study were to Map out the communities on National Grid and to evaluate the substations in some major Communities within Damaturu Local Government Area of Yobe Statefor future decision making using ArcGIS 10.3. This involved an exhaustive Mapping with hand held GPS receiver, acquiring data from Power Holding Company of Nigeria (PHCN), Conceptual Design of the Database and Location allocation analysis.

4.1 Material

ArcGIS 10.4, Etrex 10 Hand held GPS Receiver, Primary and secondary data were used for the purpose of this research

4.1.1 Primary Data

These were the data collected as a result of the field survey and it includes: Coordinate of Settlements and that of Substations captured with used of handheld GPS receiver(Etrex 10) in Minna reference datum on Geographical coordinate system format.

4.1.2 Secondary Data

The secondary data were the second hand data collected and recorded by authorities concerned. These data include the based Map of Damaturu local government area of Yobe State collected from Ministry of Land and survey Damaturu and the attribute data of the substation from Power Holding Company of Nigeria (PHCN).

4.1.3 Criticism of the sources

The quality of data used for any experiment can be determined by the validity and reliability of such data based on the assumption that the observers of such data are trustworthy and experienced. The validity of the data can be determined by the precision of the instrument used. Precision is defined as the degree of closeness of repeated measurements of the same quantity to one another. The coordinates of each point were taken repeatedly and found to be closely clustered. The reliability of data is determined by the accuracy of the data. That is, the degree of closeness of the sets of data to another sets regarded as the true values, often referred to as 'Gold Standard Data'(Idowu, T. O.*et al*, 2013)

4.2 Method

The technique applied at this juncture comprisesattribute and geometric data of the communities superimposed on digitized map of Damaturu in ArcGIS 10.4 window. Query was carried out to indication the communities on National grid. In Network analyst tool, Location Allocation solver was used determine a minimal distance on where to tap power from.

4.2.1 Georeferencing

This as achieved by adding the coordinates of scanned base mapgrid lines. It makes the map; Fit to Display, Shiftand placed the raster dataset in its approximate geographic location.

4.2.2 Digitizing

Layers for 2D features (polygon) were created in ArcCatalog and later added into ArcMap environment. The local Government Boundary was traced using select Create Features in editor tool; the same steps were repeated to major Roads.

4.2.3 Query Analysis

Queries are used to select a subset of features and table records. All query expressions in ArcGIS use Structure Query Language (SQL) to formulate these search specifications, (ArcGIS Pro, online). Database developed acts as server that enable different types of questions to be asked about the details and their attributes in the displayed map, this process is called query analysis.In this researchSQL was used when constructing a query using layer tableattributes in geoprocessing tool.

4.2.4 Spatial Distribution analysis

The spatial distribution of the existing substation was analysed using Average nearest neighbor analysis
Via the following relationship.

$$R_n = \frac{\mathrm{d}\sqrt{\mathrm{n}}}{a}$$

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Where:
Rn = the nearest neighbor index
a = the size of the study area
d= the mean distance between Substations
n= the number of Substations
The Rn values range from when there is no distance at all to 2.15. A purely random distribution has an index of 1.0 value; above 1.0 indicate a tendency towards spacing and those below 1.0 indicate clustering i.e.
Rn= 0: implies that the distribution of points is cluster
Rn= 1: implies that the distribution of points is random
Rn = 2.15: implies that the distribution of points is regular or uniform.
Above is the Nearestneighbor index used to determine the distribution pattern of the substations in the study area (Takana&Alhassan, 2017).

4.2.5 Location Allocation Analysis

Location-allocation helps you to choose which communities from a set of communities to operate based on their possible relations with demand communities. It helps you know where community should tap power to minimize distance from the existing Power Substations.

5 RESULTS PRESENTATION

Table 1 shows the coordinates of the existing substations. Figure 2 and 3 presentthe Query result of Communities on National Grid and the Query result of communities that are not on National Grid respectively; figure 4 shows the map of Location-Allocation analysis of existing Substations in DamaturuLocal Government area of Yobe State which are ten (10) in number and thirty two (32) communities under the local government. Figure5 shows the Substations and number of Demand Counts on each substation. Figure 6indications Graphical Presentation of Demand Count on each substation and finally the average nearest result is presented in figure 7.

Table1: Table showing communities on National Grid with their Coordinates

SN	Communities	Lat_N	Long_E	Stations
1	Damaturu	11.74444	11.96111	Substation 1
2	Sindiri Village	11.818215	11.908785	Substation 2
3	Kalallawa	11.93739	11.85442	Substation 3
4	Barema Farm	11.80491	11.926737	Substation 4
5	MurfaKalan	11.70444	11.83621	Substation 5
6	Gabai	11.9678	11.75178	Substation 6
7	Kukareta	11.742620	12.180095	Substation 7
8	Damakasku	11.769865	12.079559	Substation 8
9	Maisandari	11.736145	12.014	Substation 9
10	Dukkumari	11.73069	11.91666	Substation 10

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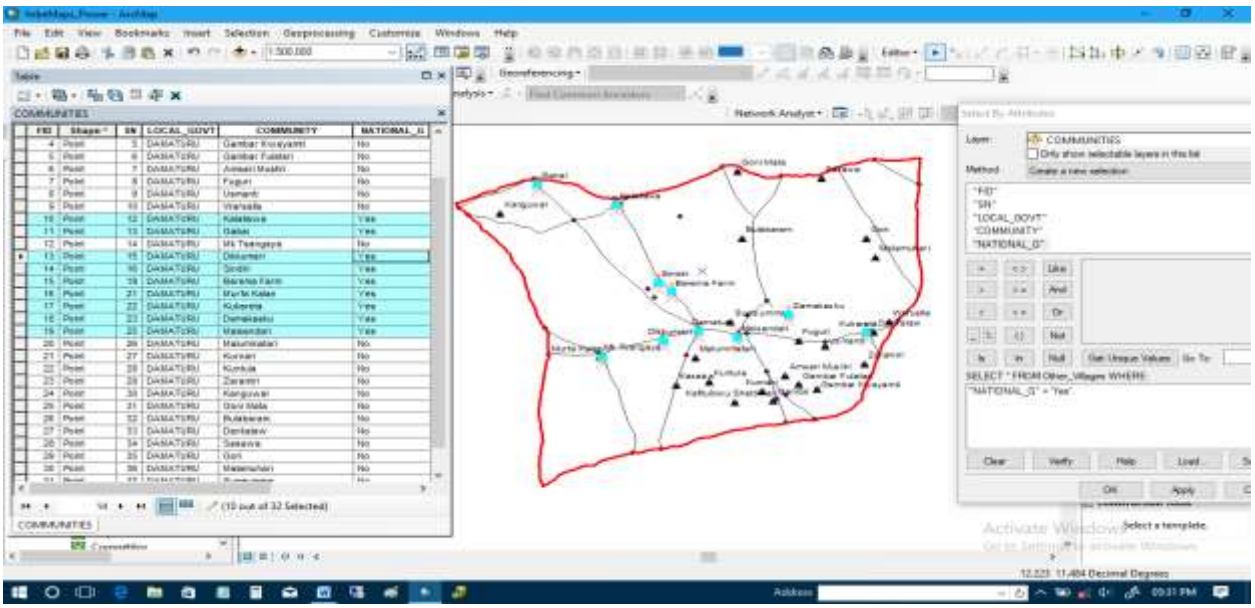

Figure 2: Query of Communities on National Grid

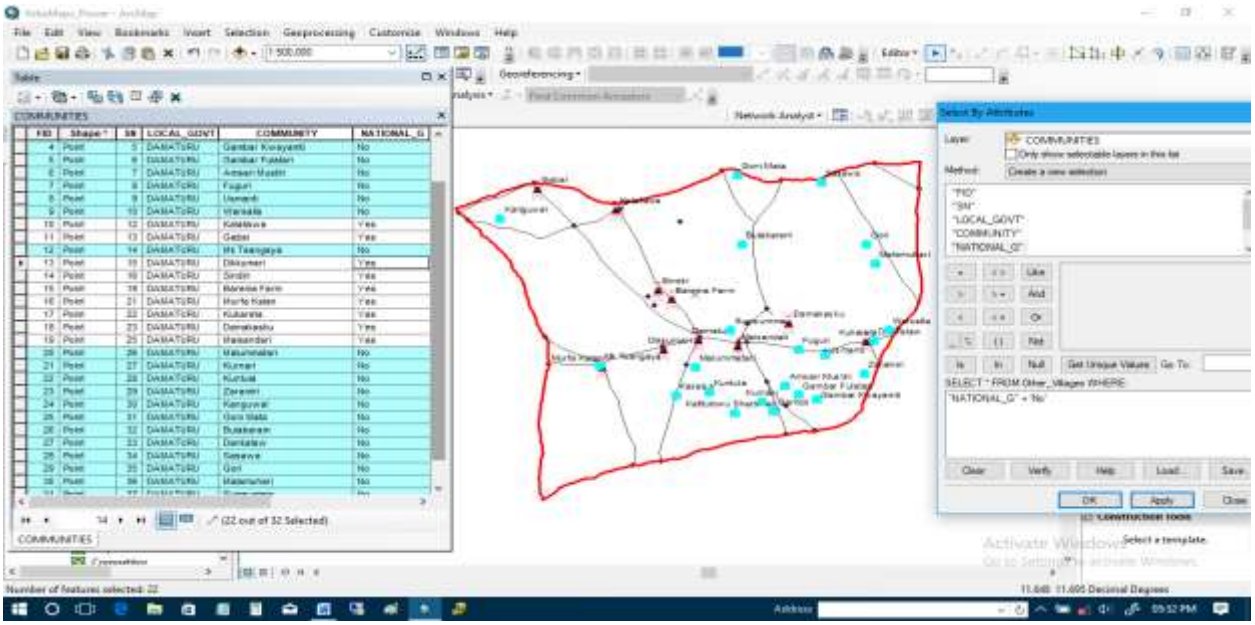

Figure 3:Query of Communities not on National Grid

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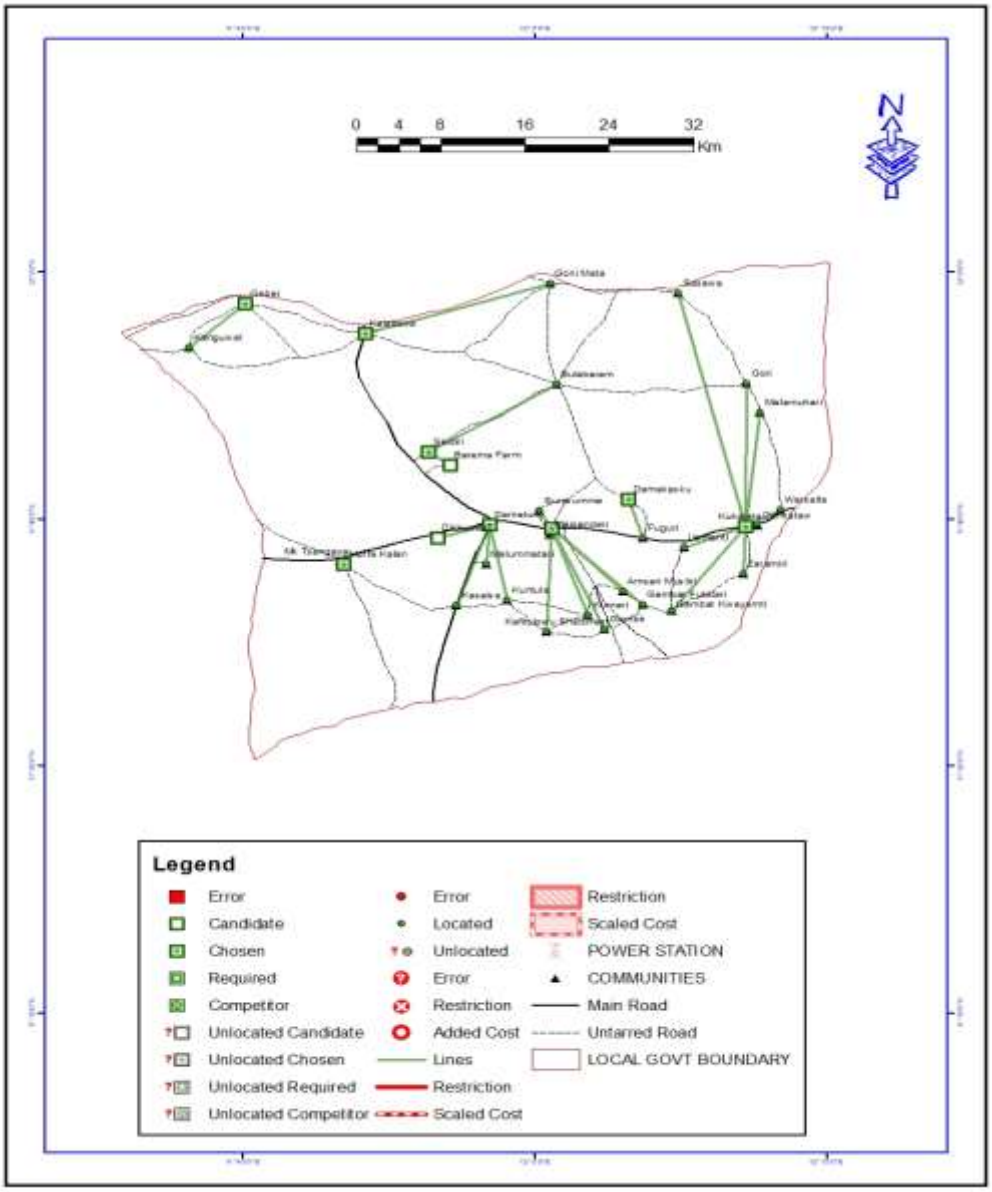

Figure 4: Map of Damaturu showing Location-Allocation analysis of the existing Substations

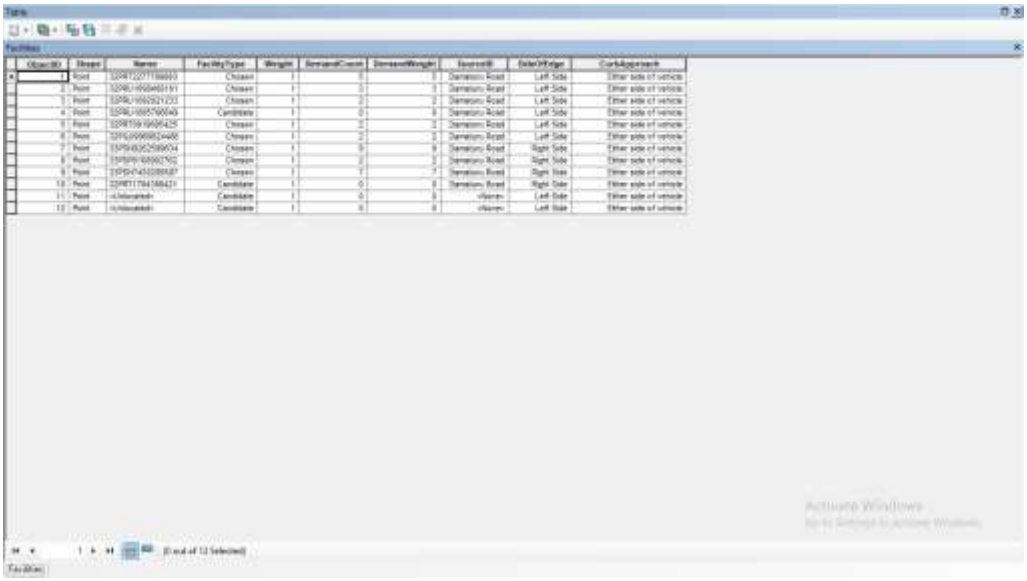

Figure 5: Table Showing the Number of Substation and Demand Counts

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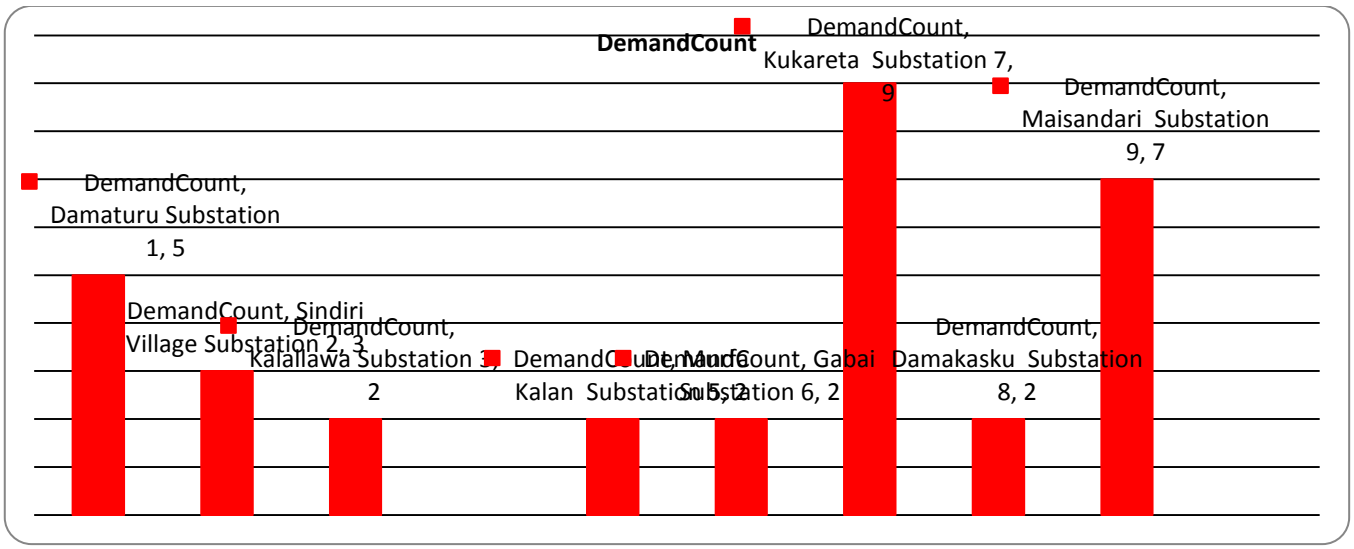

Figure 6: Graphical Presentation of Demand Count on each substation

Nearest Neighbor Ratio: 0.949271

z-score: -0.306893

p-value: 0.758925

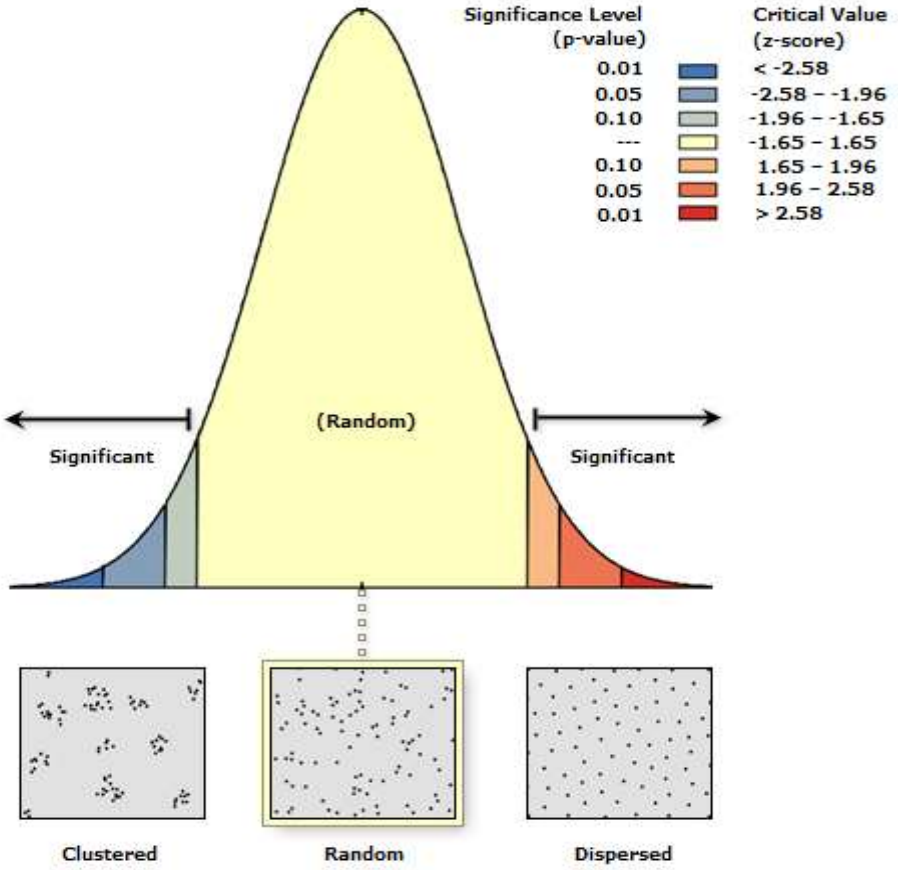

Figure 7: Average Nearest Neighbor Summary

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6. DISCUSSION OF RESULTS

Two queries were carried out to test the efficiency of the developed database using the query builder, "YES and NO" were used to indicate the communities on national Grid and thosethat are not, such as Figure 2: shows query result of communities on National Grid (YES) and Figure 3: shows query result for communities that are not on National Grid (NO),Figure 4 is map of Damaturu showing Location-Allocation analysis of theFacilities (Substations) and Demand Points (Other Communities), the result of the analysis revels that eight (8) out of the ten communities were chosen to serve as the distribution centre, symbolized with green box inscribed with a green star and green line Joining the demanding points and the distributing substation; these includeDamaturu (1), Sindiri (2), Kalallawa (3), MurfaKalan (5), Gabai (6), Kukareta (7), Damakusu (8) and Maisandari Substation (9), whileBarema farm (4) and Dikkumarisubstation (10) were not chosen as part of the distributions centre. Figure 5 is the Demand Count table showing number of demanding communities on each of the chosen substation and it is presented graphically in figure 6using bar chart showing the substations and their number of demand communities. Figure 7 depicts the z-score of -0.306892658654 and the pattern does not appear to be significantly different than random.

7. CONCLUSION

The study concentrated on theevaluation of communities on national grid for effective power distribution using geographic information system, this was achieved by determining the positions of substation using Etrex 10 hand held GPS receiver and analyses was carried out using ArcGIS 10.3. The result of the analysis revels that 10 out of 32 the communities were on national grid and 8 out of the 10 communities were chosen during location allocation analysis and they saved as the distribution substations. Spatial distribution analysis shows that the substations pattern does not appear to be significantly different than random. With this, it is concluded that the distribution is optimal and least cost best on the location allocation analysis result.

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