ANALYSIS OF SPATIAL DISTRIBUTION OF ELECTRICITY TRANSFORMERS IN JIMETA, YOLA-NORTH LOCAL GOVERNMENT AREA OF

ADAMAWA STATE, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA-NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT, FACULTY OF PHYSICAL SCIENCES,

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JULY, 2018

DECLARATION

I declare that this Dissertation entitled: ANALYSIS OF SPATIAL DISTRIBUTION OF ELECTRICITY TRANSFORMERS IN JIMETA, YOLA-NORTH LOCAL GOVERNMENT AREA OF ADAMAWA STATE, NIGERIA; has been carried out by me in the Department of Geography and Environmental Management, Faculty of Physical Sciences, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

Sela ABANA (Signature)_____ Date_____

CERTIFICATION

The Dissertation entitled ANALYSIS OF SPATIAL DISTRIBUTION OF ELECTRICITY TRANSFORMERS IN JIMETA, YOLA-NORTH LOCAL GOVERNMENT AREA OF ADAMAWA STATE, NIGERIA by Sela ABANA meets the regulations governing the award of the degree of M.Sc Remote Sensing and GIS of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

To the best of all friends, Dimliura Yohanna, am so grateful. Your love and sacrifices towards the success of this programme will ever remain alive. You are a friend indeed! You are a faithful friend that sticks closer than a brother. You have always been there for me even when others had left me thinking nothing applaudable was going to come out of what they described as a mere ambition. You shall always remain relevant to me because you did not only believe in the dreams that the Lord has put on the inside of me, you supported me in your own way to pursue them. May the Lord reward you Sir.

ACKNOWLEDGEMENT

Glory, honour and praise be ascribed to the Lord God Almighty who is the source of inspiration behind the success of this work and the entire programme. I really acknowledge the help of the Holy Spirit that guided me right from the choice of the research topic through the proposal, data collection and the final work.

With a very deep sense of gratitude, I wish to acknowledge the tireless and thorough work done by my supervisors: Prof. B.A Sawa and Prof. A.A Zemba who took time and counseled me right from the choice of the topic. You are indeed my mentors. May God reward you for doing your jobs very well. I also appreciate Dr. R.O Yusuf, Prof. E.I Iguisi, Dr. B. Akpu, Dr. M. Ismail and all other staff of the department for all their inputs during my seminar presentations. I'm also indebted to Mr. Urbanus Musa, Mrs. Hajara Mathew, Mr. Abana Chibok and all the technical staff of the YEDC Jimeta Business Unit for their gracious aid during my data collection.

Finally and very importantly, I wish to appreciate my beloved elder sister and her husband, Mr. and Mrs. David Yamai for their sacrifices that made money available for the conduct of this work. My profound appreciation also goes to my friends Dimliura Yohanna, Kama Elba, Dr. Akhan Misali Kskbiya, Moses Romanus Jideofor, Hyelnaya Midala, Abigail Titus and My elder brothers and Roommates Mr. Dogan Jacobs and Dr. Japhet Kalang for your prayers, encouragements and financial supports that helped in the accomplishment of this work. A big thank you to Rev. Peter Iordaah and all my classmates.

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ABBREVATIONS

1.	ABB - - - -	Asea Brown Boveri
2.	AM - - - -	Automated Mapping
3.	ANSI - - - -	American National Standards Institute
4.	APT - - - -	Advisory Power Team
5.	DISCOs - - -	Distribution Companies
6.	FM - - - -	Facilities Management
7.	FM - - - -	Facilities Mapping
8.	GAPS - - - -	Global Assets Protection Services
9.	GENCOs - - -	Generating Companies
10.	GIS - - - -	Geographic Information System
11.	GPS - - - -	Global Positioning System
12.	IEC - - - -	International Electrotechnical Commission
13.	IDPs - - - -	Internally Displaced Persons
14.	IEEE - - - -	Institute of Electrical and Electronics Engineers
15.	LGA - - - -	Local Government Area
16.	MHD - - - -	Magneto Hydro Dynamics
17.	NNA - - - -	Nearest Neighbour Analysis
18.	NEPA - - - -	National Electric Power Authority
19.	NERC - - - -	Nigeria Electricity Regulatory Commission
20.	PHCN - - - -	Power Holding Company of Nigeria
21.	TCN - - - -	Transmission Company of Nigeria
22.	USDE - - - -	United States Department of Energy
23.	YEDC - - - -	Yola Electricity Distribution Company

ABSTRACT

In Nigeria, challenges of power sector include among others, insufficient power generation and inadequate or lack of quality apparatuses for efficient transmission and distribution of electric power to consumers. Jimeta, being one of the major cities in Adamawa State, has experienced increase in population and spatial expansion in recent years. This is partly due to the influx of the Internally Displaced Persons (IDPs) from the northern and parts of the central regions of the State as a result of the protracting Boko Haram insurgency. This has put pressure on the available social amenities including electricity thereby making power distribution facilities, such as transformers, spatially inadequate, resulting in unequal power distribution and overloads. The aim of this study was analyze the spatial distribution of electricity transformers in Jimeta, Yola-North Local Government Area of Adamawa State, Nigeria. The study used data acquired with Hand-held GPS receiver, records of Yola Electricity Distribution Company (YEDC) and population census data, and mapped out the spatial distribution of electricity transformers in Jimeta using ArcGIS10.3 software. It further established the spatial pattern of point locations of transformers; created a geodatabase for all the transformers; assessed the level of compliance to the standards for transformer siting and also examined the extent to which population influenced their locations. Nearest Neighbour Analysis (NNA) was carried out to determine the pattern of distribution of transformer point locations. Projected population of the study area was used to produce a population density map over point locations of the transformers were overlaid. Buffer analysis in ArcGIS10.3 software was carried out to identify the location of transformers that violated the 10m setback standard of the NERC (2016). The results showed that Jimeta had a total of 324 transformers distributed across the city in various capacities ranging from 25kVA to 1000kVA. About 0.93% of the transformers are 25kVA at the lower extreme while, 200kVA transformer accounted for 34.87% which was the highest. Public transformers distributed mostly

across residential and large commercial centers accounted for 45.67% while, dedicated transformers installed for private individuals and organizations accounted for 54.33%. The Nearest Neighbourhood Analysis result generated showed clustered points at 0.01% significance level with 0.010787 ratio. Population density showed a strong influence on the distribution of transformers with 62.04% of the transformers located in the densely populated areas of the city. A total of 11 transformers (3.4%) negate the 10m safety clearance from major roads, while 31 transformers accounting for 9.6% violated the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) standards of 25 years in service. The study recommends that, distribution transformers should also be located in the newly built up areas of the city so as to boost electricity supply and to encourage commercial and industrial activities in such quarters. The government and the YEDC should replace those transformers that are over 25 years and in order to avoid deterioration of insulated materials, breakdown, fire disasters and power outages.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Electricity is simply regarded as the flow of electric current (Hassan and Akhtar, 2012). This involves the generation of electric power, its transmission and distribution to consumers. Power utility is very important for smooth performance and development of society. It does not only, supports the economy, but also, supports the well-being of individuals. For a country to obtain its managerial objectives and sustain its growth, efficient functioning of power utility must be given supreme importance (Kanmani and Suresh, 2014). This is necessary due to the fact that, adequate and constant power supply promotes almost every sector of an economy. The Electric power sector is one of the most important sectors that hasten national development. It is also critical to the developmental reforms of any country (Chatta, 2015). Electric power supply is the most important commodity for national development. With electrical energy, the people are empowered to work from the domestic level and the cottage industries, through the small-scale, medium industries, and large-scale manufacturing complexes. Nowadays, depriving people of electric power is tantamount to castration (Musa, 2009). This observation appears to be somehow exaggerative and unscientific but, from the figurative angle, it is clear that an individual deprived of electricity cannot be productive and may be as helpless as a castrated animal. Electric power generation may be through one of the following sources of energy: coal, oil or natural gas; hydro power (water turbine); nuclear power (steam turbine); solar, wind or water-wave turbine; solar thermal generator and solar voltaic generator. Transformers, among other facilities, play key roles in efficient transmission and distribution of electric power to final users.

A transformer is an electrical apparatus designed to convert alternating current from one voltage to another. It can be designed to "step up" or "step down" voltages and works on the magnetic induction principle. A transformer has no moving parts and is a completely static solid state device, which ensures, under normal operating conditions, a long and trouble-free life. It consists, in its simplest form, of two or more coils of insulated wire wound on a laminated steel core. When voltage is introduced to one coil, called the primary, it magnetizes the iron core. A voltage is then induced in the other coil, called the secondary or output coil. The change of voltage (or voltage ratio) between the primary and secondary depends on the turns ratio of the two coils (TYCO Electric Corporation, 2010).

Distribution transformers are of different types based on their sizes, capacities and uses; but they are generally classified as either liquid filled transformers or dry transformers. Liquid filled transformers make use of mineral oil or replacement fluids such as synthetic or natural esters, while dry transformers use mercury (Chatta, 2015). They are very vital electric facilities that play a major role particularly in the power distribution phase. Asea Brown Boveri (ABB) (2004) affirmed that “transformers are one of the most important units in every production process of electricity. Without them, the core activities of nearly every business or factory would come to a standstill-with serious financial consequences”. Jasni, Azmi, Azis, Yahaya and Talib (2017) observed that continuous power supply depends on the condition of the transformer as it is the ‘back-bone’ of a power system. Adequate spatial distribution and management of transformers in an area is therefore, paramount in resolving challenges relating to electricity distribution.

Geographic Information System (GIS) technology has gained wide acceptance in the planning distribution and management of facilities. As rightly noted by Yadav (2013); electricity companies are already finding GIS very useful in the management of distribution. The electric utility industry has realized that GIS is a valuable tool not only for mapping facilities but to improve decision making and better management of existing infrastructure. Although the needs and uses of GIS are slightly different in the power sector than other industries, GIS just be as valuable as an information technology in the electric utility industry. In Automated Mapping (AM), this technology helps the utilities to quickly create digital maps of their supply area using the digitization facilities of the software. These maps when digitized contain detailed information about the area serviced by the utility, and the precise location and engineering information of the distribution network equipment of the utility that are installed in the field. In facilities management (FM), the digitized map files that are so created with all the required intelligence built into them can now be used to satisfy the facilities management needs. GIS has now become effective and powerful decision making tool capable of handling the different scenarios in utility mapping and management (Davies, 2010).

Facilities Mapping (FM) is the process of digitally identifying and mapping facilities infrastructure with the explicit goal to improve operational management and planning tasks such as dispatching, inventory, and maintenance. Some examples of facilities include utilities like gas, water, telephone, electricity, airport siting, and transportation. Facilities refer to all man-made structures or other improvements whose function, size, service area, or uniqueness give them the potential to improve the well-being of the people without disruption of vital socio-economic activities (Zitta, Musa and Isa, 2014). Global Positioning System (GPS) is also integrated for mapping and analysis of utilities such as electric distribution facilities and circuits (e.g. Al-Sakkaf and Al-Ramadan, 2013; Thakur, 2016 and Zitta, Musa and Isa, 2014).

Electricity generation in Nigeria is generally regarded to be below the population demand. The power produced is far below the country's peak demand level forecast of 12,800 MW of electricity (Salihu, Olatunde, and Chukwudebe, 2014). Currently, over half of Nigerian population does not have access to grid-connected electricity, and those that do, suffer from intermittent power supply. Stable and constant electricity is vital to the economic and social welfare of Nigeria. This is not a luxury, but a necessity for the development and progress of Nigeria (Advisory Power Team, 2015).

This has therefore resulted in energy supply crisis which the Distribution Companies (DisCos) and government are trying to resolve. This situation is worsened by the network distribution problems which are due to the insufficient up-to-date information about the facilities of the DisCos. Distribution systems network carries electricity from the transmission system and delivers it to the consumer. Such network would include medium voltage power lines, sub-stations, pole-monitored transformers and low voltage (less than 1 KiloVolt) distribution wiring meters (Ighalo and Williams, 2012). Since the distribution network of a power utility has a geographical reference, it is beneficial to create the network on GIS map and constantly update the same as per existing field parameters. With periodic updating and monitoring, GIS mapping of the Electrical Network and Consumer database helps in improved planning, load management, loss reduction, better revenue realization, asset and management standard of the distribution network and possibly better consumer relationship. GIS technology helps in generating fast, accurate and reliable database management, which are very vital in taking prompt and accurate decisions necessary in electricity distribution network (Adejo, Ajileye, Alaga, Samuel and Onu, 2015).

Yola Electricity Distribution Company (YEDC, 2015), observed that there are new realities emerging after the unbundling and subsequent privatisation of the power industry in Nigeria. YEDC noted that the electricity distribution companies (DISCOs) need to re-evaluate their business, marketing and branding strategies to conform with industry standards that will provide better service to customers. This has

prompted the need for this study in the highly commercialized urban center of Adamawa State where the YEDC headquarters is located.

1.2 STATEMENT OF THE RESEARCH PROBLEM

As a result of spatial expansion and continuous growth in the population of Jimeta, the demand for power is highly above the current supply of electricity just as it is the case in the entire country (Salihu, Olatunde, and Chukwudebe, 2014). The increase is partly due to immigration as a result of the effects of insurgency that affected the northern and parts of the central regions of the State, which made the city a refuge home for most of the IDPs. This increased the population of Jimeta with increased economic activities in recent years and as such, pressure is exerted on social amenities including electricity. Consequently, power distribution facilities such as electric transformers are being overstressed due to overloading beyond their designed capacities. More so, the current spatial distribution of the existing transformers has been observed to be skewed and inadequate. While other areas have more transformers and hence enjoy more and relatively stable light, some parts of the city have only few transformers and hence do not enjoy stable light. Some of these equipments are very old and not sited based on recognized and acceptable standards. These constitute the problem which guided the course of this research for the sole purpose of finding addressing the issue.

Facilities Mapping (FM) using remote sensing and GIS techniques are widely recognized technique and one of the acceptable methods for such studies. Although, the technique is relatively new in Nigeria, it has been found to be widely used in the area of research for providing lasting solutions to geographically related problems. GIS in particular, has now become known for being an efficient and powerful decision making tool capable of handling the different scenarios in utilities mapping and management (Davies, 2010).

Utility services are therefore, an important component of the physical structure of towns and there is a need for detailed information about the location and condition of their infrastructure (Kanmani and Suresh, 2014). Organizations' adequate knowledge on the locations and conditions of their assets is important. Any organization that expects to run an efficient day-to-day operation and to manage and develop its services effectively must know what asset it has, where they are, their condition, how they are performing, and how much it costs to provide the service (Pickering, Park and David, 1994). So, to take sensible decisions essential to the operations, management and growth of distribution facilities such as electric transformers, data should be collected and fully

analyzed, which may contribute not only in efficient services, but also in the operation and maintenance of assets, and in sensible planning of new works and extensions.

Various studies on spatial distribution of facilities using geospatial techniques have been conducted across Nigeria. These include among others: studies on the distribution of educational facilities, healthcare facilities, telecommunication facilities, electric facilities and water facilities. For example, Ighalo and Williams (2012) employed the techniques of GIS and GPS to simulate the power distribution network of the Ikpoba-Hill District-Benin City, Edo State. To improve on the distribution performance of this sub-station of the then Power Holding Company of Nigeria (PHCN), the authors considered the following electric facilities in their study: Low tension electric poles, High tension electric poles, Low and High Tension (dual) electric poles, High Tension cables, Low Tension cables, High and Low tension cables, Underground cables, Transformers, and Feeders. The authors did not consider the pattern of distribution of such facilities and whether their locations were in line with any guiding standards of which this present study intended to achieve.

Chatta (2015), worked on spatial distribution and utilization of electricity transformers in Sabon Gari L.G.A of Kaduna State. The study made use of GIS, GPS and questionnaire and identified and mapped out the spatial location of transformers, built a spatial database for the transformers, examined the conditions of the transformers and explained the level of utilization of the transformers in the study area. The study was not conducted in Jimeta and the author left out the factor of population in determining the locations of transformers, of which this present study had achieve. Zitta, Musa, and Isa (2014), mapped and assessed facilities in Langtang-North L.G.A of Plateau State, Nigeria, using Remote Sensing and GIS techniques. The study made use of GIS, GPS coordinates, Langtang-North Base Map and IKONOS (1m spatial resolution) satellite imagery to map and displayed the following facilities in the study area: road network, rivers, water pipelines, filling stations, healthcare institutions, educational institutions, boreholes, transformers, communication masts and recreational centres. The study revealed that 98% of the boreholes are hand pumps and 2% are motorized, while most of the educational institutions in the study area were privately owned and that a number of transformers, GSM masts were not functioning.

In Adamawa State, geospatial techniques have also been used in studying the distribution of facilities. For example, Aliyu, Shahidah and Aliyu (2013) mapped and analyzed the spatial distribution of Post Primary Schools in Yola North L.G.A using GPS receiver, GIS and map of the study area. The study found out that there were a total of 31 Post-Primary schools in Yola North L.G.A. The result showed that 3.23% of such schools are owned by the Federal Government, 54.84% by the State, while 29.03% belong to private owners and religious organizations had 12.09%. The pattern of distribution of the schools was discovered to be random. Adamu (2014) employed the use of GIS, GPS and the landuse map of the area and analysed the distribution of Telecommunication Masts in relation to the urban landuses in Jimeta-Yola; Ismail and Usul (2013) worked on a GIS-based analysis of healthcare facilities in Yola, Nigeria. The study explored the potential use of GIS for modeling the spatial distribution and accessibility of the healthcare delivery system in Yola. The result showed that there were a total of 56 healthcare facilities of primary, secondary and tertiary categories distributed in Yola metropolis. They foundd that 64% were public and 36% private; and Chidama (2011) also analyzed the spatial distribution of GSM masts in Yola in line with National Communication Commission (NCC)'s standard. The study made use of GPS for data collection and GIS for the analysis.

Considering the afformention previous studies, it is obvious that not all have employed the use of GPS, remote sensing and GIS in studying the spatial distribution of electric facilities. Only one of the researchers studied the distribution of electricity transformers, with obviously none conducted in the study area. The only study reported, failed to assess the locations of these facilities in line with standards guiding their installations, and none did show the point locations of facilities, particularly transformers in relation to population density. It is against this background that this present study provides answers to the following research questions:

1. Where are the existing electricity transformers located within Jimeta?
2. What is the spatial pattern of distribution of electricity transformers in Jimeta?
3. What is the nature of the existing geodatabase for transformers in Jimeta?
4. To what extent had population concentration influenced the location of electricity transformers in Jimeta?
5. What is the level of compliance with the Nigeria Electricity Regulatory Commission (NERC, 2016) standards for siting electricity transformers in Jimeta?
6. Where are the transformers that have exceeded their service lives located in Jimeta?

1.3 AIM AND OBJECTIVES

The aim of this study is to analyze the spatial distribution of electricity transformers within Jimeta, Yola-North LGA of Adamawa State, Nigeria. This aim was achieved through the following specific objectives, which are to:

i. identify and map out the locations of existing electricity transformers in Jimeta;
ii. examine the spatial pattern of distribution of electricity transformers in Jimeta;
iii. create a geodatabase for electricity transformers in Jimeta;
iv. assess the extent to which population concentration influences the location of transformers in Jimeta;
v. examine the level of compliance with the NERC (2016) standards for siting transformers in Jimeta;

vi. Identify and map out the locations of transformers that have exceeded their service lives in Jimeta.

1.4 SCOPE OF THE STUDY

This study analyzed the spatial distribution of electricity transformers in Jimeta-Yola North LGA, Adamawa State-Nigeria, using geospatial techniques. It is specifically concerned with step-down transformers as the major determinant facilities in the power distribution system and how population and urban landuse activities influence their locations. The locations of each of the existing transformer was identified and mapped out and a geodatabase of transformers created. The study covered the analysis of the spatial pattern of distribution of the existing transformers in Jimeta and examined their locations in line with NERC (2016) and ANSI/IEEE (1989) standards. Under the guiding standards, the ages of the transformers were assessed, as well as their safety from major roads were considered. Other distribution facilities such as high and low tension electric poles, high and low tension cables, underground cables and feeders, prepaid meters were not considered in this study. The temporal scope for this study is restricted to the year 2017.

1.5 JUSTIFICATION FOR THE STUDY

Generally, countless challenges are known to bedevil the power sector, some of which include insufficient power generation and inadequate or lack of quality apparatuses for efficient transmission and distribution. Often, DISCOs are confronted with unplanned urban development areas, which do not match their efforts. For example, small industries unexpectedly sprang up in areas planned as residential. As a result, transformers and cables are overloaded and damaged. This is problematic since DISCOs are not notified when new loads are added to existing ones (Barros, Ibiwoye and Managi, 2011). These and many other challenges such as government policies that

brought about the recent privatization of the power sector from PHCN make it necessary for DISCOs like YEDC to embark on rebranding for maximum customer service delivery. As rightly observed by (YEDC, 2015), rebranding if carried out in a thorough and thoughtful way, can play out in many wonderful ways over the long term, as well improve awareness, repositioning of the company, increase revenue and promote customer satisfaction. As a company engaged in the distribution of electricity, YEDC considers rebranding, as a way to reap tremendous benefits for all stakeholders. It is against this backdrop that the on-going rebranding is considered a step in the right direction for effective employee reorientation and better service delivery.

This study is timely due to the fact that the YEDC lacks up-to-date information about the conditions of its facilities and their pattern of distribution, as well as its quest to rebrand the company's operations. It is on this note that, this study intends to analyze the spatial distribution of electricity transformers in Jimeta with a view of coming up with lasting solutions to power distribution challenges in the study area.

With current challenges in the power sector, such as lack of equity in power distribution in urban areas, insufficient up-to-date information about YEDC's facilities necessitates the conduct of this study. This research craved to achieve a quality and up-to-date information about the absolute and relative locations of electric transformers in Jimeta. It further proffered ways on how to improve on the quality of power distribution and general service delivery of the company. It also provided the opportunity to build up a geodatabase and produced digital maps for the existing transformers and to portray how the various urban landuses determine transformers' distribution. The work will also, based on its findings, recommend a balanced power distribution process. Finally, a well documented report about transformers will be presented at the end of this research to serve as a decision-making tool for efficient power distribution mechanism that could be used by those concerned with power distribution.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

Various authors have considered the subject of spatial distribution of objects and phenomena on the earth's surface, including electricity distribution facilities. The concept of space is core to geography as a discipline. This is because geography is a discipline that deals with human and environmental interrelationships within the context of space and time. The distribution of objects on the space (earth's surface) and time is therefore, of great interest to a spatial analyst. This is responsible for the use of certain techniques and tools in solving spatio-temporal related problems, such as mapping, quantitative techniques, remote sensing and GIS among others. This chapter attempts to explain the conceptual framework within which the subject of this research work is considered. It further delved into the body of literature and looked at the works of other researchers for comparison and discussions.

2.2 CONCEPTUAL FRAMEWORK

The framework of concepts that informed this study has been discussed under the follows:

2.2.1 Concept of Power Generation

There are two methods of generating electricity namely; conventional method and non conventional method (Sule, 2010). The conventional method makes use of prime movers such as petrol engine, diesel engine, steam turbine, while non-conventional methods do not use prime movers. This includes Magneto Hydro Dynamic (MHD) generators, solar cells, fuel cells, wind, thermoelectric generators etc. Most of electricity generators are three phase-ac generators known as synchronous generators or alternators. They use rotating rectifiers called brushless excitation systems to maintain the generator voltage and control the reactive power flow at 30KV, 50Mw to 1500Mw capacities (Hadi, 2004). Thus electric power generation may be through the following sources of energy: coal, oil or natural gas; hydro power (water turbine); nuclear power (steam turbine); solar, wind or water-wave turbine; solar thermal generator and solar voltaic generator.

Different countries use one or more sources for generating electric power depending on their availability in a country. For example, Amotsuka, (2008) observed that the availability of natural fuels such as coal, crude oil, natural gas of 180 trillion cubic feet and Rivers in Nigeria lead it to utilize hydro plants and steam gas turbines for electricity generation at Afam, Delta, Egbin, Sapele, Kainji, Shiroro, Jebba and the proposed Mambila electricity generating stations. Another source of fuel for generating electricity at very small scale in Nigeria is Uraninium which is used at National Nuclear Research Centre Zaria. Generated power cannot be wholly utilized at the generating stations and its immediate environ. Therefore, it must be

transmitted and distributed at suitable voltage to other points and consumers (Chinwuko, Mgbemena, Aguh and Ebhota, 2014).

2.2.2 Concept of Power Transmission

Power transmission entails the process by which electrical power is conveyed from generating plants or stations to distribution, which completes the processing and delivers it to consumers (Yildirim and Nisanci, 2010). Power transmission network includes transmission lines and substations of various high voltage levels. Power generated at generation plants are sent to a network of high-voltage (500, 230 or 150 kV) transmission lines. These transmission lines supply power to medium voltage (e.g. 23 or 22kV) distribution networks (distribution primary system), which supply power to still lower voltage (Mishra, Khair, Pawar, Thakur and Satpute, 2014).

According to the United States Department of Energy (USDE) (2015), Power transmission lines facilitate the bulk transfer of electricity from a generating station to a local distribution network. These networks are designed to transport energy over long distances with minimal power losses which is made possible by boosting voltages at specific points along the electricity supply chain. The components of transmission lines consist of structural frames, conductor lines, cables, transformers, circuit breakers, switches, and substations. Transmission systems are generally administered on a regional basis by a regional transmission organization (RTO) or an independent system operator (ISO).

2.2.3 Concept of Power Distribution

The electric power distribution system is dedicated to delivering electrical energy to the end users (Parkpoon, 2013). A distribution system carries power from substation transformer through feeder circuit to distribution transformer located near the customers (Rawal and Pandya, 2015). It is the final and most important phase in the electricity production because this is the stage where the purpose of generating electric power is harnessed. Power distribution connotes the use of apparatuses such as transformers, cables, poles, and prepaid meters among others in order to deliver electric power to the consumers. Electricity distribution is the final stage in the delivery of electricity to end users. A distribution system's network carries electricity from the transmission system and delivers it to consumers. Typically, the network would include medium-voltage (less than 50 kilovolts) power lines, substations and pole-mounted transformers, low-voltage (less than 1 kilovolt) distribution wiring and sometimes meters (Chatta, 2015).

The goal of generation and transmission of electricity is therefore defeated when power does not get where it is being put to use. Adejoh *et al.* (2015) observed that efficient functioning of the transmitted power cannot be achieved without proper record keeping and monitoring of the distribution network system. The primary purpose of an electricity distribution system is to meet the customer's demand for energy after receiving the bulk electrical energy from transmission or sub-transmission substation (Kanmani and Suresh, 2014).

A distribution system is one of the main parts of the power system. It is necessary to carefully consider technical issues, the impact on natural environment, the effect on local communities, and various regulations. However, there are various issues coming up like power theft, poor distribution, and complexity in network planning among others. Power distribution system consequently, has to keep the record of numerous poles, circuits, power lines, and transformers. However, it has become difficult and hard to record due to the complexity of the networks (Mishra *et al*., 2014).

2.2.4 Concept of Distribution Transformers

Jasni *et al.* (2017) declared that an electrical transformer is an electrical apparatus used to step up or step down the voltage from the generator to be supplied to the end user. Transformers are essential pieces of electrical equipment that help to transmit and distribute electricity efficiently and reliably. They also help maintain power quality and control, and facilitate electrical networks (ABB, 2012). Transformers are an essential part of any electrical system. They come in various sizes and voltage ratings. Transformers are used for transforming power from one voltage level to another (Naval Facilities Engineering Command (NFEC) (1990). Technically speaking, at the distribution level, there are two main categories of transformers: Liquid filled (using mineral oil or replacement fluids such as synthetic or natural esters) and Dry-type. The liquid filled transformers are the most compact and cost efficient solution, whereas dry-type transformers are preferred in environments where fire safety is of special importance such as, for example, underground substations, mining sites, marine and some industrial applications (See Plates 1 and 2). In liquid transformers, as the main dielectric media in oil-immersed transformers, the oil and oil impregnated paper will degrade with time, under thermal, electrical, chemical stresses and other factors. Oil in transformers can be replaced after serious deterioration, because of its mobility. On the contrary, the replacement of oil impregnated paper is rather difficult when it degrades seriously, especially the paper covering windings (Ruan *et al.,* 2017).





Plate 1: Liquid-filled Transformer **Plate 2: Dry-type Transformer**

Distribution transformers are also classified based on their purposes of installation, as to whether they are for public services or dedicated for private individuals, industrial or organizational use. The classifications have also been made based on their modes of installation, these include: pad-mounted transformers (distribution transformers mounted on concrete pads) and pole-mounted transformers (distribution transformers mounted on electric poles). For the purpose of this study, the public and dedicated distribution transformers will be used being the types of step-down transformers available in the study area.

2.2.5 Conditions of Electricity Distribution Transformers

The importance of transformers in the distribution system of electricity cannot be overemphasized. They play a key role in the distribution of electric power to the final consumers.

Global Asset Protection Services (GAPS) (2015) observed that from the point of electric power generation to the site of industrial power use, a series of transformers convert voltages and currents up and down as needed for transmission, distribution and utilization. Each transformer links its areas of supply, connected to the primary, to a load, connected to the secondary, and at the same time adjusts the output voltage to required values. Without these links, loads will not be powered. Despite their importance in the electric power distribution, in Nigeria, transformers are often taken for granted. They are mostly overloaded, particularly the public ones, thereby causing overheating, noise, energy sparking and sometimes explosions leading to fire outbreaks. GAPS (2015) outline some of the consequences associated with the failure of a transformer, which are as follows:

i. A transformer failure can result in a fire that spreads to an important building, structure or nearby electrical equipment such as transformers, switchgear and distribution system equipment.
ii. A transformer failure can generate a corrosive atmosphere and seriously damage the surrounding atmospheric environment.
iii. A transformer failure can cause significant environmental pollution.
iv. The loss of transformed power (through the unit) will cause a major loss of production or output considering both direct and indirect (consequential) effects of the power outage.
v. Auxiliary equipment expected to be involved in transformer-related electrical breakdown or ensuing fire cannot be replaced within 2 weeks.

Okakwu, Olowasogo and Airoboman (2015) conducted a research on fault analysis in distribution transformers, using the distribution transformers connected to Berkley 11-kV Feeder of Ajale Business Unit of the then PHCN, Lagos State, Nigeria as a case study. The study used data obtained from primary and secondary sources using direct interviews and fault report log books in the dispatch office of the then PHCN. The data collected for the period between 2010- 2012, were analyzed and interpreted with simple statistics and presented in tables, pie charts and bar charts for clarity. The study showed that arcing or high current breakdown, general overheating due to inadequate cooling or sustained overloading, localized overheating or hot spots and low energy sparking or natural discharges are the four major faults/problems associated with distribution transformers connected to Berkley 11KV feeder. It also revealed that the frequency of fault's occurrence in an installed transformer is very high. The study also revealed that various reasons, such as lightning surges, deterioration of insulation, overloading, and loose connections, among others are responsible for transformer faults in Berkley 11-kV feeder. The authors observed that this is not peculiar to Berkley area as it also affects the whole of Obalende and Nigeria as a nation.

2.2.6 Distribution Pattern of Transformers

Spatial distribution of objects on the surface of the earth takes either one of the following spatial patters: cluster, random or regular. This can be determined using Nearest Neighbor Analysis (NNA). The NNA uses the distance between each point and its closest neighboring point in a layer to determine if the point pattern is random, regular or clustered (Chang, 2008). It is interpreted as clustered when the Nearest Neighbourhood Index (NNI) is tending towards 0, random when it is closer or equal to 1.0 and regular when the result is closer or equal to 2.15 (Sherwood, 1970). Nearest Neighbor Analysis examines the distances from each point and the closest point to it, and then compares it to expected values for a random sample of points from a complete spatial randomness (CSR) pattern (Aliyu *et al.*, 2013).

2.2.7 Concept of Geodatabase

A database is an organized, integrated collection of non-redundant data stored so as to be capable of use by relevant applications with the data been accessed through some logical paths. Geodatabase is also referred to as spatial database and it is the heart of GIS. This is the process whereby real world entities and their interrelationships are analyzed and modeled in such a way that maximum benefits are derived while utilizing minimum amount of data (Damilola, 2015).

A geodatabase supports an object-oriented vector data model. In this model, real-world entities are represented as objects with properties, behavior, and relationships. The object types include simple objects, geographic features (objects with location), network features (objects with geometric integration with other features), annotation features, and other more specialized feature types. The model defines relationships between objects, as well as rules for maintaining the referential integrity between related objects (Olaniyi and Usman, 2006).

2.2.8 Transformer Service Life

Transformer age is an important factor to consider when identifying candidates for replacement or rehabilitation. Age is one indicator of remaining life and upgrade potential to current state-of-the art materials. During transformer life, structural strength and insulating properties of materials used for support and electrical insulation (especially paper) deteriorate. However, actual service life varies widely

depending on the manufacturer, design, quality of assembly, materials used, maintenance, and operating conditions.

According to the U.S. Department of Interior and Bureau Reclamation (2005), Standards Organizations such as American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE, 1989) consider transformer service life to be 25 years. This estimate is based on continuous operation at rated load and service conditions with an average ambient temperature of 40ºC and a temperature rise of 65ºC. This estimate is also based on the assumption that transformers receive adequate maintenance over their service life. According to ABB (2004), a transformer should be disposed off after the service years of 20. ABB is a transformer manufacturing company, their standard for transformer lifespan is based on maximum utilization and profit making, but since that is not always the case particularly in Nigeria where electricity is not constant, the ANSI/IEEE (1989) standard of 25 years service life for transformers will be used in this study. Table 2.1 presents the average life span of 25 years for distribution transformers which is also in line with the outline of Shomolu (1994) in Chatta (2015).

Table 2.1: The Life Expectancy Period of Some Power Supply Equipments

Electrical Equipment	Life Expectancy (Years)
Power Transformers	50
Grounding Transformers	25
Distribution Transformers	25
Circuit Breakers	25
Transformer Line Tower	50
Current Transformers (CTs)	30

Potential Transformers	30
Capacitor Banks	10
Protective Relays	20
System Control and Data Acquisition	10

Source: Chatta, (2015)

2.2.9 Standards for Siting Transformers

Generally speaking, there are standards for siting and use of facilities including electrical equipments. According to NFEC (1990), system designs and installation practices are governed by regulations in the U.S National Electric Code (NEC) and the National Electric Safety Code (NESC). The NEC contains regulations governing the installation of electrical conductors and equipment within or on public and private buildings, mobile homes, recreational vehicles, float dwellings, and other premises such as yards, carnivals, parking lots and industrial substations. The NESC covers standards for safeguarding people from hazards arising from installation, operation and maintenance of electrical conductors and equipment. The provisions contained in the NEC define minimum requirements only, and are not intended to be used as design specifications. Minimum standards relating to electrical equipment have been established by the National Electrical Manufacturers Association (NEMA), the Institute of Electrical and Electronics Engineers (IEEE), and the American National Standards Institute (ANSI).

There are national and international accepted standards organizations that are responsible for enacting regulations and setbacks of electrical equipments from major roads and buildings. Safety clearance for the location of distribution of transformers differs from one country to another, but there are those widely recognized and acceptable for used internationally, for example, the ANSI/ IEEE (1989) standards. The electric regulatory body in Nigeria that is saddled with this responsibility, among others, is the Nigerian Electricity Regulatory Commission (NERC), established in 2005 (Ajumogobia, 2015). Parmar (2012) presented the safety clearances for transformers as shown in Table 2.2.

Table 2.2: Safety Clearance for Transformers from Buildings and Main Roads

Transformer Capacity	Distance from Buildings (m)
Up to 75kVA	3.0
75kVA to 333kVA	6.0
More than 333kVA	9.0
Pole and Pad-Mounted Transformers	3.6 (Distance from Main Roads)

Source: Palmar, (2012)

This safety clearance for transformers from buildings and main roads could not be found in the materials of any recognized regulatory body that is widely acceptable for standard to be adopted. This has made the adoption of this standard for use in this research unacceptable, because the source cannot be verified.

ABB (2004) identified 7-10m as the average distance of transformers from roads depending on the volume of liquid in the transformer. ABB sets its installation standards based on IEEE and the International Electrotechnical Commission (2008). These are two of the world wide recognized organizations responsible for establishing standards for electrical and electronic engineering. In Nigeria, the NERC, is responsible for tariffs regulation and monitoring of the quality of services of the then PHCN and now Discos, including installations of electric facilities. In Distribution Code for the Nigeria Electricity Distribution System (2016), the NERC referred readers to the latest standards by the IEEE for comprehensive safety clearance.

The United Arab Emirates (UAE) Ministry of Interior (2011) in its Fire and Life Safety Code adopted 7.6-15m as the standard distance for siting a transformer from roads, buildings and other structures so as to curtail the impacts of disasters resulting from their failures. This range of standard distance depends on the transformer oil capacity. The Western Power (2014) recommended 5.5-7m for transformers between <630kVA to 1000kVA purposefully for the reduction of noise, fire incidences impacts and accidents. The Eatons Distribution Transformers (2017) recommends 36inc which is roughly 12m clearance from roads, buildings and other structures. Eatons family of transformers are dry-types and their standard distances cannot be applied to the transformers in Jimeta because they are liquid-filled. The 10m distance given by the ABB (2004) which is according to the IEEE and IEC standards is therefore adopted for this study.

2.2.10 Population and Electricity Distribution

The National Council on Power (NACOP), 2016) observed that Nigeria's population is the seventh largest in the World with over 190 million people and still growing by at least 2 per cent per annum. By United Nations' statistics, Nigeria's population will reach nearly 230 million within the next 20 years from 2016. This report estimates that at 2 per cent annual growth rate, the population will reach 267 million by 2030. This reveals the speedy growth of the Nigerian population for which electricity and other social amenities are required to sustain. The current status of electricity generated in Nigeria with regard to its population is grossly inadequate. Today, 60% to 70% of the Nigerian population does not have access to electricity (Oyedepo, 2012). This challenge has been in existence since 1970s when the Udoji's Federal Government awards improved the economic life of the workers. This made the workers to increase their electricity consumption by purchasing several sophisticated and automating machines that consumed quite a lot of energy (Awosope, 2014). The power utility company, on the other hand, was not prepared for this increase in consumption. This challenge has consistently left a deficit in consumption and generated electricity in Nigeria's electricity consumption history. Thus, this has led to consistent imbalance in the demand and the supply of electricity (Awosope, 2014). This implies that high population with improved economic life presses high demand on electricity which of course makes it a necessity to increase power distribution facilities for efficient distribution.

2.2.11 Electricity Development in Nigeria

The power sector in Nigeria has experienced a lot of reformation and changes from one structure to another. This started in 1898 when the first generating power plant was installed in Marina, Lagos. Awosope (2014) noted that after the amalgamation of the southern and the northern protectorate in 1914, some major cities had a dose of electricity supply, including: Port Harcurt (1928), Kaduna (1929), Enugu (1933), Maiduguri (1934), Yola (1937), Zaria (1938), Warri (1939) and Calabar (1939), respectively. In 1950 the Niger Dams Authority was inaugurated for the benefit of generating electricity through hydro power systems. As a result of this, the Colonial Government established the Electricity Corporation of Nigeria (ECN) under the ordinance no.15 of 1950. On 1st of April 1972, ECN and NDA merged to form a unified body known as National Electric Power Authority (NEPA) with the actual merging taking place on the 6th of January 1973 when the first manager was appointed.

Between 1999-2005 (The advent of democratic government), an act was enacted establishing Power Holding Company of Nigeria (PHCN), an Initial Holding Company (IHC), as a result of Government effort to revitalize power sector. This was an intended name for privatization which was meant to transfer assets and liabilities of NEPA to PHCN. It was officially commissioned on the 5th of May 2005 and was to carry out business of NEPA which was still on (Awosope, 2014). In the same vein, the National Integrated Power Projects (NIPP) was inaugurated in 2004 to be able to catalyze and fast track the upgrading of adding more capacity to the current available electricity capacity in the country. This was basically a private initiative which is currently being supervised by the Niger Delta Power Holding Company (NDPHC) **(**Babatunde and Shuaibu, 2008**).**

The PHCN, as a Company, was unbundled into 18 companies as follows: six (6) generating companies, one (1) transmission company (i.e. Transmission Company of Nigeria-TCN), and eleven (11) distribution companies. The generating companies are Egbin Electricity Generating Company (EEGC), Sapele, Ughelli, Afam, Shiroro and Kainji. There are also some new Independent Power Producers under the auspices of the Niger-Delta Power Holding Company (Awosope, 2014). The 11 distribution companies according to Ajumogobia and Okeke (2015) are Abuja Electricity Distribution Company (AEDC), Benin Electricity Distribution Company (BEDC), Eko Electricity Distribution Company (EkEDC), Enugu Electricity Distribution Company (EnEDC), Ibadan Electricity Distribution Company (IbEDC), Ikeja Electricity Distribution Company (IkEDC), Jos Electricity Distribution Company (JEDC), Kaduna Electricity Distribution Company (KdEDC), Kano Electricity Distribution Company (KnEDC), Port-Harcourt Electricity Distribution Company (PHEDC), Yola Electricity Distribution Company (YEDC). Currently, the Federal Government owns 100% of the transmission company, while its hold on the generating companies is 20 per cent (with 80 per cent of equity sold to private investors) and in the case of the distribution companies, eleven of them that have been sold, government only sold 60 per cent and is still holding 40 per cent. In other words; the transmission company of Nigeria (TCN) is 100 per cent owned by the Federal Government, generating companies (GENCOs) 20 per cent by the owned by government and 80 per cent private sector. For DISCOs, 60 per cent is owned by private sector and 40 per cent owned by government (Babatunde and Shuaibu, 2008). Even though, the TCN is controlled by the government, the management of TCN is handled by a Canadian company, Manitoba Hydro Company. On the 30th of September 2013, the Federal Government handed over certificates of ownership to the private owners of the DISCOs. Since then the generation and distribution of electricity have been transferred to the private investors. On Wednesday February 12, 2014, the NERC at a meeting held with power generating and distributing companies in the country unanimously agreed that the Transition Electricity Market (TEM) idea should be suspended for the meantime (Awosope, 2014, Babatunde and Shuaibu, 2008).

2.2.12 Electricity Generation, Transmission and Distribution in Nigeria

According to Nigerian Power Sector Guide (NPSG, 2013), the structure of the Nigerian Power Sector is made up of 3 major sub-sectors, namely: power generation, transmission and distribution.

2.2.12.1 Power Generation in Nigeria

There are currently 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry (NESI) with a total installed capacity of 10,396.0 MW and available capacity of 6,056 MW. Most generation is thermal based, with an installed capacity of 8,457.6 MW (81% of the total) and an available capacity of 4,996 MW (83% of the total). Hydropower from three major plants accounts for 1,938.4 MW of total installed capacity (and an available capacity of 1,060 MW). The total installed electricity net generation in Nigeria was majorly on the Gas Thermal Plant with 64%, Hydro with 23% and Steam Thermal Plant with 13% (Onochie, Egware

and Eyakwanor, 2015). Klynveld Peat Marwick Goerdeler (KPMG) Nigeria Advisory Services (2013), noted that there are 6 electricity Generation Companies in Nigeria (See Table 2.3).

Table 2.2.3: Names and Installed Capacities of the Generation Companies

S/N	Generation Company	Plant Type	Capacity (MW)
1	Afam Power Plc (1-V)	Thermal	987.2
2	Egbin Power Plc	Thermal	1320
3	Kainji/Jebba Hydro Electric Plc	Hydro	1330
4	Sapele Power Plc	Thermal	1020
5	Shiroro Hydro Electric Plc	Hydro	600
6	Ughelli Power Plc	Thermal	924
Total			**6181.2**

Source: KPMG Nigeria (2013)

2.2.12.2 Power Transmission in Nigeria

The Transmission Company of Nigeria (TCN) is a successor company of PHCN, following the unbundling of the sector, and is currently being managed by a Management Contractor, Manitoba Hydro International (Canada). Manitoba is responsible for revamping TCN to achieve providing stable transmission of power without system failure. Currently, the transmission capacity of the Nigerian Electricity Transmission system is made up of about 5,523.8 km of 330 KV lines and 6,801.49 km of 132 KV lines.

The TCN is made up of two major departments: System Operator and Market Operator. The Market Operations (MO) is a department under TCN charged with the responsibility of administering the wholesale electricity market, promoting efficiency and where possible, competition. The system operator is focused on system planning, administration and grid discipline. Furthermore, one of the major areas of focus of Manitoba Hydro International is to re-organise TCN and ensure that the Market Operator and the System Operator become autonomous.

2.2.12.3 Power Distribution in Nigeria

This is the final phase in the production of electricity. It involves the use of electric facilities and equipments such as transformers, meters, electric poles and cables to distribute electric power to customers or final users. Since power is not utilized where it is being generated, it has to be transmitted and finally given to users and this is a very important level that defines the purpose of the first two. There are companies that are saddled with the responsibility of carrying electricity to the customers across the length and breadth of the country. There are 11 electricity distribution companies (Discos) in Nigeria. The coverage areas of the 11 companies are shown on Table 2.4.

Table 2.4: The Eleven (11) Distribution Companies (DISCOs)

S/N	DISCOs	Percentage Load Allocation
1	Abuja Distribution Company	11.50%
2	Benin Distribution Company	9.00%
3	Eko Distribution Company	11.00%

4	Enugu Distribution Company	9.00%
5	Ibadan Distribution Company	13.00%
6	Ikeja Distribution Company	15.00%
7	Jos Distribution Company	5.50%
8	Kaduna Distribution Company	8.00%
9	Kano Distribution Company	8.00%
10	Port Harcourt Distribution Company	6.50%
11	Yola Distribution Company	11.50%
Total		**100%**

Source: Onochie, Egware and Eyakwanor (2015)

2.2.13 Factors Affecting Electricity Generation, Transmission and Distribution in Nigeria

Lathem and Watkins, (2016) pointed out that in Nigeria, the average annual per capita power consumption (155 kWh) is among the lowest in the world. In 2015, much of Nigeria's installed capacity was unavailable. Nigeria's estimated available capacity from the grid of approximately 4,500 MW meets only approximately one-third of the estimated demand for power from the grid. According to the Chairman of the Nigeria National Committee of the World Energy Council, planning experts estimated that for the Nigerian economy to grow at a rate of 10%, the country's electricity requirement must reach 30,000 MW by 2020 and 78,000 MW by 2030. Therefore, to improve the economy's current GDP growth and reduce the current electricity supply gap, market intervention and fundamental power sector reform are vital.

One of the key indices in gauging the development of any nation is its electricity consumption per capita. Every facet of a nation's social, economic and industrial development is linked to the availability and utilization of reliable electric power. Absence of electricity for a long period causes discomfort and hampers productivity. It is also a known fact that electricity

consumption has become a parameter by which the standard of living as well as the level of industrialization of nations is measured. Unfortunately, the majority of Nigerians have no access to electricity and the supply to those provided is not regular (Chatta, 2015).

There are numerous factors affecting the Nigerian electricity at all stages of production. Sule (2010) observed that there are many factors that affect electricity in Nigeria. He identified the major ones which include but not limited to:

i. The Niger Delta crisis which leads to the vandalization of oil and gas pipe lines, oil gas exploration and exploitation facilities.
ii. The kidnapping of foreign and indigenous professionals that manned oil and gas facilities in Nigeria resulting into abandoning of oil and gas exploration.
iii. The inability of Nigeria government in collaboration with oil multinational companies to fully utilize gas that is being flared, due to gas flaring. The gas is a good source of energy for the generation of electricity.
iv. Low level of annual rainfall in Nigeria due to global warming which leads to global climate change that affects water level at hydro generation stations. Reliance on Hydro can be constrained by the volume of water available during the period of draught and during the months of March to June when water level goes down.
v. Lack of water management in Nigeria is affecting water level at the hydro generation stations.
vi. Bribery, Corruption and Mismanagement in the power sector. This includes misappropriation of funds, sabotage, stealing of equipments and personalization public properties meant for the masses.
vii. The absence of research and development in Nigeria which focuses on investigating the different types of electricity generating potentials in Nigeria and how to utilize them. The research and

development in the area of electricity generation, transmission and distribution can help in collecting data and offer services to government and private investors in the power sector.

viii. Non diversification of existing electricity generating potentials in Nigeria.

Nigeria only utilizes oil, gas and dams for electricity generation. There are other alternative potentials existing such as renewable sources of energy (solar, wind, biomass) and nuclear which can supplement the existing hydro, oil and gas generating potentials.

ix. There is poor planned maintenance culture, in which routine maintenance is not carried out regularly. Good maintenance culture leads to availability of electricity utilities in which electricity power is made available to consumers. The sector cannot be maintained if they do not have enough funds to buy the needed spare parts and pay for their running cost. Good maintenance culture is very essential in keeping any physical systems, such as electricity generation, transmission and distribution networks in operational readiness. Maintenance of electricity utilities is a combination of any action carried out to retain the utilities in or restore them to normal operational standard. Basically, maintenance can be classified into two categories, namely; planned maintenance and unplanned maintenance.

x. The electricity consumers in Nigeria are highly indebted to the PHCN (now DISCOs) due to poor electricity delivery, none settlement of electricity bills, corruption by bill collectors. Illegal connections and high maintenance cost of equipment due to vandalization by thieves, wind also lead to low revenue generation by PHCN.

xi. Failing down of electricity transmission and distribution lines by winds as well as vandalization of these lines by thieves, construction works, fluid, soil erosion.

xii. The transmission line losses due to long distances between generating stations and load centers.

xiii. Currently, there is the issue of non-compliance of customers to the metering policy of the DISCOs due to the cost implication of mounting an electric meter. The DISCOs also are known to increase the bills for electricity consumption that makes it difficult for the customers to cooperate.

xiv. The Niger Delta crisis also impacts on the Gas supply for turbines of the hydroelectric dams thereby interrupting the process of power generation.

The A PT (2015) observed that the power sector is plagued with structural issues in all key areas: generation, gas supply, transmission and distribution. To name a few of these challenges, the operational capacity of the country's power plants is less than a third of their installed capacity. Chronic vandalism has crippled oil and gas pipelines, creating gas shortages at power plants. Underinvestment in maintenance and infrastructure has constrained our transmission grid. Finally, high collection and commercial losses have impacted the financial viability of the privatised distribution companies.

At 126kWh per capita, Nigeria is far behind other developing nations in terms of grid-based electricity consumption. Based on the country's GDP and global trends, electricity consumption should be four to five times higher than it is today. For example, Ghana's per capita consumption (361kWh) is 2.9 times higher than that of Nigeria, and South Africa's 3,926kWh is 31 times higher. At 45%, Nigeria's electrification rate is low – much lower than that of Ghana (72%) and South Africa (85%). Furthermore, unreliable power supply forces both households and industry to rely on privately owned generators for much of their power. These generators are more than twice as expensive (NGN 62 - 94/kWh) than grid-based power (end user tariff of NGN 26 - 38/kWh). There are three stages in the delivery of power to customers: generation at the power plant (requiring a source of primary energy, i.e., water or gas), transmission to the distribution companies and distribution to the end user. Only 25% of Nigeria's 12,522MW of installed capacity reaches the end user. Widespread inefficiency means that only 3,879MW of this capacity is operational (averages January to 15 August, 2015), with 3,600MW transmitted and 3,100MW distributed (APT, 2015).

2.2.14 GIS and Electricity Facility Mapping and Management

The use of GIS in the power system has greatly enhanced the efficiency in the energy sector. Proximity to the furthest customer and the cost, are the reasons that make the distribution system as an important part of electrical utility, which improves the reliability of general power system. Analyses such as selection of suitable areas, optimum path finding, the profile analyses, the engineering design of wires and towers, and the cost estimation can all be done using GIS. Electric utilities are realizing the benefits of GIS technology in the management of facilities for engineering, construction operations, and maintenance and services purposes. Problems of planning in distribution system can be solved by using new methods and

specific techniques. Complexity of electrical distribution system and necessity of accurate up-to-date information of the network assets is a reasonable intention for introducing new method of information technology (Damilola, 2015).

GIS has been very useful in the electrical power system. Problems of planning in distribution system can be solved by using new methods and specific techniques like GIS because of necessity of accurate up-to-date information of the network assets. GIS helps utilities discover new things about their investments and risks, and allows the simultaneous assessment of technical, financial, and environmental factors (Al-Sakkaf and Al-Ramadan, 2013). GIS and Spatial Informatics Techniques have come as the boon to solve many problems in the Electric power system where demographical and geographical spread was the root cause of problem (Sekhar, Rajan and Jain, 2008).

2.2.15 Global Positioning System

Al-Sakkaf and Al-Ramadan (2013) defined GPS as a location system based on a constellation of about 24 satellites orbiting the earth at altitudes of approximately 11,000 miles. GPS satellites are orbited high enough to avoid the problems associated with land based systems, yet can provide accurate positioning 24 hours a day, anywhere in the world. The GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers owned by users (Thakur, 2016). GPS satellites broadcast signals from space that are picked up and identified by GPS receivers. Each GPS receiver then provides three-dimensional location (latitude, longitude, and altitude) plus the time. GPS can provide any point on earth with a unique address (its precise location).

2.3 LITERATURE REVIEW

Relevant literatures were reviewed in line with the set objectives. It was carried out under the following headings:

2.3.1 Location of Electricity Distribution Transformers

Thakur (2016) mapped out and analyzed the distribution of electric poles, transformers, and transmission lines in Bhopal city of India. The study made use of coordinates taken GPS and high resolution satellite imageries upon which the point location of the facilities were overlaid and analysed in ArcGIS 9.1 software. Various objects like road network and landuses were also superimposed on the power

distribution system GIS layer. The study only chose Vaisali feeder in the area of Kotra in Bhopal city as a case study. The result revealed that the feeder did not have proper information of poles, transformers and minimum path for the power flow. The Distribution Company had poor maintenance of installed facilities, lack of proper planned network and lack of monitoring to prevent losses and manual updates of consumer records. From their field work, they have observed that most of the transformers were unnumbered and they were not sited in proper locations, some of the poles were unnumbered, some poles were in the middle of houses, some poles were still concrete, and some poles were bent which caused so much inconvenience to the public. The study further revealed some problems of obscurity of some electric facilities by others. The study displayed some detailed analyses of the distribution network but, the major problem with it is that it also considered a small part of the city which cannot support a holistic decision making in tackling challenges of power distribution in the city of Bhopal.

Adejoh *et al.*, (2015) employed the techniques of remote sensing and GIS in assessing electrical distribution system of Olonada community of Ife Central Local Government, Ile-Ife, Nigeria. The study assessed the spatial relationship between the then PHCN assets and their customers' connectivity in the study area and suggested ways on how to improve and manage electricity distribution. The study made use of satellite imagery, GPS device points, transformer details, the number of customers connected to transformer and the energy consumed by each customer. It also made use of ArcGIS 9.3 and Microsoft software for the analyses. The result showed that, the study area had only one transformer rated 500kVA with four up-risers connected to numerous distribution lines serving 250 buildings with average consumption rate of 2.1KW with an excess of 25.6KW, indicating that the transformer was overloaded. The study failed to consider a larger area with high distribution network, but rather restricted to just a small fraction of the city which had only one transformer serving 250 buildings. The study area was too small and the findings cannot be used to generalize the situation over the ancient city of Ile-Ife.

Chatta (2015) employed the techniques of GIS in studying spatial distribution and utilization of electricity transformers in Sabon Gari LGA Zaria, Kaduna State. The study made use of geographic coordinates of the existing transformers collected using a GPS receiver, questionnaire and some information on transformers gotten from the then PHCN's office in the study area. It identified and mapped out the locations of all transformers in Sabon Gari LGA using ArcGIS software, created a geodatabase, and analysed responses from questionnaire. The results were maps showing the distribution of all transformers, public transformers and dedicated transformers. The study identified highly commercialized and industrial

areas in Sabon Gari as having more transformers which were mostly dedicated ones owned by banks and some industries. The study could not establish the spatial pattern of distribution of the electric equipment in the study area. It also failed to consider the level of adherence of the transformers to their siting standards.

Zitta, Musa, and Isa (2014), mapped out and assessed facilities in Langtang-North L.G.A of Plateau State, Nigeria, using Remote Sensing and GIS techniques. The study made use of GIS, GPS receiver, Langtang-North Base Map and IKONOS (1m spatial resolution) satellite imagery to map and displayed the following facilities in the study area: road network, rivers, water pipelines, filling stations, healthcare institutions, educational institutions, boreholes, transformers, communication masts and recreational centres. The study failed to relate the distribution of such facilities and utilities to the population of the study area, and also it could not consider the standards for siting those facilities.

2.3.2 Transformer Distribution Patterns

Nearest Neighbour Analysis (NNA) has been employed by several authors in the study of the spatial distribution of objects and facilities on the surface of the earth. For example, Aliyu, Shahidah and Aliyu (2013) used NNA in determining the spatial distribution of post primary schools in Yola North LGA of Adamawa State, Nigeria. According to the authors, observed GPS coordinates of all post-primary schools in Yola North LGA were obtained, which were used to create a digital map showing the location of post-primary schools within the study area. These coordinates were used to determine the distances from one point to its Nearest Neighbors in a particular unit area. The distances were computed using a computer program written in MATLAB 2009a programming language. The distances obtained were then used in determining the distribution pattern of these schools using Nearest Neighbor Analysis statistical tool, where the value of Nearest Neighbor index (Rn) was computed and was found to be Rn=1.1124. This result obtained indicates that random distribution pattern of the facilities exists in the study area. The test of significance on the value of Rn was then computed using Z-distribution and from the value of Z obtained, it shows that the value of Rn is significant. The study was conducted on educational

facilities not electrical distribution facilities such as transformers. The authors used a computer program written in MATLAB 2009a programming language to compute the distances between the locations of the schools. In this present study, ArcGIS 10.3 was employed for the NNA of transformer point locations.

Odior, Oyawale and Ovuworie (2010), studied some operations of electric power supply system in Benin City of Nigeria. The study used data from the records of the then PHCN and analyzed the pattern of electric power supply in the study area. However, the result showed that the average power supply to Government Reserved Area (GRA) was more regular and stable than that of Siluko area of Benin City which is a public residential area with different characteristics from that of the GRA. However the study did not pay attention to the point pattern of distribution of electricity facilities particularly transformers, which determines whether the pattern of point locations of objects on the surface of earth is cluster, random or dispersed.

2.3.3 Geodatabase Creation for Electricity Transformers

Omilabu, Igbokwe, Ejikeme, Igbokwe and Njoku (2015) developed a utility information system for management of electricity distribution of Iyaji residential layout, Oyo, Oyo State, Nigeria. They collected data using Garmin Handheld GPS receiver and downloaded into the computer system to obtain the coordinates of the electric poles, transformer and other features of interest which were not on the existing map. The coordinates obtained using the GPS receiver was in World Geodetic System (WGS 1984) coordinate system. The data was later imported into ArcGIS 9.3 through notepad software for updating the map. In their creation of geodatabase, 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 analyzed and modeled in such a way that maximum benefits would be derived while utilizing a minimum amount of data. In their work, data on electricity distribution system facilities such as transformers, electric poles, and cable lines were created on tables separately with their attributes. The transformers geodatabase contained the coordinates, transformer owner, capacity, lifespan, location, voltage, condition and image. The authors were abled to consider more than one electric distribution facility and not only transformers, but the study area is a political ward in the Oyo West LGA, which may be liken a point in relation to the entire LGA and the state at large. This challenge could not allow them to consider more than two transformers which are the only ones obtainable in the area. In their geodatabase creation for transformers, vital information such as year of

manufacture, load, asset code, and the amperes of the various transformer phases with their neutrals were left out. This implies that their database was deficient in terms of information that can support important decisions.

Kanmani and Suresh (2014) analysed electricity distribution system using geospatial technology in Hosur town of Krishnagiri district, Tamil Nadu, India. In their study, the location of each distribution transformer in the Hosur town was collected using GPS device. Hosur town was delineated from the satellite image using the GIS technique. Survey of India topo-sheets and satellite imageries were used to prepare various thematic layers viz landuse/landcover map and transportation network map. The study utilized GIS and GPS points to determine the geographical location of each distribution transformer in the study area and a database was created for the routine maintenance. The geographic location of each distribution transformer in the study area was acquired using GPS instrument. It was found that there were 154 distribution transformers which were pole mounted. Details, such as distribution transformer (DT) ID, its voltage capacity, pole structure, section ID, etc were collected from the Tamilnadu Electricity Board. However, their work failed to look at the conditions of such distribution network facilities. Also, their database lacked some vital information about the year of manufacture of such transformers and when they were commissioned, as well as their ages in service.

Databases are very useful when connected with spatial information. Ighalo and Williams (2012) noted that complete information system for the distribution of electrical energy can be used to improve planning, maintenance and management standards. This on the other hand can improve on the distribution of the insufficient energy generated. Databases for poles, High Tension/Low Tension (HT/LT) line and transformers was created in GIS by the authors, describing the spatial locations of all equipment. The transformers database built by the authors contain transformer location, Serial number, make, capacity, manufacturing year, installation year, number of connections. It also shows status and condition of Transformer fuses, jumpers, oil leakage, and oil level. Max Load recorded by transformer was included in the databases. Latitude (X) and Longitude (Y) of each transformer was calculated using field calculator. The length of line of HT/LT was calculated using field calculator. Poles database contains the condition of poles and type of poles (Hassan and Akhtar, 2012).

2.3.4 Distribution of Transformers in Relation to Population

The Ghanian Resource Center for Energy Economics and Regulations (RCEER) (2005) attributed high growth in the electricity consumption of 10 to 15 percent per annum to population, economic growth and increased urbanization. This also shows that whenever there is high population, socioeconomic activities and urbanization are encouraged thereby pressing higher demand on power. With this, we know that there cannot be adequate electricity supply without adequate distribution and there cannot be efficient electricity distribution without sufficient distribution facilities such as transformers.

Emodi and Yusuf (2015) conducted a research on improving electricity access in Nigeria: obstacles and the way forward. The study majorly examined the obstacles hindering the improvement of electricity access in Nigeria. The authors identified the problem of zoning on the electricity grid which occurs when property zoned for residential use are converted to industrial use which requires more energy. This has caused grid overload and transformer explosions in some locations. The current privatization of the power sector has increased the physical sabotage of the grid system through the dismantling of parts in the grid by both the old and new utility operators. The study is not quite specific as to what extent the problem of zoning on the electricity grid and sabotage of equipments contribute to less power supply.

Naibbi and Tukur (2017) conducted a study towards ensuring optimal electricity generation and supply in Nigerian. The study sampled more than 40 articles both published and unpublished covering the subject matter from different journal articles, books and reports from various government agencies and media organs. This information were studied, and numerical data were processed in both Microsoft Excel and GIS environment for tables and graphic presentations. The authors observed that inaccessibility of electricity in the country is more severe in the northern parts. They further revealed that the North-East has the highest percentage with about 72% of its households unable to access electricity. The authors succeeded in relating electricity supply to population in the entire country, but failed to consider the spatial locations of key distribution facilities even among the populace of the major cities in Nigeria. This present study tried to look at whether the distribution of population has influence on the location of electricity transformers in Jimeta.

2.3.5 Level of Compliance with Standards for Siting Transformers

Studies have been conducted towards assessing the level of compliance with standards for siting electricity transformers in Nigeria and several other parts of the world. This is important because if electrical equipments are allowed to be sited indiscriminately, there would be adverse consequences to both man and environment. For example, Omilabu *et al.* (2015) developed a Utility Information System for management of electricity distribution of Iyaji residential layout in Oyo State, Nigeria. The authors employed buffer operations in ArcGIS 9.3 to determine buildings that contravene the setback rule of 6m. Only one of such buildings was found within the study area. Best route analysis was also performed from building to transformers in case of any fault or fire outbreak that affects electrical facility or buildings. The authors could not indicate which standard organizations recommended the setback rule of 6m which made it unreliable for adoption. The whole of the study area considered by the authors had only 2 transformers and the setback was studied in relation to residential buildings. For this present study, 10m setback rule as enshrined in ABB (2004) based on the IEEE standards and as supported by the distribution code for Nigerian electricity distribution system in NERC (2016) was used to determine the safety clearance of major roads from transformer locations.

2.3.6 Transformer Service Life

According to Ijewere (ND), a power system needs to pay attention to the life expectancy of its component plant and major accessories. In the case of the then PHCN, virtually every plant it had was ordered and built between 1965 and 1990. The concern here is that the bulk of the equipment may also need to be replaced within a few years of one another and this may pose financial problems to the organization responsible or the government. This is true not just for the generation plant, but also distribution apparatuses which include transformers.

This study identified and mapped out the locations of transformers that exceeded their service life according to ANSI/IEEE standards. This is so that the condition of the transformers in this category can be further examined and critically analyzed. Jasni *et al.* (2017) observed that in condition

assessment, health index is used to examine the condition of the transformer and whether it needs to be maintained, repaired and upgraded, replaced, monitored or have contingency control. This is carried to ensure that the risk of having old transformer which are capable of generating problems is avoided.

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.2 THE STUDY AREA

The study area for this research is Jimeta,Yola-North Local Government Area (LGA) of Adamawa State, Nigeria.

3.2.1 Location and Size

Jimeta is the headquarters and the major settlement in Yola-North L.G.A and forms part of the administrative capital of the state. It is bounded by Yola South to the South and West, and Girei LGA to the North and the East. It lies between Latitudes $9^0$13'44" to $9^0$20'45"N and Longitudes $12^0$27'36" to $12^0$33'30"E (See Figure3.1), and covers an area of about 305 km^2 (Ishaku, 2011). It was established to accommodate immigrants into the older Yola Town. Situated at the bank of River Benue, it eventually subjugated Yola commercially, industrially and administratively (Monday, Ilesanmi and Ali, 2013).

3.1.2 Topography and Climate

The topography of Yola North (Jimeta) is relatively plain, rising from 95m to 190m above sea level, with the River Benue running from East to South of the study area. It has a tropical climate marked by dry

and rainy seasons. Ishaku (2011) reported that the rainy season usually starts from May to October while dry season is usually from November to April. The mean annual rainfall of Jimeta is between 700mm and 1600mm per annum. Its temperature can be as low as 18^0C between December and January while the maximum temperature can be up to 42^0C between March and April. The topography and climate of the area affects the distribution of temperature which in turn presses for the need of electricity to aid in the thermal comfort regulation. This is because Yola can be extremely hot during March and April. Studying the spatial locations of electricity distribution transformers in Jimeta is important as it provided an opportunity to bring out findings that can be used for decisions by the YEDC in ensuring optimum distribution of transformers in all parts of the city.

3.1.3 Population

According to the 2006 National Population Census (NPC), Jimeta and a few villages constituting the 11 political wards of the LGA had 199,674 people with 54.3% male (108,379) and 46.7% female (91,295). In 2010, the projected population at 3.5% growth rate stood at 229,131 people which is about 254,042 in 2013 (Monday, Ilesanmi and Ali, 2013). This trend reveals the rapid growth in the population of Jimeta which in turn requires sustainable social services especially electricity.

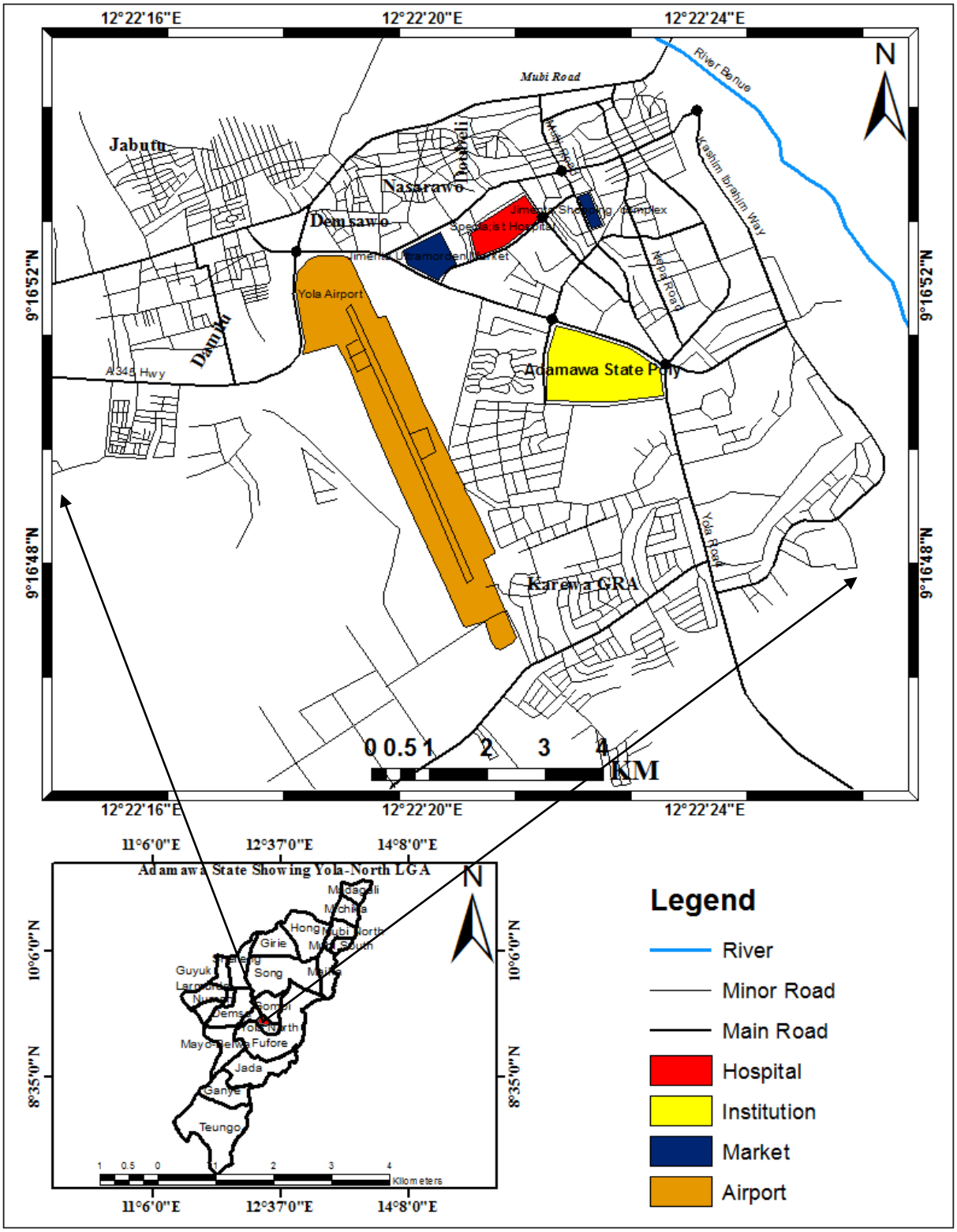


Figure1: The Study Area

Source: Adapted from Google Map of Jimeta (2017)

3.1.4 Landuses and Economic Activities

Jimeta, being part of the Adamawa State capital, is an urban center and one of the economic nerves of the state. The major landuses in the area include commercial, industrial, residential, recreational, institutional, and educational landuses. Jimeta has the largest market in the whole of Adamawa state (Jimeta Ultramodern Market) which facilitates buying and selling of goods and services. Other major commercial places in Jimeta are the Shopping Complex, Bishop Street, and Target junction. The major industries located in Jimeta are Adama Beverages, Adamaplast, Faro, Nagge Yoghurts, Bakery houses, and Sachet Water factories.

Recreational facilities include hotels (e.g Yola International Hotel, Chebian Heritage), parks, sport facilities. Educational institutions include primary, secondary and tertiary institutions; notable among which are the Federal College of Education (FCE) Yola; Adamawa State Polytechnic Yola (SPY); Aliyu Mustapha College, General Murtala Ramat Mohammed College, Yola; Capital School Jimeta; Concordia College Yola. Institutional landuses include among others government offices like the Federal Secretariat Yola; Adamawa State Secretariat; YEDC headquarters. Health institutions include: Specialist Hospital Yola; Peace Hospital Yola; Jimeta Clinic and Haske Clinic among others.

The major economic activities within Yola North LGA are trading, farming, fishing, administration and industrial works. Basic infrastructural facilities are available but their condition, distribution and efficiency are far below average in the slums and other locations where the low income earners live (Monday, Ilesanmi and Ali, 2013). The landuses and economic activities in the study area play important role in determining the locations of electricity distribution facilities, especially transformers. This is because adequate power is needed in sustaining the growth of socioeconomic activities in an area.

3.2 METHODOLOGY

3.2.1 Reconnaissance Survey

A preliminary survey was conducted by the researcher in order to be more familiar with the study area. This is because the researcher has the prior knowledge of the study area having lived in the city. During this phase of the research, a visit was paid to the YEDC headquarters in Jimeta and the office was officially informed about the study which specifically focused on the distribution of its facilities and the support of the management was solicited for, so as to ease the process of data collection. An official record of the number of electric transformers within Jimeta was also obtained from the Jimeta Business (BU) of the YEDC.

3.2.2 Types of Data Used

For the conduct of this research, the following types of data were collected:

1. Geographic Coordinates of the existing electric transformers in Jimeta. This set of data was acquired by the researcher who engaged the YEDC technical staff at the Jimeta BU. The coordinates were collected using a hand-held GPS receiver (GERMIN 78SC) which has the capability to save all the way points in the course of the field work. Manual recording sheet was also used in order to avoid cases of missing data.
2. Data on the conditions of the existing transformers. These data were obtained from the YEDC and also during the field work. Information such as the functionality of the transformers, average loading and year of installation were collected.
3. Data on the characteristics of the existing transformers. Data such as the capacity of the individual transformers, type, and manufacturer, among others were also obtained from the YEDC and verified during the field work.
4. Population for each political ward in Jimeta. The 2006 population census data were obtained from the National Population Commission (NPC) and projected using the Newman's (2001) method.
5. Administrative Map of Jimeta Urban Center. This was obtained from the Adamawa State Ministry of Land and Surveys.
6. Google Image of the study area. This was downloaded from the Google Earth Pro software, georeferenced and digitized as a base map for the study area.

3.2.3 Sources of Data

The types of data above were obtained from both primary and secondary sources. The primary data sources include direct field measurements and observations. This entails the use of Global Positioning System receiver (GPS) GERMIN 78SC model to acquire the coordinates of the electric transformers' point locations and a score sheet to obtain the attributes of each transformer.

Secondary sources of data were Adamawa State Ministry of Land and Survey, and YEDC, where data regarding the existing number of transformers were obtained, NPC for population of each political ward in the study area, and the administrative map of Yola North Local Government Area was acquired. Journals, textbooks, news papers, published and unpublished thesis and dissertations, which were used for literature review and comparison.

3.2.4 Base map extraction

The Google image of the study area was downloaded using the Google Earth Pro. The image was imported into ArcGIS10.3 where georeferencing and an on-screen digitization was performed on it in order to obtain the base map of the study area which was also used subsequently for result presentations. Although, the details of road network on the study area map is high compared to the one used for results presentation. This was deliberately done so as to reduce too much information on the maps on which results were presented. The map was compared with the administrative map of the LGA which has the boundaries of political wards which was used for producing the population density map over which the location of transformers were laid.

3.4.5 Data Analyses

Data obtained were analyzed as follows based on the set research objectives:

i. **Objective 1: To identify and map out the locations of existing electricity transformers in Jimeta.**

This was achieved through the use of a handheld GPS receiver (GARMIN 78SC) for obtaining the geographic coordinates of the existing transformers in Jimeta. The YEDC staff at the Jimeta (BU) were engaged during this field survey. These data (point locations) were used to produce digital maps of the transformers. These point locations were overlaid and presented on a downloaded, georeferenced, and digitized base map of the study area as an electricity transformers map using ArcGIS 10.3 software. They were displayed on digital maps based on whether they are for public or dedicated uses.

ii. **Objective 2: To examine the spatial pattern of location of electricity transformers in Jimeta**.

This was achieved by analyzing the spatial distribution of the point locations of transformers presented on the base map of the study area. Here, Nearest Neighbourhood Analysis (NNA) was employed to examine the distribution pattern of the transformers. The NNA uses the distance

between each point and its closest neighbouring point to determine if point pattern is clustered, random or dispersed. The result was generated from the NNA analysis carried out using ArcGIS 10.3 software which gives clustered points when the Nearest Neighbourhood Index (NNI) is tending towards 0, random when it is closer or equal to 1.0 and regular when the result is closer or equal to 2.15 (Sherwood, 1970).

iii. Objective 3: To create a geodatabase for electricity transformers in Jimeta.

This objective was achieved by creating a geodatabase for both the spatial and attributes data of the electricity distribution transformers in Jimeta from which, queries, were made to answer other research questions and manipulations, updates and retrievals can be made with time. The coordinates and their attributes were copied into Microsoft Excel 2007 environment from the GPS device and then saved as CSV (comma delimited) format. This was then imported into ArcGIS 10.3 from which queries were made for subsequent analyses.

iv. Objective 4: To assess the extent to which population influences the location of transformers in Jimeta.

This objective was achieved by first producing the population density map based on the political wards of Yola-North LGA. Point locations of the transformers were overlaid on the population density map and query by selection was used to assess how the various parts of the city influenced the locations of the facilities in relations to their population. The population density map was produced in ArcGIS 10.3 using the 2017 projected population from the 2006 population census according to Newman's (2001) method of projection at 0.5% annual growth rate. This method uses the population of an area in the recent year, population in the base year, annual growth rate and number of intermediary years to project the population of such an area from one year to another. The use of 2006 population census data was necessary because the 1991 census was conducted before Jimeta became an LGA. The present Yola North and South LGAs were both under the defunct Yola LGA. Therefore, the places called political wards in Yola-North LGA today were not political wards under Yola LGA during the 1991 population census.

The projected population of each political ward was added on the attribute table of the wards boundary map of the study area through the Editor tool of the software. The attribute table was then queried to produce density map that shows three categories of density (Low, Medium and High). The locations of the transformers were then displayed on the population density map.

The Newman's (2001) formular used for projecting the population is given as:

$$P_n = P_o + \left(\frac{1+R}{100} x P_o\right) n$$

Where:

$P_{n=}$ Population in the recent year

$P_{o=}$ Population in the base year

R= Annual growth rate

n= Number of intermediary years

The result of the projected population is shown in Table 3.1

Table 3.1: Political Wards' Population of Jimeta

Political Ward	Population (2006)	2017 Projected
Ajiya	14359	21467
Alkalawa	23043	34449
Limawa	14426	21567
Rumde	11493	17182
Luggere	15354	22954

Karewa	22227	33229
Nasarawo	15331	22920
Gwadabawa	21209	31707
Doubeli	31077	46460
Jambutu	17331	25910
Yelwa	10337	15454
Total	**196,187**	**293,299**

Source: Author's Projection, (2017)

v. Objective 5: To examine the level of compliance with the NERC (2016) standards for siting transformers in Jimeta.

Buffer Analysis was employed to achieve this objective in line with ANSI/IEEE (1989) standards. The standards approve a Safety Clearance of 10m distance of transformers from major roads as also enshrined in the NERC (2016) Distributon Code for Nigerian Electricity Distribution System. A 10m buffer zone was created around each transformer and the transformers whose buffer zones encroach into major roads were mapped out.

Objective 6: To identify and map out the transformers that have exceeded their service lives in Jimeta.

This objective was achieved by finding the years of service of the existing transformers in Jimeta. The years of service were gotten by simple arithmetic applied on the record obtained from the YEDC Jimeta Business Unit, i.e. the year of commission of each transformer was subtracted from 2017 giving its years in service. The results for all the transformers were subjected to the ANSI/IEEE (1989) standards in order to identify those that have spent more than the required years in service. The standards approve maximum of 25 years of transformers in service, and Transformers that have spent 25 years and beyond in service were identified by querying the 'YrsInService' field of the geodatabase and shown on the map.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This Chapter deals with the presentation of results and discussion. It first presents the result of the spatial locations of the existing transformers in Jimeta and then explains the possible factors responsible for such distribution. Maps and screenshots containing different types of transformers and the operations

performed are presented and discussed based on their various capacities. The Nearest Neigbour Analysis summary that revealed the spatial pattern of the transformer distribution is also presented and discussed in relation to other researchers' findings as reviewed in the literature. Screen prints of the transformers geodatabase, and maps showing the level of violation of the standards for siting transformers have also been dicussed.

4.2 LOCATION OF TRANSFORMERS IN JIMETA

Step-down electricity transformers are located in all parts of Jimeta in varying spatial concentrations. This is basically due to the mixture of landuses which the transformers serve to convert alternating current from one voltage to another in order to meet the power demands of the people. These transformers are either public or dedicated depending on the purpose for which they are installed.

4.2.1 Location of Public and Dedicated Transformers in the Study Area

Public transformers are those transformers that are located in areas where the distribution of electric power can be accessed by the general public. These areas include public residential areas, large commercial centres, Barracks, Government establishments' quarters, Public Housing Estates, Federal and State Secretariats among others. Appendix I shows the list of the public transformers' coordinates, capacities and locations (addresses). For easy identification, popular names of individuals and organizations were used in some cases to name the locations of some public transformers. This is because some of these transformers were located at places where it was difficult for the researcher to identify with specific addresses.

Dedicated transformers are those purposefully commissioned to meet the power distribution needs of certain organizations, businesses and individuals. They are mostly of lower capacities, ranging from 100kVA to 200kVA with very few 300kVA and 500kVA, depending on the electric power demand of such an organization or a household. They are mostly purchased by an individual or organization but installed and maintained by the YEDC in the premises of the clients. There are also very high capacity dedicated transformers which range between 750kVA and 1000kVA. They are commissioned for large government projects such as the Yola Water Treatment Plant, Jimeta. Some of these transformers are also located at the industrial areas of Adamaplast, Faro, Adama Beverages, Nagge Yogurts among others (See Appendix II).

Transformers, as the key players in the electricity distribution system, are distributed spatially across Jimeta urban centre. Jimeta, being an urban area and one of the socioeconomic nerves of Adamawa State, has a total of 324 Step-down transformers distributed across the landscape of the city. These transformers comprise of both the public and dedicated ones having different capacities ranging from 25kVA to 1000kVA. The public transformers were mapped and

shown on Figure 4.1 with their individual Field Identification (FID) number as indicated in the attribute table of the geodatabase. The FID of each of the transformers, as appeared on the map, are indicated under FID column of the Appendix I for reference purposes.

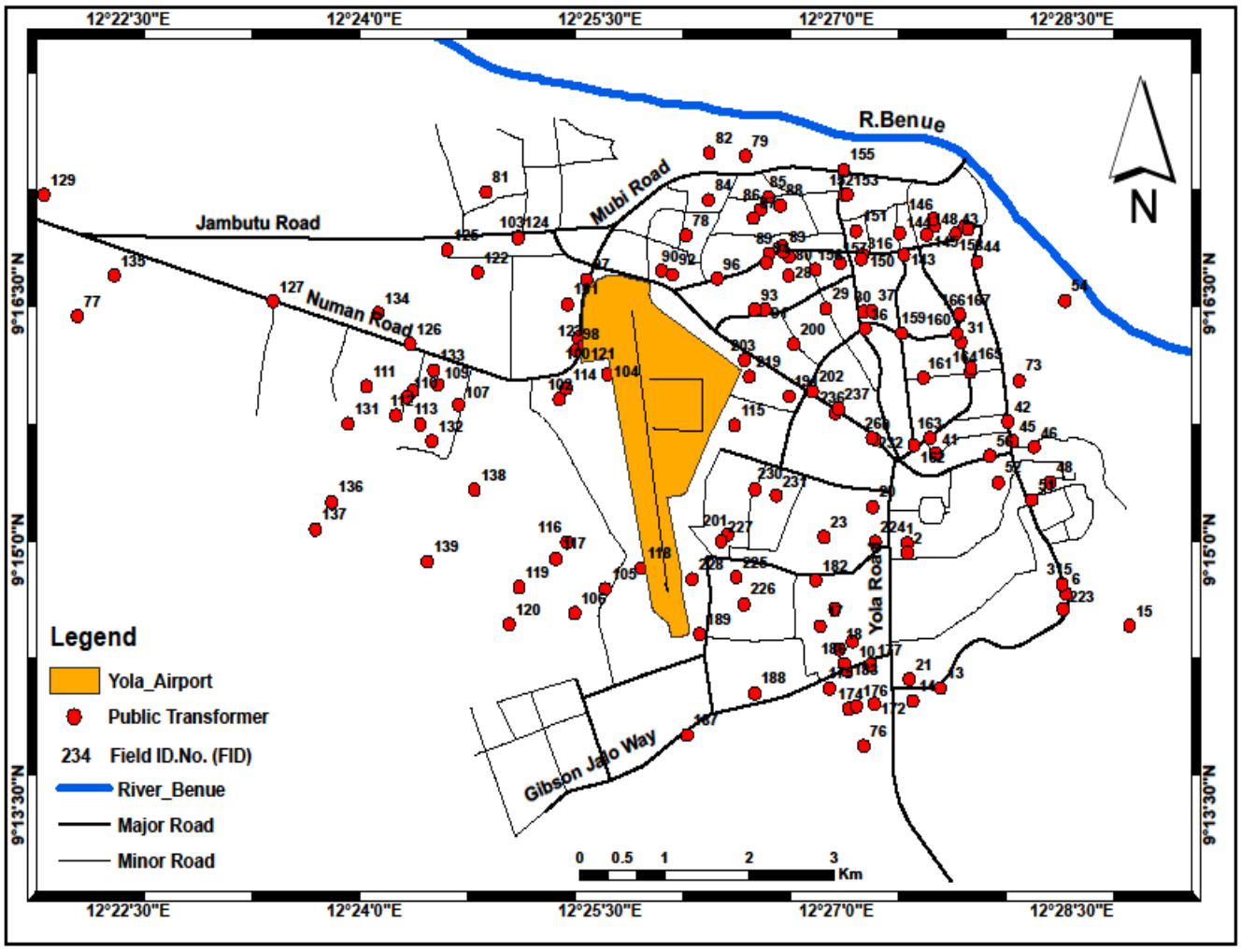


Figure 4.1: Spatial Location of Public Transformers in Jimeta
Source: Modified from Google Image of the study area (2017)

There are a total of 148 public transformers accounting for 45.67% of the overall transformers in Jimeta. Transformers in this category have capacities, mostly ranging from 300kVA to 500kVA. They are purchased, installed and maintained by the distribution company (YEDC) for the general public in the areas located. They are spatially distributed across all parts of the city in varying patterns due to the mixture of the urban landuses. They are mostly located in the northern (e.g. Doubeli and Nasarawo) and western parts (e.g. Demsawo and Bachure) of the city, as well as some few places in the southern part (e.g. Malamre and Karewa). This is due to the fact that the areas are mostly made up of residential buildings of the middle and the lower income earners who do not use personal transformers dedicated for their own use but rather rely on the public ones. The public transformers appear to be mostly located across areas such as, Luggere,

Angwan NEPA and Dogire of the city basically because the areas were dominated with large commercial centers and residential areas.

There are a total of 176 dedicated transformers accounting for 54.33% of the overall total of distribution transformers in Jimeta. Although, they appear to have the higher percentage over the public transformers, they are mostly of very low capacities with a few of very high capacities, making the transformers installed for public use in the medium category. They are mostly located along the city streets where there most of the private organizations were located (See Figure 4.2). They are sited mostly in premises of commercial banks, shopping malls, telecommunication masts spots and offices, Large internet cafes, such as APTI Ventures, 21st Centuary, Bit Byte; Boarding Secondary Schools, such as Concordia College and GMMC, Offices of Government parastatals, Water Boards and houses of influential individuals, as well as business places. The FID is also used to label tha locations of the dedicated transformers and they are indicated under the FID column of the Appendix II for reference purposes.

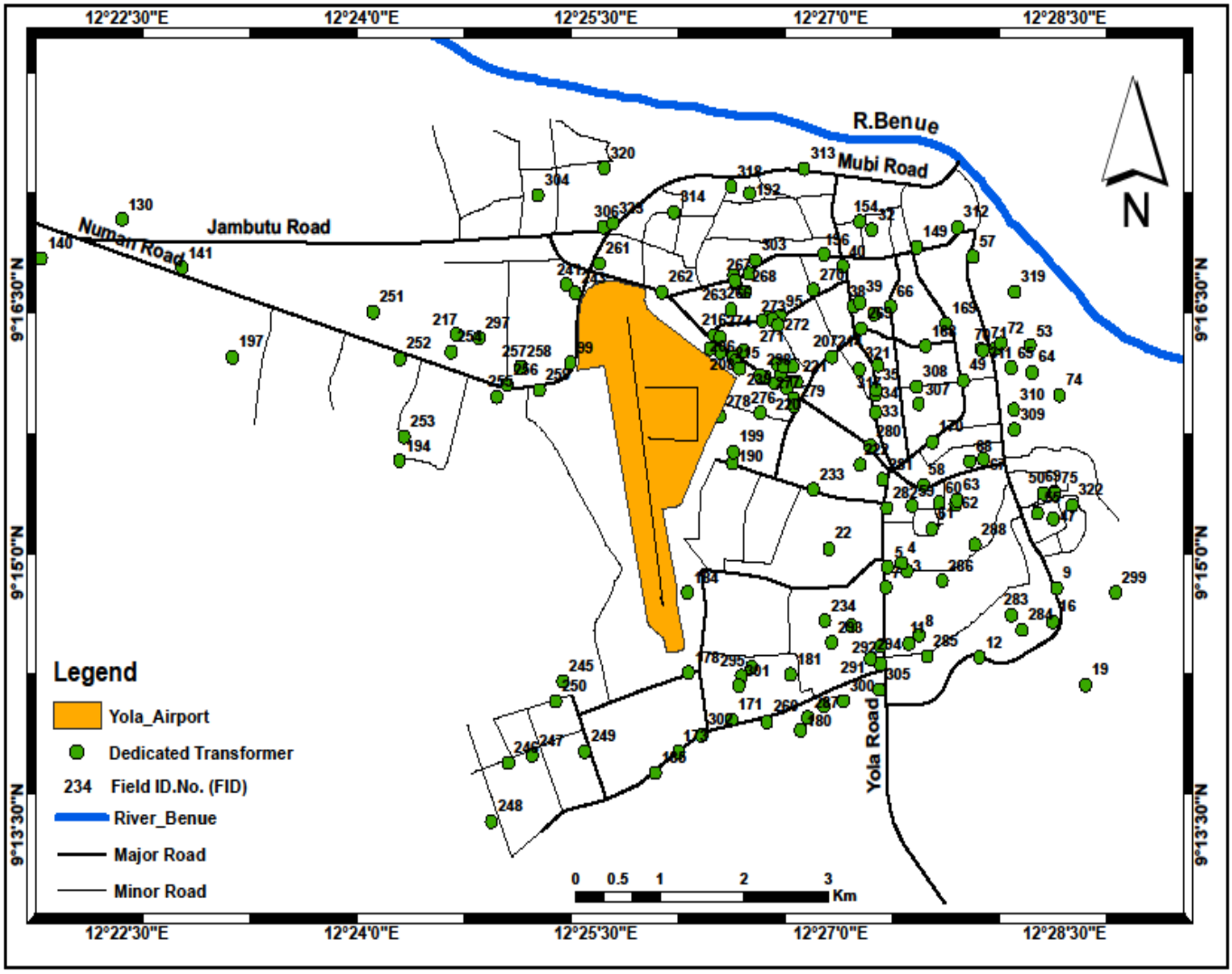


Figure 4.2: Spatial Location of Dedicated Transformers
Source: Modified from Google Image of the study area (2017)

These urban landuse characteristics have different levels of demand for electricity and hence influenced the distribution of transformers within the study area. Figure 4.3 displays the spatial locations of Step-down transformers (both public and dedicated) in Jimeta as at April, 2017. The addresses of the location of transformers on Figure 4.3 can also be traced with FID on appendix I and II.

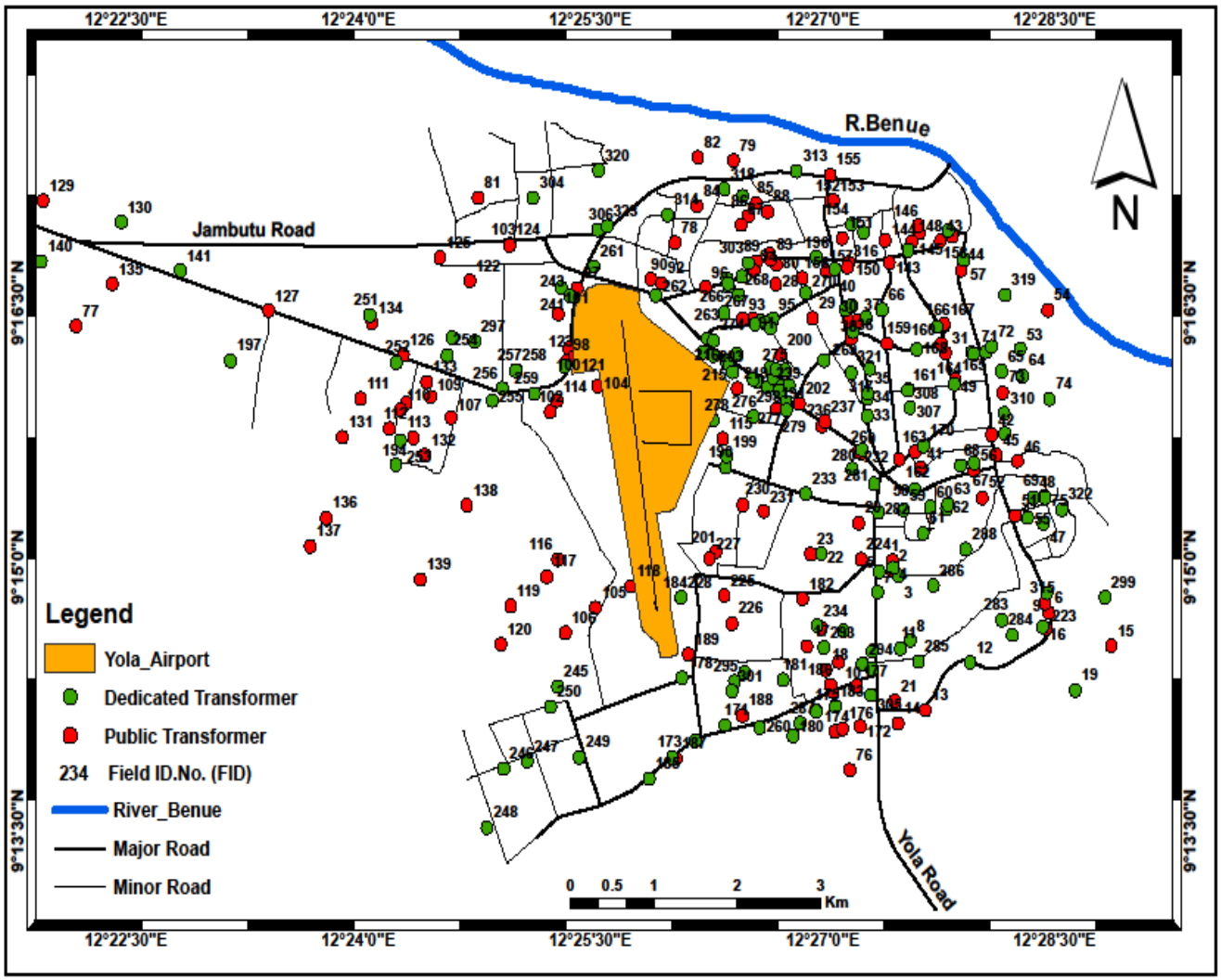


Figure 4.3: Spatial Locations of both Public and Dedicated Transformers in Jimeta
Source: Modified from Google Image of the study area (2017)

Generally speaking, the spatial distribution of electricity transformers in Jimeta is uneven (Figure 4.3). This is because some areas of the city have more transformers than others as a result of landuse activities which determine to a large extent, their pattern of spatial distribution. Places of high commercial activities, industries, offices of public and private organizations and areas of high class residential buildings appeared to have more concentration of transformers than places of low commercial activities and of lower class residential areas.

These findings agree with that of Chatta (2015) who identified and mapped out 100 transformers (both public and dedicated ones) in Sabon Gari LGA of Kaduna State, Nigeria. This present study has also mapped out and showed the locations of transformers in highly commercialized and industrial areas as

carried by the same work of Chatta (2015). The results of this research are also similar to that of Zitta, Musa and Aliyu (2014) who succeeded in mapping and displaying some facilities and utilities including transformers in Langtang North LGA of Plateau State, Nigeria. Although electricity transformers are a few of the facilities (e.g Boreholes, Hotels, Schools, GSM Masts, Water facilities among others) mapped by these authors, this work concentrated on transformers alone with the aim of avoiding incomprehensiveness of reports on multiplicity of facilities. This present study, as the two cited above, had mapped out the locations of the existing transformers as objects on the surface of the earth. This present study, had therefore, agreed with the works of the previous authors in content and mode of results presentation (maps).

4.2.4 Spatial Distribution of Transformers in Jimeta by Capacity

Transformers are distributed in their various capacities within the study area. The capacity of a transformer determines the load which it can carry. Low capacity transformers carry low loads and high capacity transformers service areas of high electricity demands in Jimeta. The capacity of Step-down transformers in Jimeta is distributed within the range of 25kVA and 1000kVA (See Table 4.1).

Table 4.1: Transformers in Jimeta based on their Capacities

Capacity (kVA)	N0.	Percentage (%)
25	3	0.93
50	9	2.78
100	42	12.96
200	113	34.87
300	65	20.06

500	86	26.54
750	3	0.93
1000	3	0.93
Total	**324**	**100**

Source: Author's Analysis (2017)

Transformers with 25kVA and 50kVA are mostly pole-mounted across newly built-up areas of Karewa, Damilu and Wuro Jabbe. There are those with 100kVA which are sited at MTN, Glo and Airtel offices, as well as NNPC, some Filling stations (e.g. Toatal, Oando, AP Filling stations), Small Hotels (e.g Hotel La-Birem, Taraba Lodge), Internet Cafes (e.g. 21st Century and APTI Ventures) and in compounds of high income earners across Dogire and Damilu. Another category is the 200kVA transformers which has the highest percentage were sited in places such as the Yola NNPC mega station, Bakery companies (e.g. Tasty Menu, Oasis and Jimeta Modern Bread), Startimes, Banks and houses of Government Officials and Businessmen. Transformers with 300kVA capacities were found at Big Hotels (Bagale Hotel, City Green Hotel), Government establishments such as the Yola Airport, State Secretariat, higher institutions of learning such as Adamawa State Polytecnic and FCE Yola, Hospitals (e.g. Peace Hospital, Bekaji Clinic and Galbose Hospital), Barracks and public residential areas, as well as some commercial institutions like United Bank for Africa (UBA) main branch, First Bank Plc, Zenith Bank among others. Transformers with 500kVA were mostly located in public residential areas and other places such as YEDC Offices, NTA Office, INEC Office, Adamawa State Polytechnic, FCE Yola, FAAN, Airforce Base, Army Barrack among other places. The 750kVA and 1000kVA transformers were located in the industrial zone of the city. This is possibly because industries require high voltage and steady power supply for production. They are sited at Adamaplast, Adama Beverages, Faro and Nagge Yogourts, as well as at Yola Water Treatment Plant and Water Board (See Figure 4.4).

These transformers are categorized into Public or Dedicated transformers according to DISCOs' field categorization.

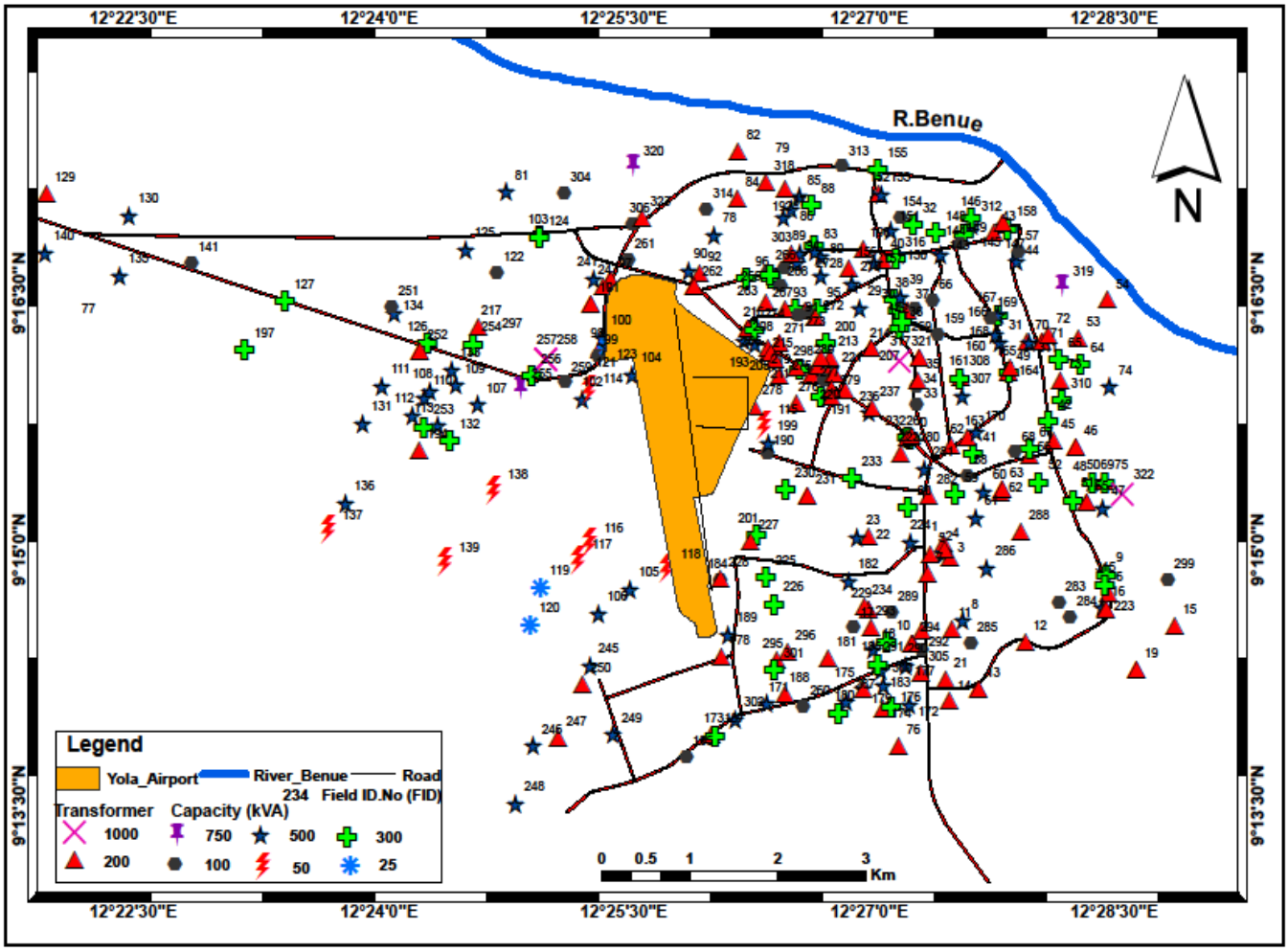


Figure 4.4: Spatial Distribution of Transformers in Jimeta by Capacity
Source: Modified from Google Image of the study area (2017)

The point locations of the transformers on the Figure 4.4 are labeled with the FID and can be traced to the FID column of Appendix I and II.

4.3 SPATIAL PATTERN OF LOCATION OF TRANSFORMERS IN JIMETA

Nearest Neigbour Analysis (NNA) is a very important tool for determining the spatial distribution pattern of objects on the surface of the earth. This spatial analytical tool of GIS in ArcGIS 10.3 was employed to examine the distribution pattern of the electricity transformers in Jimeta. The result shows clustered points at 0.01% significance level with the Nearest Neighbour Ratio (NNR) of 0.010787 (See Figure4.5).

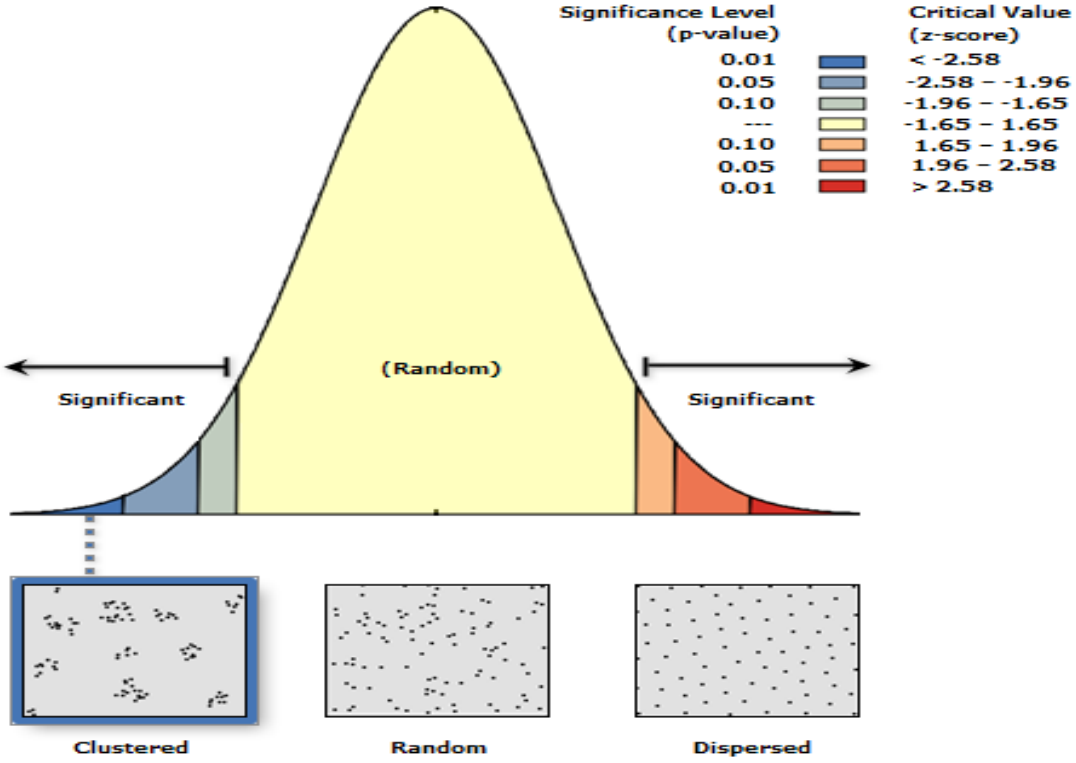


Figure 4.5: The Distribution Pattern of Transformers in Jimeta

Source: Author's Analysis (2017)

Given the z-score of -25.0345496985, there is less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

Observed Mean Distance:	247.3900 Meters
Expected Mean Distance:	22934.3878 Meters
Nearest Neighbor Ratio:	0.010787
z-score:	-25.034550
p-value:	0.000000

Based on the average nearest neighbor summary results, the observed mean distance from one transformer to another is 247.3900m resulting to clustered distribution. This is far below the expected mean distance of 22934.3878m which results to regular distribution pattern. The clustered nature of the transformers distribution is as a result of the mixed-nature of the various urban landuses which is responsible for the differences in electric power demand and supply which also affects the location of electricity distribution facilities. For instance, Adamawa Investment House, Federal Inland Revenue office, NNPC Mega station, INEC Office, NPC office, Central Bank, U.B.A, First Bank, Diamond Bank, Zineth Bank, Fidelity Bank, Skye Bank, Guarantee Trust Bank, Keystone Bank, Luka Shopping Mall, ABTI Ventures, Lamido Cinema, among others are all located along the Ahmadu Bello Way or popularly known as Bank Road and all these organizations have transformers dedicated for sufficient power supply.

There are many other places within the city where there are high commercial activities mixed with offices of both private and government establishments. For example, Bishop's Street, Jimeta Shopping Complex, Target Junction, Police Roundabout, Mubi Roundabout, Kashim Ibrahim Way, Yola Road, Atiku Abubakar Way, among others have many organizations and commercial centers located along their axis that do not share transformers with others even though, they are very close to one another.

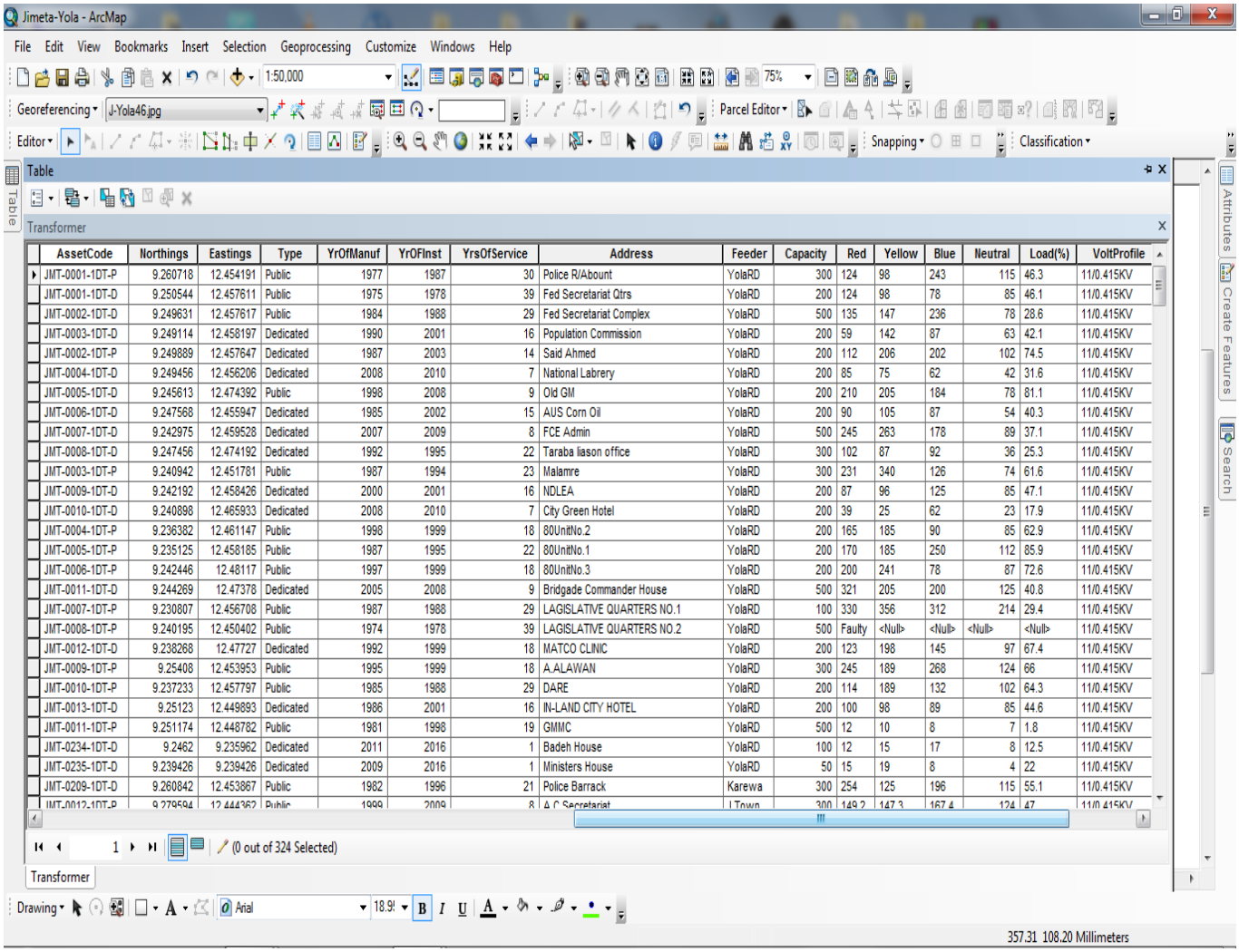
Among residential areas occupied by high income earners, the distribution seems to be clustered because the fact that the demand for electricity is higher than areas of low income earners and slums. Consequently, most houses prefer to have personal transformers dedicated for their own use. For example, Government Reserved Area (GRA) Karewa, State Low-cost, Nepa, Dogire among others are high-class residential areas mostly having transformers. Generally speaking, clustered points of transformers appear to dominate places of high commercial activities

intermingled with offices of government and private establishments, as well as the high-class residential areas that require constant power supply.

In areas of the middle and lower classes of residential buildings and slums where commercial activities and household demand for electricity is low in relation to other places, transformers distribution appeared to be skewed towards areas of middle class residential buildings and commercial centers, indicating the relatively low demand of electricity in such areas. The distribution appeared to be random in lower class residential areas and the city outskirt, indicating low demand and supply of electricity in such areas (e.g Jambutu, Damilu, Karewa extension). The findings of this research confirmed the study made by Odior, Oyowale and Ovuworie (2010) whom in their research on some operations of electric power supply system in Benin City, found that the average power supply to Government Reservation Area (GRA) was more regular and stable than that of Siluko which is a residential area characterized with low income earners.

4.4 GEODATABASE OF TRANSFORMERS IN JIMETA

Geodatabase plays a key role in GIS analysis. It provides the opportunity for information on objects to be stored, manipulated, retrieved and updated with time. It is the process whereby real world entities and their interrelationships are analyzed and modeled in such a way that maximum benefits are derived while utilizing minimum amount of data (Damilola, 2015). A geodatabase was created not just to help in satisfying the other objectives of this work, but also for future purposes since data in a database can be updated with time. The geodatabase contains both spatial and attribute data (See Figure 4.6).



AssetCode	Northings	Eastings	Type	YrOfManuf	YrOFInst	YrsOfService	Address	Feeder	Capacity	Red	Yellow	Blue	Neutral	Load(%)	VoltProfile
JMT-0001-1DT-P	9.260718	12.454191	Public	1977	1987	30	Police R/Abount	YolaRD	300	124	98	243	115	46.3	11/0.415KV
JMT-0001-1DT-D	9.250544	12.457611	Public	1975	1978	39	Fed Secretariat Qtrs	YolaRD	200	124	98	78	85	46.1	11/0.415KV
JMT-0002-1DT-D	9.249631	12.457617	Public	1984	1988	29	Fed Secretariat Complex	YolaRD	500	135	147	236	78	28.6	11/0.415KV
JMT-0003-1DT-D	9.249114	12.458197	Dedicated	1990	2001	16	Population Commission	YolaRD	200	59	142	87	63	42.1	11/0.415KV
JMT-0002-1DT-P	9.249889	12.457647	Dedicated	1987	2003	14	Said Ahmed	YolaRD	200	112	206	202	102	74.5	11/0.415KV
JMT-0004-1DT-D	9.249456	12.456206	Dedicated	2008	2010	7	National Labrery	YolaRD	200	85	75	62	42	31.6	11/0.415KV
JMT-0005-1DT-D	9.245613	12.474392	Public	1998	2008	9	Old GM	YolaRD	200	210	205	184	78	81.1	11/0.415KV
JMT-0006-1DT-D	9.247568	12.455947	Dedicated	1985	2002	15	AUS Corn Oil	YolaRD	200	90	105	87	54	40.3	11/0.415KV
JMT-0007-1DT-D	9.242975	12.459528	Dedicated	2007	2009	8	FCE Admin	YolaRD	500	245	263	178	89	37.1	11/0.415KV
JMT-0008-1DT-D	9.247456	12.474192	Dedicated	1992	1995	22	Taraba liason office	YolaRD	300	102	87	92	36	25.3	11/0.415KV
JMT-0003-1DT-P	9.240942	12.451781	Public	1987	1994	23	Malamre	YolaRD	300	231	340	126	74	61.6	11/0.415KV
JMT-0009-1DT-D	9.242192	12.458426	Dedicated	2000	2001	16	NDLEA	YolaRD	200	87	96	125	85	47.1	11/0.415KV
JMT-0010-1DT-D	9.240898	12.465933	Dedicated	2008	2010	7	City Green Hotel	YolaRD	200	39	25	62	23	17.9	11/0.415KV
JMT-0004-1DT-P	9.236382	12.461147	Public	1998	1999	18	80UnitNo.2	YolaRD	200	165	185	90	85	62.9	11/0.415KV
JMT-0005-1DT-P	9.235125	12.458185	Public	1987	1995	22	80UnitNo.1	YolaRD	200	170	185	250	112	85.9	11/0.415KV
JMT-0006-1DT-P	9.242446	12.48117	Public	1997	1999	18	80UnitNo.3	YolaRD	200	200	241	78	87	72.6	11/0.415KV
JMT-0011-1DT-D	9.244269	12.47378	Dedicated	2005	2008	9	Bridgade Commander House	YolaRD	500	321	205	200	125	40.8	11/0.415KV
JMT-0007-1DT-P	9.230807	12.456708	Public	1987	1988	29	LAGISLATIVE QUARTERS NO.1	YolaRD	100	330	356	312	214	29.4	11/0.415KV
JMT-0008-1DT-P	9.240195	12.450402	Public	1974	1978	39	LAGISLATIVE QUARTERS NO.2	YolaRD	500	Faulty	<Null>	<Null>	<Null>	<Null>	11/0.415KV
JMT-0012-1DT-D	9.238268	12.47727	Dedicated	1992	1999	18	MATCO CLINIC	YolaRD	200	123	198	145	97	67.4	11/0.415KV
JMT-0009-1DT-P	9.25408	12.453953	Public	1995	1999	18	A.ALAWAN	YolaRD	300	245	189	268	124	66	11/0.415KV
JMT-0010-1DT-P	9.237233	12.457797	Public	1985	1988	29	DARE	YolaRD	200	114	189	132	102	64.3	11/0.415KV
JMT-0013-1DT-D	9.25123	12.449893	Dedicated	1986	2001	16	IN-LAND CITY HOTEL	YolaRD	200	100	98	89	85	44.6	11/0.415KV
JMT-0011-1DT-P	9.251174	12.448782	Public	1981	1998	19	GMMC	YolaRD	500	12	10	8	7	1.8	11/0.415KV
JMT-0234-1DT-D	9.2462	9.235962	Dedicated	2011	2016	1	Badeh House	YolaRD	100	12	15	17	8	12.5	11/0.415KV
JMT-0235-1DT-D	9.239426	9.239426	Dedicated	2009	2016	1	Ministers House	YolaRD	50	15	19	8	4	22	11/0.415KV
JMT-0209-1DT-D	9.260842	12.453867	Public	1982	1996	21	Police Barrack	Karewa	300	254	125	196	115	55.1	11/0.415KV
JMT-0012-1DT-P	9.279594	12.444362	Public	1999	2009	8	A.C Secretariat	I.Town	300	149.2	147.3	167.4	124	47	11/0.415KV

Figure 4.6: The Attribute Table of the Geodatabase of Electricity Transformers in Jimeta
Source: Author's Analysis (2017)

The spatial data include the coordinates of the transformers point locations stored in terms of Northings and Easthings. This data is a very important element of the geodatabase because it provides information about the geographical location of the individual transformers in Jimeta.

Some of the attribute data built in the geodatabase include: type of transformer, year of manufacture, year of installation, service years, address, feeder, capacity, average ampere for the three phases and the neutral (red, yellow, blue and neutral), average loading, voltage profile, asset code and manufacturer. Data on all these variables are important and being in the geodatabase, they can provide additional information about the transformers at any time need. For instance, the

database can be queried to display either public or dedicated transformers under the 'Type' field. This can also be done based on the capacity of the various transformers in the database and the result can be used to make effective decisions that can improve managerial practices and operations of the Disco and the government.

With these in the database, query can be made to display the actual locations of either all or a particular category of transformers (See Figure 4.7). Also, updates can be made with time to satisfy the needs of the distribution companies, general public and interested researchers who can make use of the database in solving other challenges that border around the electricity distribution system of the study area.

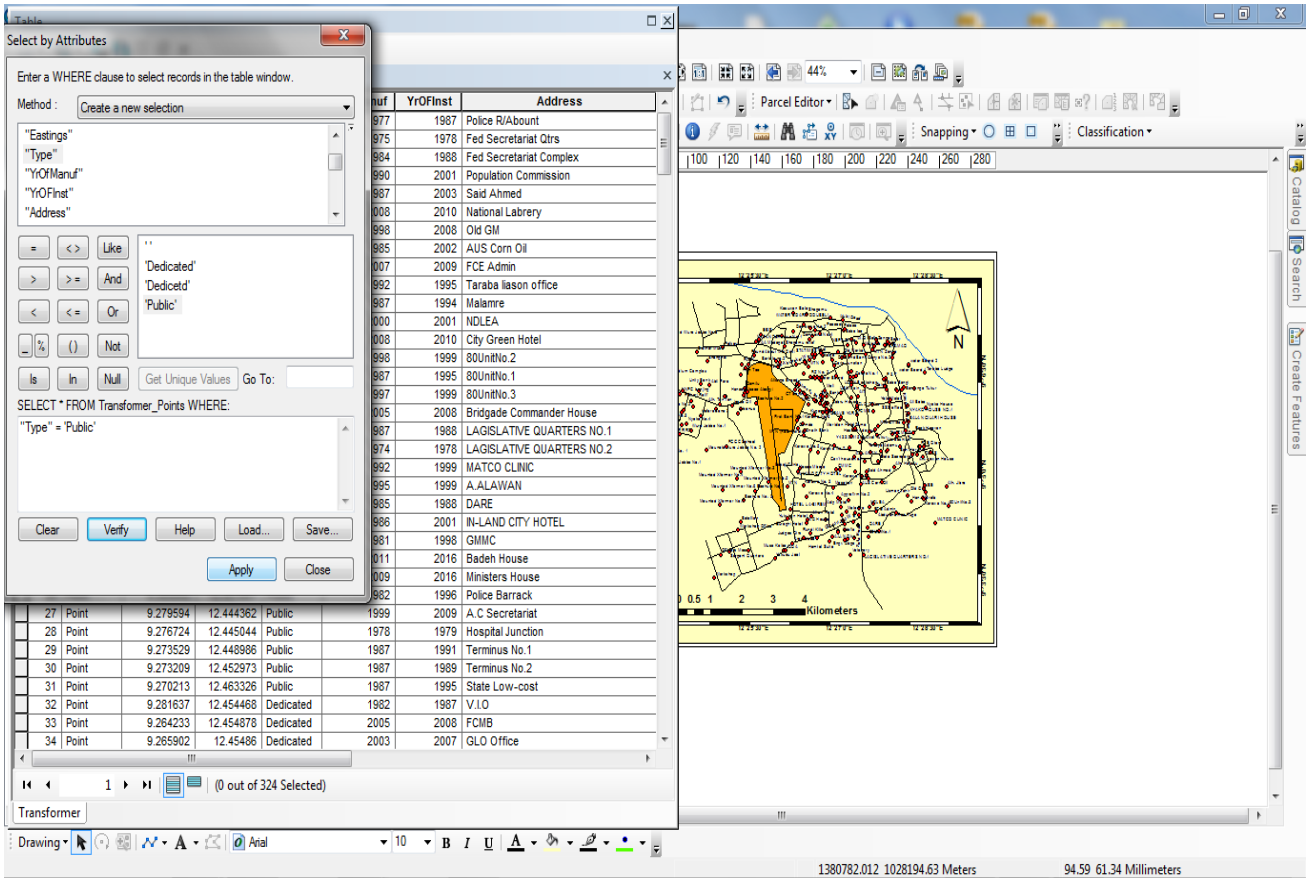


Figure 4.7: Screen-print of Geodatabase Query Processes
Source: Author's Analysis (2017)

This geodatabase is in line with the ones created by Ighalo and Williams (2012) and Kanmani and Suresh (2014) with little differences in the attributes of transformers. The geodatabase in this present study bridge the gap left by Omilabu, Igbokwe, Ejikeme, Igbokwe, and Njoku (2015). This is because in this work, concentration was only on the step-down transformers but, in a far wider area than theirs. Also data such as voltage amperes, load, and year of installation, year of manufacture, manufacturer, and asset code has been added to those created in their study. Ogbokwe and Njoku (2015) used only two transformers in their study area which revealed the small nature of the study area. In contrast, this study used information on 324 transformers with more comprehensive attributes than theirs.

4.5 INFLUENCE OF POPULATION ON TRANSFORMER DISTRIBUTION

Population is the main driver for electricity, but the major factor that determines the demand for electric power and usage is the level of socioeconomic activities, as well as the level and strength of electrical appliances employed for commercial, domestic, industrial, technological and institutional uses in an area. Population therefore plays a vital role, to an extent, in determining the amount of electricity required in an area since the number of people determines the level of economic activities going on in an area. It is expected that as the demand for electricity increases, the need to increase electricity distribution facilities such as transformers also increases in order to support adequate and efficient power distribution and utilization. The transformer point locations were overlaid on the projected 2017 population density map in order to examine the level at which population has influenced the situation of the facilities (See Figure 4.8). The FID in appendix I and II can be used to traced the address of the transformer locations.

The population density map was produced in ArcGIS 10.3 using the 2017 population as projected from the 2006 population census (See Table 3.1). The projected population of each political ward was added on the attribute table of the wards boundary map of the study area using the Editor tool of the software. The attribute table was then queried to produce density map that shows three categories of density. These are: Low density areas having population ranging from 15454 -17182, Medium density with 17183-25910 and finally the densely populated areas with 25911 people and above.

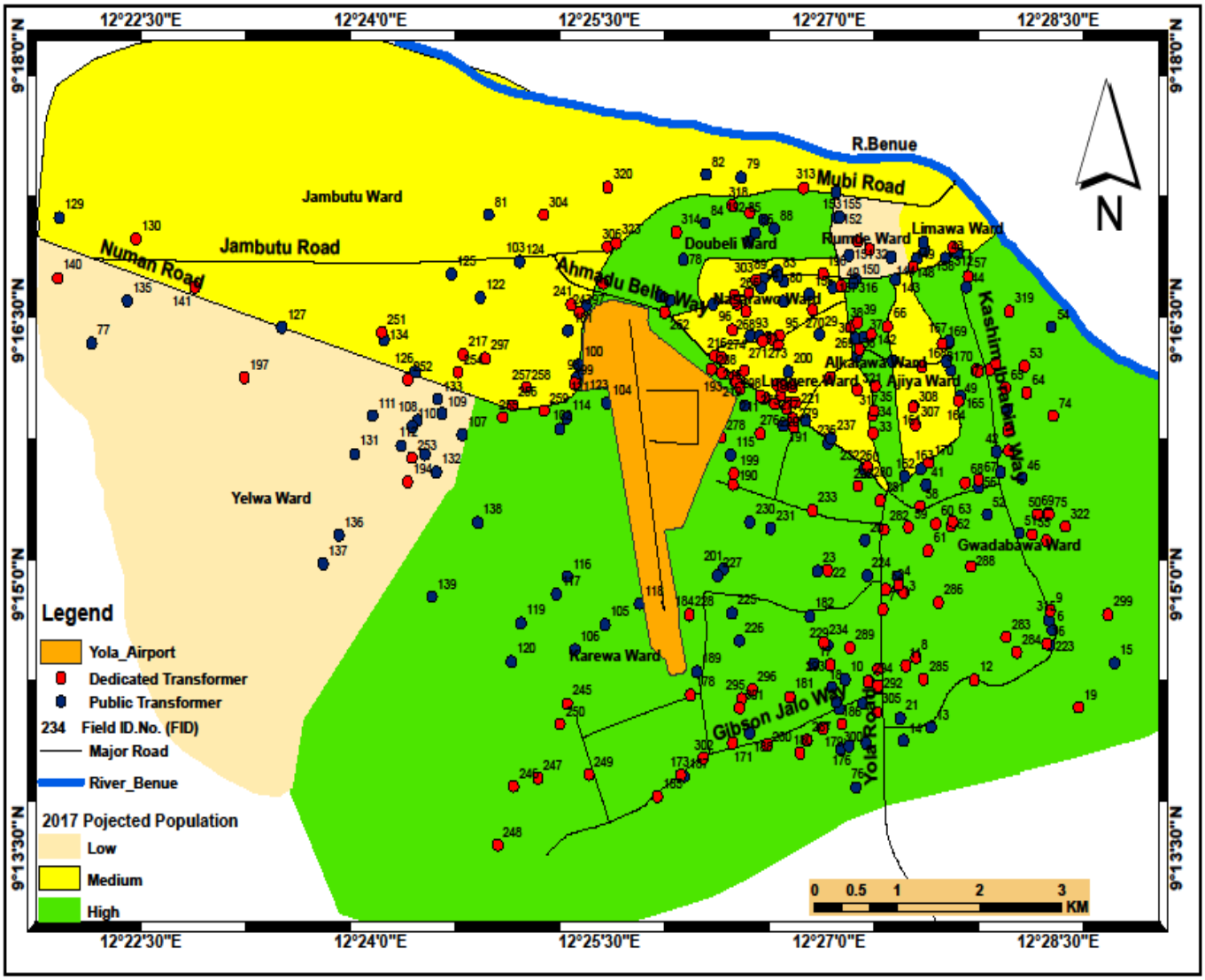


Figure 4.8: The Location of Transformers on Population Density Map

Source: Author's Analysis (2017)

The low population density wards include Rumde and Yelwa wards having 11.13% of the total projected population. The medium density wards are Jambutu, Nasarawo, Luggere, Limawa and Ajiya accounting for 39.15% of the total population and finally, the high density wards are Doubeli, Alkalawa, Karewa and Gwadabawa accounting for the remaining 49.72% of the total population of Jimeta (See Table 4.2).

Table 4.2: Population Density based on Political Wards and their Number of Transformers

Population Density	Political Wards	Total Population	Percentage (%)	No. of Transformers	Percentage (%)
Low	Rumde and Yelwa	32,636	11.13	26	8.02
Medium	Jambutu, Nasarawo, Luggere, Limawa and Ajiya	114,818	39.15	97	29.94
High	Doubeli, Alkalawa, Karewa and Gwadabawa	145,845	49.72	201	62.04
Total		**293, 299**	**100**	**324**	**100**

Source: Author's Analysis, (2017)

Table 4.2 discloses the low, medium and high population density political wards and the number of transformers they have. The low density wards influenced 26 transformers in their various capacities accounting for 8.02% of the total number of transformers in the study area. The medium density wards attracted up to 97 transformers making 29.94% of the total number of transformers, while the high density wards had 201 transformers accounting for 62.04% respectively. This result implies that the population of the study area has an influence on the distribution of transformers which also buttresses the point that population is the main driver for electricity because population is responsible for the level of economic activities that press demand on power supply. Different factors are actually responsible for the demand and supply of electric power in an area, but the population factor is the ultimate. This supported the assertions of Awosope (2014) and the Resource Center Electric Economics and Regulations (2005) that population and the level of socioeconomic activities determine the level of demand for power.

4.6 COMPLIANCE WITH NERC (2016) STANDARDS FOR SITING TRANSFORMERS

A Safety clearance of 10m buffer zones were created around each transformers in Jimeta that are along the road; and a query was made to unravel the number of transformers that violate the setback regulations set by the NERC (2016) standards as supported by the IEC (2016) electrical installation standard and the IEEE (1993) standards for siting transformers which specify a 10m distance from major roads. The query result indicated that 11 transformers accounting for 3.4% were below the above standards, which states that distribution transformers should be sited at least 10m away from main roads (See Figure 4.9). These transformers were located less than 10m away from the main roads.

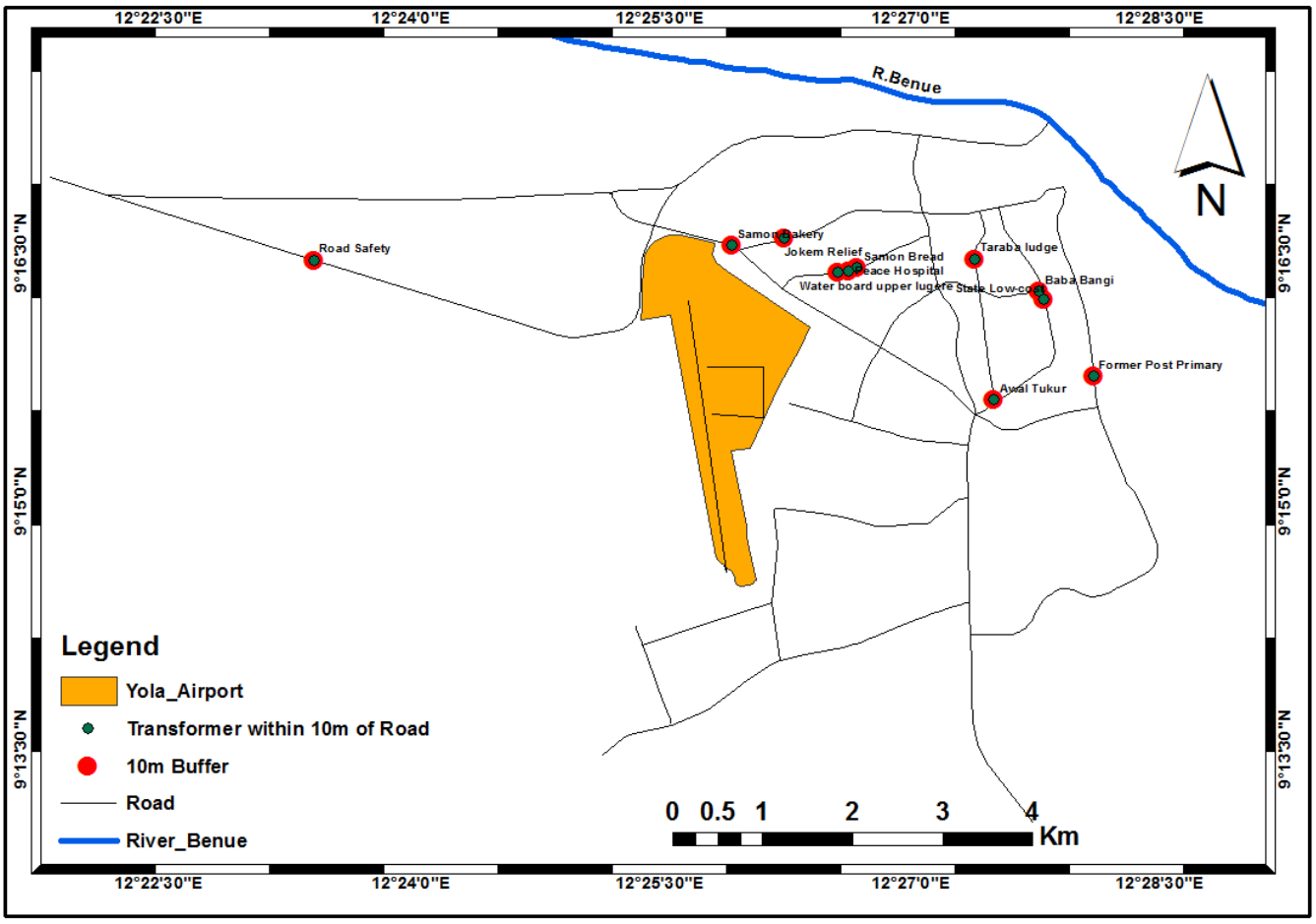


Figure 4.9: Transformers Sited within 10m Buffer from Major Roads
Source: Author's Analysis (2017)

These transformers that violate the standard were mostly located within the city center and road intersections, where there are a lot of traffic and commercial activities. This implies that such areas are at high risk of fire incidences, accidents, transformer explosions, effects of Electromagnetic Fields (EMF) among other dangers associated with transformer faults.

4.7 TRANSFORMER SERVICE LIFE

Electricity transformers have the capabilities, under normal operating conditions, to serve far beyond their required expected years of disposal, but the consequences of engaging very old transformers are enormous. These may include deterioration of insulation materials, power outage, fire incidences, increased temperature of the equipment and explosion among others.

The ANSI/IEEE (1989) standard for transformer service as recorded by the U.S. Department of Interior and Bureau of Reclamation (2005) and also reported by Shomolu (1994) is 25 yars. Figure 4.10 reveals the result of the query operation carried out on the geodatabase to map out the transformers that have spent 25 years and above in service within Jimeta.

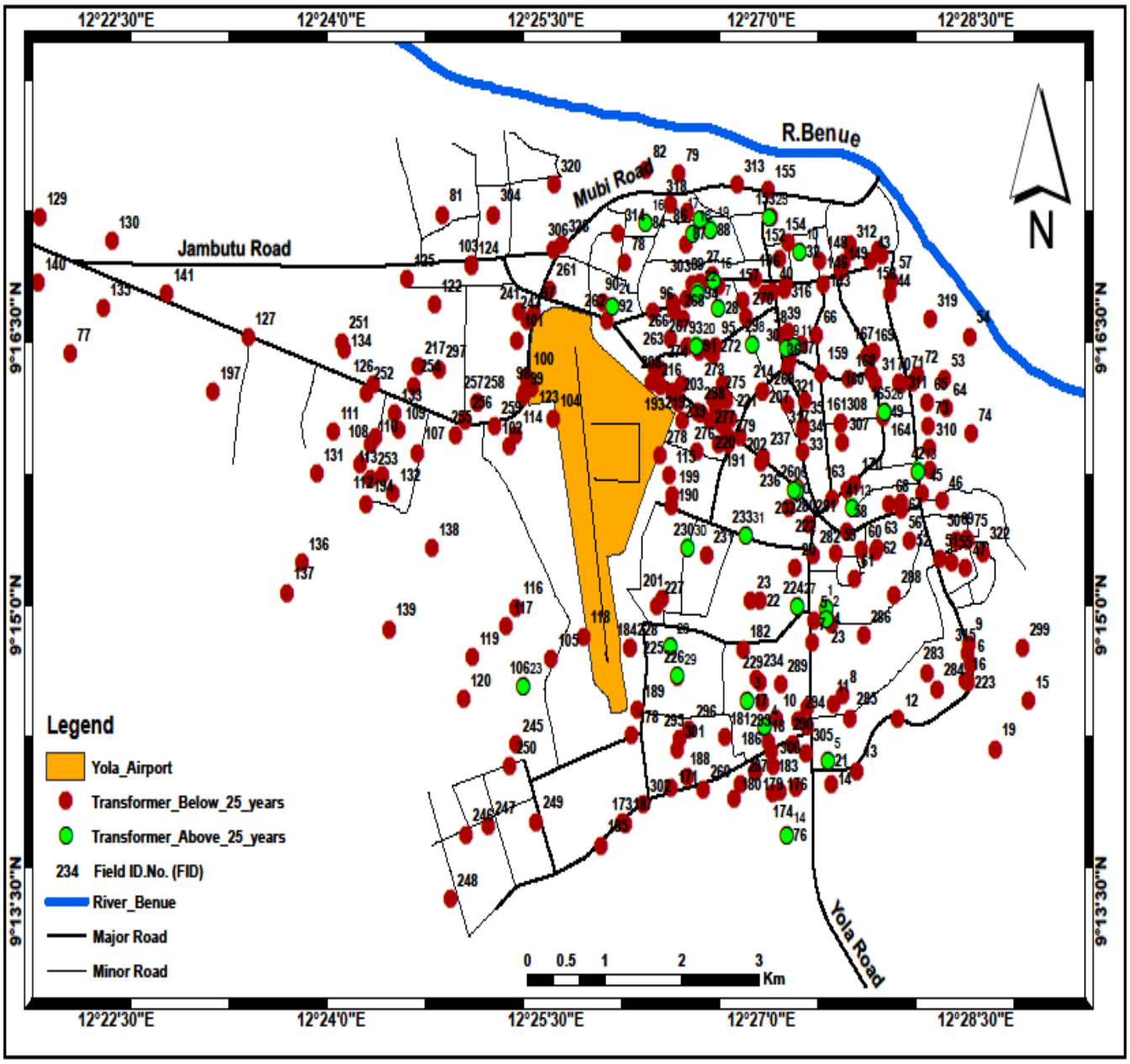


Figure4.10: Query Operation showing the Locations of old Transformers (25 and above)

Source: Author's Analysis, (2017)

Appendix III contains the coordinates, type, year of commission, years of service and the locations of the transformers that exceeded the maximum 25 years in service within Jimeta. The FID in appendix I and II can be used to trace the address of the transformer locations. These transformers were identified from the geodatabase created. The appendix shows that 30 out of the 31 old transformers which accounted for 96.77% were public ones located in the city center and other places with age-long history of development with the city itself. They are mostly of medium capacities ranging from 200kVA to 500kVA

found in areas of residential and old public buildings. This reveals the nonchalant attitude of the government and the DISCOs in terms of maintenance of the public transformers. Figure 4.11 shows the locations of the old transformers in Jimeta.

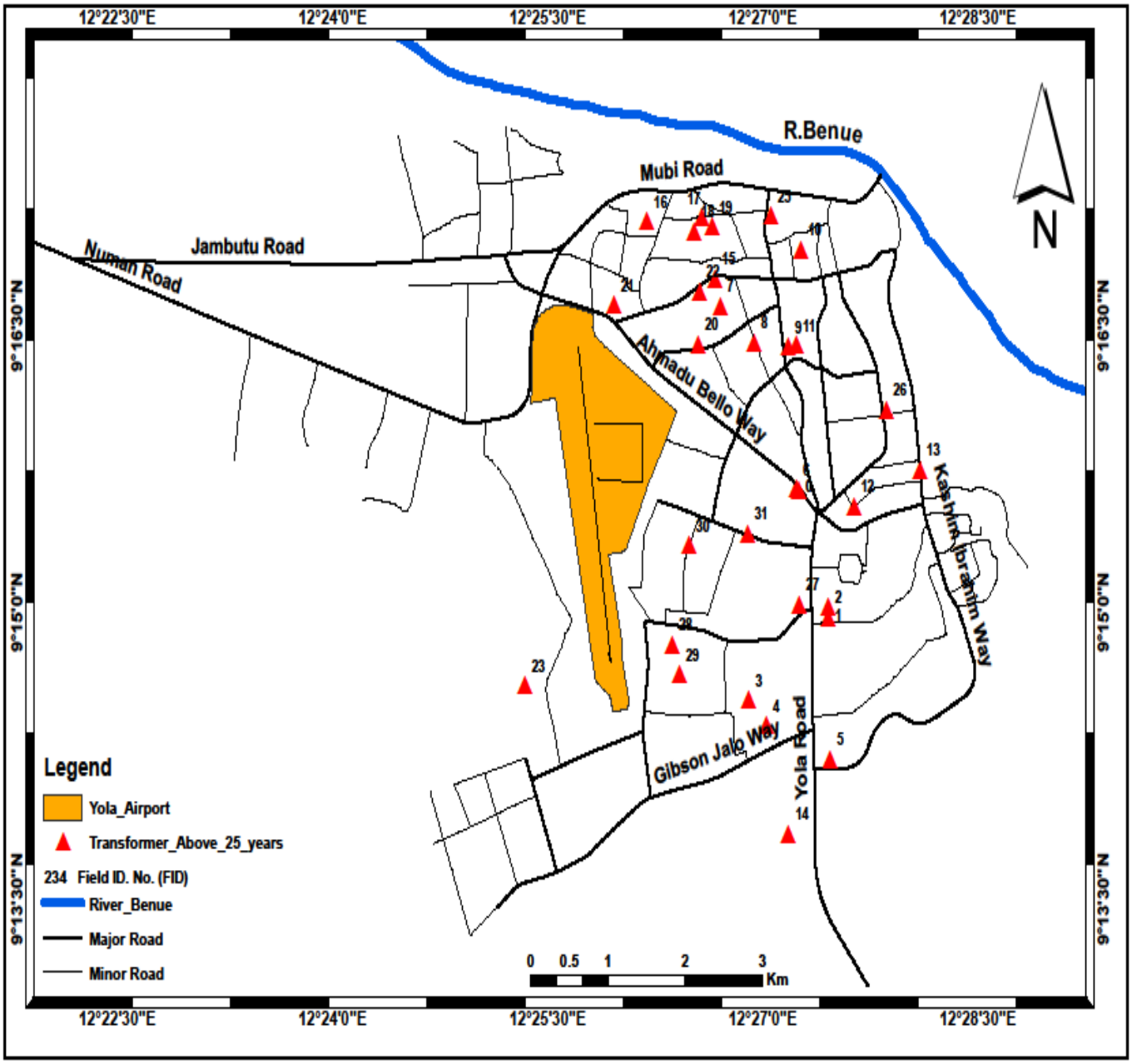


Figure4.11: Transformers that Require Replacements based on ANSI/IEEE Standards
Source: Author's Analysis (2017)

Figure 4.12 indicates that 31 out 324 transformers accounting for about 9.6% of the overall total are within the disposable/replaceable age of 25 and more years in service based on to the ANSI/IEEE standards, as outlined by Shomolu (1994). These transformers are mostly located

within the city center and in places with evidences of early development. Some of these equipments are located in areas such as Federal Secretariat Complex, Legislative Quarters, Police Roundabout, Police Barrack, Karewa Masakare, Taminus, Former Post-Primary Board, among others. This finding does not claim that the transformers in question are not functional, neither does it crave to finalize that they should not be used further. Rather, it seeks to inform, based on the ANSI/IEEE standards, that the risk involved in using them is high and will require close monitoring and maintenance, if they must be used. This is to be able to avoid the ugly unforeseen dangers associated with their old-age predicaments such deterioration of insulated materials, breakdown, fire disasters and power outage.

CHAPTER FIVR

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter deals with the summary of the research and conclusions based on the findings, as well as outlines some recommendations for proper decision making by the concerned authorities and the general public.

5.1 SUMMARY

The summary of this study is presented as follows based on the research objectives:

To identify and map out the locations of existing electricity transformers in Jimeta;

The results of this study revealed that Jimeta had a total of 324 distribution transformers in their various capacities ranging from 25kVA to 1000kVA mounted across the city. About 0.93% of such transformers were of 25kVA capacity, 2.78% had 50kVA, and 12.96% were of 100kVA. Those of 200kVA accounted for 34.87%, the highest percentage, while those of 300kVA account for 20.06% of the total number of the transformers in Jimeta. Transformers with 500kVA capacities accounted for 26.54% while, those of 750kVA and 1000kVA had 0.93% each, of the total number of the distribution transformers. There were 148 public transformers accounting for 45.67% of the overall total, mostly ranging from 300kVA to 500kVA. These transformers serve public residential areas, large commercial centers, Barracks, Public housing estates among others. A total of 176 dedicated transformers which account for the remaining 54.33% were identified and also mapped out. This category of transformers are mostly of lower capacities ranging from 25kVA to 200kVA, with few very high capacity transformers of about 750kVA and 1000kVA which are dedicated for large industries and water treatment plants.

To examine the spatial pattern of distribution of electricity transformers in Jimeta;

The NNA result produced clustered points at 0.01% significance level with the Nearest Neighbour Ratio (NNR) of 0.010787. Based on the average nearest neighbor summary results, the mean distance from one transformer to another is 247.3900m resulting to clustered distribution.

To create a geodatabase for electricity transformers in Jimeta;

The Geodatabase created contains both spatial and attribute data. The spatial data are the coordinates for the location of each transformer in Jimeta. The attribute data include other useful information about the distribution transformers such as the type, year of manufacture, year of installation, year of service, asset code, capacity, average loading, and address of each of the transformers among others.

To assess the extent to which population concentration influences the location of transformers in Jimeta;

The high density populated wards in the study area have attracted high commercial activities and as such have the highest percentage of 62.04% of the total number of transformers. The medium density populated wards have 29.94% of the overall total number of transformers distributed across, while the low density wards have only 8.02%. In this case, population demonstrated high influence on the locations of transformers. This is true, possibly because population is the main driving factor that is responsible for activities placing high demand on electric power.

To examine the level of compliance with the NERC (2016) standards for siting transformers in Jimeta; and to identify and map out the locations of transformers that have exceeded their service lives in Jimeta.

The study found out that the locations of 11 transformers accounting for 3.4% violate the public safety clearance of 10m distance enshrined in ABB transformer safety clearance, IEC and IEEE standards. In relation to the ANSI/IEEE standards on the years in service that a transformer should spend, 31 distribution transformers accounting for 9.6% of the overall total are above 25 years in service.

5.2 CONCLUSION

In conclusion, the spatial distribution of electricity transformers in Jimeta is skewed and clustered in areas where there are concentrations and mixture of urban landuse activities. The geodatabase created contains useful data which can always be manipulated, retrieved and updated with time. The distribution of transformers in relation to population density of the study area revealed the spatial trend for electricity demand in Jimeta. This is because the distribution is in proportion to the density of population. This confirmed the fact that population determines the urban landuse activities that press demand on electricity, which in turn affects the spatial distribution of electric facilities including transformers. About 31 (9.6%) distribution transformers have served beyond their useful life span of 25 years and 11 (3.4%) are located within the 10m buffer zone across the main roads of the study area.

5.3 RECOMMENDATIONS

In line with the findings of this work, the following recommendations are made in order to support effective decision making by the government, YEDC, the public and other concerned organizations:

1. Distribution transformers should be provided in the newly built up areas of Jambutu, Wuro Jabbe, Damilu, Karewa and Gwadabawa by the YEDC, so as to boost electricity supply and to encourage commercial and industrial activities in such quarters.

2. Organizations such as banks located in the same area with the same level of electricity demand can merge their use of transformers since their maintenance does not require regular attention. This will reduce the clustered nature of the distribution and also the risk of fire disaster.
3. The YEDC should build a comprehensive electricity distribution system geodatabase in order to provide holistic information about its assets. This will equally be of great help in terms of decision making.
4. The YEDC should deploy more transformers, for efficient power supply, to areas of medium and low population densities in order to encourage economic growth and a balanced spatial distribution of urban landuse activities in the city.
5. Transformers located within 10m buffer zone across the major roads in the study area should be relocated away by the YEDC. This will to promote safety of the road users and the general public. Future installations should also comply with the standards.
6. The Government and YEDC should invite experts to technically examine the transformers that have served above 25 years so they can be replaced, if need be, with new ones in order to avoid the dangers associated with their breakdown and explosion.
7. Future researches should concentrate on the pattern of electric power demand and supply. Other transformer installation standards such the fencing standards, the safety clearance of transformers from buildings and that of the High-Tension cables from residential areas, should be assessed in the future research.

5.4 KEY FINDINGS

The Study has:

1. identified and mapped out the locations of 324 electricity transformers of varying capacities in the study area, of which 45.67% are for public while 54.33% dedicated for private individuals and organizations.
2. established that the spatial pattern of distribution of electricity transformers in the study area is clustered at 0.01% significance level with the Nearest Neighbour Ratio (NNR) of 0.010787.
3. determined that the locations of 11 transformers accounting for 3.4% violate the public safety clearance of 10m distance from major roads as enshrined in ABB transformer safety clearance, IEC and IEEE standards.

5.5 LIMITATIONS

This study had the following limitations:

1. The study did not look at the distribution of electric current into the existing transformers and the level of usage by the consumers.
2. It could not look at the changes of the transformers distributions over time in the study area, but stick to only 2017 which is the year of study.
3. In relating population to the distribution of transformers, the study could not determine the number of persons or households per each transformer in the study area.

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Appendix I

Public Transformers in Jimeta

S/N	Northing	Easting	Capacity (kVA)	FID	Location
1	9.260718	12.45419	300	0	Police R/About
2	9.250544	12.45761	200	1	Fed Secretariat Quarters
3	9.249631	12.45762	500	2	Fed Secretariat Complex
4	9.245613	12.47439	200	6	Old GM
5	9.240942	12.45178	300	10	Malamre
6	9.236382	12.46115	200	13	80UnitNo.2
7	9.235125	12.45819	200	14	80UnitNo.1
8	9.242446	12.48117	200	15	80UnitNo.3
9	9.230807	12.45671	100	17	Legislative Quarters No.1
10	9.240195	12.4504	500	18	Legislative Quarters No.2
11	9.25408	12.45395	300	20	A.A Lawan
12	9.237233	12.4578	200	21	DARE
13	9.251174	12.44878	500	23	GMMC
14	9.260842	12.45387	300	27	Police Barrack
15	9.279594	12.44436	300	31	A.C Secretariat
16	9.276724	12.44504	500	36	Hospital Junction

17	9.273529	12.44899	500	37	Terminus No.1
18	9.273209	12.45297	300	41	Terminus No.2
19	9.270213	12.46333	500	42	State Low-cost
20	9.271522	12.4531	300	43	Target Junction
21	9.273302	12.45388	200	44	Ganye No.1
22	9.259306	12.46061	300	45	Jalingo Junction
23	9.262472	12.46827	300	46	Former Post Primary
24	9.280822	12.46272	200	48	Bakin Kogi
25	9.278053	12.46501	500	51	Old Min. Of Works
26	9.260531	12.46879	200	52	Gambo Jimeta
27	9.259953	12.47108	200	54	Rock Heaven
28	9.256515	12.47273	500	56	Madam Aisha
29	9.254778	12.47083	300	73	Boni Haruna
30	9.256515	12.46728	300	76	Yahaya Adamu
31	9.27428	12.47431	200	77	Taraba Lodge
32	9.259081	12.46635	200	78	Old GM
33	9.266436	12.46946	200	79	Ali Baba
34	9.172724	12.25303	200	80	Veterinary Clinic
35	9.172724	12.25829	500	81	50 Housing
36	9.172724	12.24517	500	82	Shagamu relief
37	9.172724	12.25165	500	83	Shagamu
38	9.172724	12.25472	500	84	Old B.M
39	9.172724	12.25392	500	85	Gamdo
40	9.172724	12.25544	200	86	Kasuwan Bola
41	9.165487	12.26331	500	87	Okene
42	9.165487	12.26131	200	88	Demsawo No.1
43	9.165487	12.26265	500	89	Demsawo No.2
44	9.165487	12.26253	500	90	Demsawo No.3

45	9.165487	12.26863	500	91	Demsawo No.4
46	9.165487	12.26243	300	92	Hotel D-Pride
47	9.165487	12.26315	500	93	Total Station
48	9.165487	12.25491	500	94	Capital School
49	9.165487	12.25349	300	96	Bartola no.1
50	9.165487	12.25476	200	97	Bartola no.2
51	9.165487	12.25244	200	98	P.Z No. 2
52	9.165487	12.26863	500	100	Bagale
53	9.27643	12.43742	300	101	Jokem Relief
54	9.276342	12.42361	200	102	P.Z No. 1
55	9.269488	12.42251	200	103	Hancoh
56	9.270708	12.42273	500	104	Damilu
57	9.27393	12.42159	200	105	Highland Tea
58	9.264658	12.42072	500	106	Urbanus Bachure
59	9.28053	12.41632	300	107	Kofare Agric
60	9.26708	12.42581	500	108	Bachure No.2
61	9.246086	12.4256	500	109	Bachure No.1
62	9.2437	12.42235	500	110	Bachure No. 3
63	9.264098	12.41006	500	111	Kofare Zone 3
64	9.265438	12.40518	500	112	Boni Quarter No.1
65	9.26607	12.40784	500	113	Boni Quarter No.2
66	9.264844	12.40461	500	114	Nyako No.1
67	9.265892	12.40029	500	115	Nyako No.2
68	9.263057	12.40339	500	116	Nyako No.3
69	9.262188	12.40598	500	117	Nyako No.4
70	9.265668	12.42146	50	118	Mounted Xformer No.1
71	9.26211	12.43931	50	119	Mounted Xformer No.2
72	9.250645	12.42153	50	120	Mounted Xformer No.3

73	9.249002	12.42035	50	121	Mounted Xformer No.4
74	9.248087	12.42938	50	122	Mounted Xformer No.5
75	9.246255	12.41646	25	123	Mounted Xformer No.6
76	9.24262	12.41541	25	124	Mounted Xformer No.7
77	9.269838	12.42332	25	125	Mounted Xformer No.8
78	9.27707	12.41203	100	126	Shonghai
79	9.269838	12.42332	500	127	Isaac Abegyi
80	9.28042	12.41634	300	128	Palkari
81	9.279253	12.40886	500	129	Brother Musa
82	9.27006	12.40492	300	131	Palkari Relif
83	9.274225	12.39038	300	132	Road Safety
84	9.28978	12.34145	300	133	Timber Shed
85	9.288267	12.36379	200	134	Sangere Bode
86	9.262245	12.39832	500	135	Babangida Sabo
87	9.260523	12.40722	300	136	Wuro Jabbe No.1
88	9.26745	12.40738	500	137	wuro Jabbe No.2
89	9.273048	12.40153	500	138	Mohammed Hussaini
90	9.276742	12.37353	500	139	Jaret
91	9.254567	12.39659	500	143	Samunaka No. 1
92	9.25188	12.39486	50	144	Mounted Wuro Jabbe No.1
93	9.255774	12.41175	50	145	Mounetd wuro Jabbe No. 2
94	9.288506	12.3444	50	146	Mounted Wuro Jabbe No.3
95	9.278764	12.45726	500	147	Ganye No.2
96	9.280908	12.45682	300	148	Majalisa
97	9.281603	12.46048	500	150	Wuro Bello
98	9.282294	12.46037	300	151	Shinco Down
99	9.281572	12.4637	500	152	Zango Area
100	9.280761	12.45966	300	153	Old Union Bank

101	9.278768	12.45294	500	155	Old Market
102	9.281092	12.45221	500	156	YEDC Office
103	9.284613	12.45094	200	157	Palace
104	9.284672	12.45124	500	158	Babanle Mai Nama
105	9.287075	12.45086	300	159	Peacock
106	9.277337	12.44788	200	160	Geriyo Junction
107	9.277983	12.45048	500	161	Blind Workshop
108	9.281269	12.46406	300	162	Safar
109	9.271072	12.45698	100	163	LCCN Bookshop
110	9.271047	12.46284	500	164	Baba Bangi
111	9.266742	12.4593	200	165	Sport Council
112	9.260114	12.45831	200	166	Awal Tukur
113	9.260833	12.46005	200	167	Hassan Adamu
114	9.2673	12.46428	300	172	Yola Motel
115	9.267708	12.46436	200	174	House of Assembly (UBE)
116	9.272789	12.46312	300	175	Rebadu’s Square
117	9.272933	12.46313	500	176	P & T
118	9.234861	12.45411	500	177	Recruitment No.1
119	9.234337	12.45139	200	182	Nyibango No.1
120	9.236328	12.44933	500	183	Nyibango No.2
121	9.234615	12.45222	300	186	Engr. Dogo
122	9.238652	12.45373	500	187	Madam Ruth
123	9.246899	12.44794	500	188	Masakari
124	9.238102	12.45121	500	189	Udofia
125	9.238782	12.45089	300	191	Malkhohi
126	9.231756	12.43425	300	200	JUDA
127	9.235847	12.44142	200	201	Rundi Killa
128	9.241655	12.43561	500	202	Hotel La-Birem

129	9.264927	12.44507	300	203	Karewa No.6
130	9.270052	12.44559	300	219	Mali
131	9.251393	12.43854	300	223	Bekaji Clinic
132	9.265422	12.44755	200	224	Mahmud Clinic
133	9.268512	12.44037	200	225	Bekaji Bore-hole
134	9.266848	12.44086	200	226	NRC
135	9.244152	12.47411	200	227	Karewa No.1
136	9.250695	12.45422	500	228	Karewa No.2
137	9.247223	12.43948	300	229	Karewa No. 3
138	9.244573	12.4403	300	230	Karewa No.4
139	9.25075	12.4379	200	231	Moses Mbale
140	9.247028	12.43481	200	232	Approfirm No. 1
141	9.244151	12.44991	200	236	Approfirm No.2
142	9.255825	12.44145	300	237	Karewa No.5
143	9.255202	12.44371	200	238	Karewa No.7
144	9.260842	12.45387	200	239	Zumo
145	9.263315	12.44998	500	315	Adamawa State Polytechnic
146	9.263742	12.45028	200	316	Grave Yard
147	9.268828	12.44438	100	317	

Source: Field Survey, (2017)

Appendix II

Dedicated Transformers in Jimeta

S/N	Northing	Easting	Capacity (kVA)	FID	Location
1	9.249114	12.4582	200	3	National Population Commission
2	9.249889	12.45765	200	4	Sa'id Ahmed
3	9.249456	12.45621	200	5	National Library
4	9.247568	12.45595	200	7	AUS Corn Oil
5	9.242975	12.45953	500	8	FCE Admin
6	9.247456	12.47419	300	9	Taraba Liaising Office
7	9.242192	12.45843	200	11	NDLEA
8	9.240898	12.46593	200	12	City Green Hotel
9	9.244269	12.47378	500	16	Bridgade Commander House
10	9.238268	12.47727	200	19	Matco Clinic
11	9.25123	12.44989	200	22	In-Land City Hotel
12	9.2462	9.235962	100	24	Badeh House
13	9.239426	9.239426	50	25	Minister's House
14	9.281637	12.45447	300	26	V.I.O Office
15	9.264233	12.45488	100	32	FCMB
16	9.265902	12.45486	100	33	GLO Office
17	9.266372	12.45494	200	34	Sabru House
18	9.274313	12.45248	300	35	Shopping Complex out
19	9.274708	12.45319	500	38	Shopping Complex in

20	9.278154	12.45138	200	39	First Bank PLC
21	9.254067	12.47381	500	40	GGSS Yola
22	9.267283	12.46422	200	47	SSS Office
23	9.256517	12.47278	300	49	FCE Quarters
24	9.27057	12.47135	200	50	Sanusi Barkindo's Residence
25	9.254619	12.47218	200	53	A.A Lawan House
26	9.279067	12.46525	100	55	Computer Center, Malamre
27	9.257317	12.45999	100	57	MTN Century
28	9.255306	12.45874	300	58	Police Headquarters
29	9.255636	12.46169	500	59	State High Court
30	9.253122	12.46086	500	60	State Secretariat
31	9.255436	12.46339	200	61	Government printing Press
32	9.255858	12.46354	200	62	Federal High Court
33	9.253083	12.45695	300	63	Gov't house No.1
34	9.256422	12.4528	300	64	Gov't house No.2
35	9.274317	12.45646	100	65	Taraba Lodge
36	9.259792	12.46637	300	66	Kwairanga Jada
37	9.259547	12.46489	100	67	Atardashi
38	9.256644	12.47396	200	68	Prof. Jibrin Aminu's Residence
39	9.270233	12.46609	200	69	Deputy Governor's House
40	9.270272	12.46764	200	70	Bridget Commandant's Guest House
41	9.270833	12.46826	200	71	Bamanga Tukur's Residence
42	9.265844	12.4745	500	72	Murtala Nyako's House
43	9.256519	12.47403	300	74	Prof. Iya Abubakar
44	9.165487	12.25569	300	75	Samon Bread
45	9.268939	12.42233	100	95	A.P Filing Station
46	9.256724	12.41734	500	99	FGGC, Yola
47	9.291453	12.69068	500	130	Oil Mill

48	9.278022	12.38089	100	140	D&L Hotel
49	9.273592	12.45471	100	141	N.N.P.C Oppo. Bamanga
50	9.279964	12.45926	100	142	MTN Office, Zango
51	9.282412	12.45318	100	149	MTN Office, Babanle
52	9.27055	12.46018	100	154	Zain Office
53	9.272683	12.46238	100	168	MTN Office, Sport Council
54	9.261425	12.46092	500	169	NTA Office
55	9.234915	12.43955	500	170	Judges Quarters
56	9.231876	12.43389	200	171	Musa Kaibo
57	9.239442	12.43493	200	173	Duraghi Hotel
58	9.236248	12.4494	200	178	A.U.N Quarters
59	9.233955	12.44688	300	179	Homtel Suite
60	9.239264	12.44581	200	180	Brigade Commander G/House
61	9.247054	12.43482	100	181	MTN Office
62	9.229861	12.43138	100	184	Yakubu Joel
63	9.259383	12.43959	100	185	MTN Office, Estate
64	9.285084	12.44141	200	190	Lamido Cinema
65	9.269974	12.43835	500	192	INEC Office
66	9.259612	12.40409	200	193	FIRS
67	9.269294	12.43975	200	194	Concordia Collage
68	9.27919	12.44939	200	195	Diamond Bank
69	9.269501	12.38629	300	196	Intercontinental Bank
70	9.262855	12.43768	200	197	First Bank No.1
71	9.260428	12.43971	500	198	Zineth Bank
72	9.27327	12.44347	200	199	Water Board
73	9.269533	12.43968	200	204	GT Bank
74	9.269128	12.43995	200	205	Ecobank
75	9.269505	12.45018	200	206	Zain Office

76	9.26784	12.43448	500	207	Inland Revenue
77	9.267563	12.4431	100	208	Access Bank
78	9.266988	12.44412	200	209	Union Bank
79	9.267594	12.44292	300	210	UBA Bank
80	9.26784	12.44479	200	211	Key Stone
81	9.26859	12.44601	200	212	Sky Bank
82	9.269509	12.45018	200	213	UBA Main
83	9.268431	12.44034	200	214	Resort Saving & Loan
84	9.271577	12.43762	200	215	Alkama Bread
85	9.271659	12.41014	200	216	Unity Bank
86	9.267128	12.44572	200	217	First Bank No.2
87	9.266589	12.44539	100	218	Ecobank Opp. Market
88	9.267111	12.44643	200	220	AUN Saver Cafe
89	9.25923	12.45322	200	221	Fed. Politecnic Office
90	9.256898	12.44825	300	222	Police Barrack
91	9.244383	12.44948	200	233	Police Quarters
92	9.245641	12.45772	200	234	Favour Estate
93	9.25643	12.41564	100	235	
94	9.268828	12.44438	200	240	
95	9.241243	12.43126	500	241	C.B.N
96	9.276414	12.42191	500	242	FAAN
97	9.25487	12.43523	500	243	Air Force Quarters
98	9.275623	12.42285	200	244	Air Port Quarters
99	9.26345	12.22354	300	245	NAF Office
100	9.238622	12.4215	500	246	Batallion
101	9.230815	12.41569	500	247	Officers Mess
102	9.231548	12.41829	200	248	Sergeants' Quarters
103	9.225235	12.41391	500	249	Workshop

104	9.231922	12.42385	500	250	Garrison Quarters
105	9.236698	12.42075	200	251	Workshop Office
106	9.273789	12.40128	100	252	Stadium Complex
107	9.269331	12.40414	200	253	NNPC benjing
108	9.26191	12.4046	300	254	Wayam Hotel
109	9.269991	12.40959	300	255	Stainless Furniture
110	9.265688	12.41447	750	256	Adamawa Plast
111	9.26686	12.41556	300	257	Alh. Ten Ten
112	9.268571	12.41705	1000	258	Faro Beverages
113	9.26857	12.417	500	259	Faro Beverages
114	9.266349	12.41899	100	260	Jasco Oil
115	9.234744	12.4433	100	261	Abti Faro Qtrs
116	9.278387	12.42544	100	262	Round About Mai Doki
117	9.275696	12.43212	200	263	Samon Bakery
118	9.274016	12.4395	200	264	Adamawa Home & Savings
119	9.277263	12.44031	100	265	Bagale Hotel
120	9.276496	12.43999	300	266	Chambian Hotel
121	9.277263	12.43977	100	267	Basmic Co ltd
122	9.276935	12.43985	300	268	Yasakoma
123	9.275738	12.44098	100	269	MTN Office
124	9.164228	12.26434	300	270	Alh. Mohammed Aji
125	9.275903	12.44825	500	271	Specialist Hospital
126	9.273105	12.44384	100	272	Peace Hospital
127	9.272558	12.44448	200	273	Aliyu Mustapha
128	9.27294	12.44281	100	274	Water Board upper Luggere
129	9.271388	12.43832	300	275	Adamawa Investment
130	9.268662	12.44503	200	276	Jaret Suit
131	9.26418	12.44256	200	277	Kugama

132	9.265575	12.44609	200	278	Fedility Bank
133	9.263838	12.43825	200	279	Bekaji Bore-hole
134	9.2648	12.4462	200	280	Acct General
135	9.261016	12.45428	200	281	Maridian Hotel
136	9.257854	12.45561	500	282	Y4 33/0.415Kv
137	9.255099	12.45608	200	283	Oasis Bakery
138	9.142495	12.28471	100	284	Usman Tahir
139	9.144545	12.28125	100	285	Hon. Marafa
140	9.154301	12.27393	100	286	Abdurahaman Tuga
141	9.248187	12.46197	500	287	Alh. Atiku Abubakar
142	9.142495	12.28471	500	288	Abti AUN Invt. Qtrs
143	9.251626	12.4655	200	289	Alh. Haladu
144	9.243908	12.45232	100	290	Malamre Bore-Hole
145	9.241927	12.45538	200	291	Tasty Menu
146	9.240774	12.45439	200	292	Skybank (Mainstreet Bank)
147	9.240303	12.45537	100	293	Fed. Mortgage Bank
148	9.242292	12.45019	200	294	Adip Motel
149	9.240737	12.45432	200	295	Dantsoho Hotel
150	9.239112	12.44054	200	296	Yukuben Hotel
151	9.239935	12.44166	200	297	Alheri Hotel
152	9.135951	12.27787	100	298	ABTI Faro
153	9.267734	12.44258	200	299	NNPC Mega Station
154	9.139136	12.29147	100	300	Alh. Jibro’s Residence
155	9.23672	12.45144	500	301	House of Assembly
156	9.238212	12.44029	300	302	YEDC’s M.D House
157	9.233491	12.43633	500	303	YEDC Area Head Office
158	9.305747	12.47689	200	304	Startimes
159	9.283434	12.42733	100	305	Ebis

160	9.320089	12.48401	200	306	NNPC Opp. Nafan
161	9.281878	12.42586	100	307	Nafan
162	9.265029	12.45948	500	308	Atiku Abubakar's House No.1
163	9.266683	12.45924	300	309	Atiku Abubakar's House No.2
164	9.2626	12.46965	200	310	Bala Ngilari's House
165	9.264505	12.46961	300	311	Murtala Nyako's House No.1
166	9.270138	12.46631	500	312	Deputy Governor's Office
167	9.281857	12.4636	200	313	Shamad Oil
168	9.287454	12.44726	100	314	Water Board Doubeli
169	9.283271	12.43337	100	317	Water Board Demsawo
170	9.304741	12.47185	200	318	AIT Office
171	9.285776	12.43947	200	319	Alh. Adamu Mohammed Doubele
172	9.276154	12.46953	750	320	Water Board 1
173	9.276202	12.46951	750	321	Water Board 2
174	9.136474	12.29321	1000	322	Water Board 3
175	9.257421	12.47911	1000	323	Water Board 4
176	9.282233	12.42684	200	324	A.A. Madagali

Source: Field Survey, (2017)

Appendix III

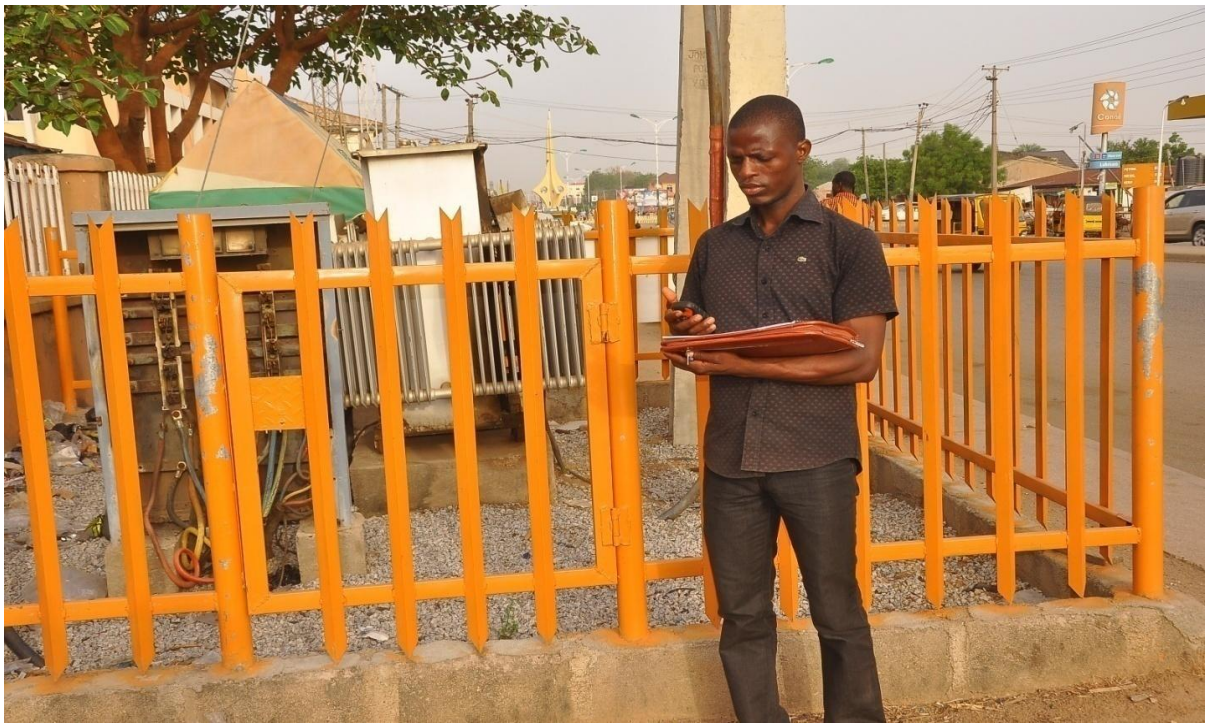
Transformers that Exceeded their Service Lives

	Northing	Easting	Capacity (kVA)	Type	Year of Commission	Years of Service	Location
1	9.260718	12.45419	300	Public	1987	30	Police R/Abound
2	9.250544	12.45761	200	Public	1978	39	Fed Secretariat Qtrs
3	9.249631	12.45762	500	Public	1988	29	Fed Secretariat Complex
4	9.230807	12.45671	100	Public	1988	29	Legislative Quarters No.1
5	9.240195	12.4504	500	Public	1978	39	Legislative Quarters No.2
6	9.237233	12.4578	200	Public	1988	29	Dare
7	9.276724	12.44504	500	Public	1979	38	Hospital Junction
8	9.273529	12.44899	500	Public	1991	26	Terminus No.1
9	9.273209	12.45297	300	Public	1989	28	Terminus No.2
10	9.281637	12.45447	300	Dedicated	1987	30	V.I.O
11	9.273302	12.45388	200	Public	1987	30	Ganye No.1
12	9.259306	12.46061	300	Public	1988	29	Jalingo Junction
13	9.262472	12.46827	300	Public	1991	26	Former Post Primary
14	9.172724	12.25303	200	Public	1987	30	Vetenary
15	9.165487	12.26331	500	Public	1987	30	Okene

16	9.165487	12.26131	200	Public	1982	35	Demsawo No.1
17	9.165487	12.26265	500	Public	1989	28	Demsawo No.2
18	9.165487	12.26253	500	Public	1991	26	Demsawo No.3
19	9.165487	12.26243	300	Public	1986	31	Hotel D-Pride
20	9.165487	12.25349	300	Public	1992	25	Bartola no.1
21	9.165487	12.25476	200	Public	1989	28	Bartola no.2
22	9.165487	12.26863	500	Public	1986	31	Bagale
23	9.2437	12.42235	500	Public	1986	31	Bachure No. 3
24	9.28978	12.34145	300	Public	1989	28	Timber Shed
25	9.284613	12.45094	200	Public	1989	28	Palace
26	9.267708	12.46436	200	Public	1989	28	House of Assembly
27	9.250695	12.45422	500	Public	1986	31	Karewa No.2
28	9.247223	12.43948	300	Public	1986	31	Karewa No. 3
29	9.244573	12.4403	300	Public	1980	37	Karewa No.4
30	9.255825	12.44145	300	Public	1980	37	Karewa No.5
31	9.256898	12.44825	300	Public	1976	41	Police Barrack

Source: Field Survey, (2017)

Appendix IV



A: Transformer Coordinates Acquisition at the YEDC Office, Jimeta Business Unit



B: Coordinates Acquisition at the Target Junction, Jimeta