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Spatial Distribution of Electric Transformers in Narayi Ward, Chikun Local Government Area of Kaduna State, Nigeria

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ABSTRACT

This paper looks at the spatial distribution of electric transformers in Narayi Ward, Chikun Local Government Area of Kaduna State. Handheld GPS was used to obtain coordinates of electric transformers in Narayi Ward. Data on characteristics of transformers was obtained from Narayi Business Unit of Kaduna Electricity Distribution Company (KAEDCO). The coordinates were used to map the locations of the transformers. Average Nearest Neighborhood Analysis was used to show the pattern of distribution; Buffer Analysis was used to check the compliance with Nigerian Electricity Regulatory Commission (NERC) 10m standard; while query was used to show the transformer service life. Analysis revealed Average Nearest Neighborhood Analysis result showed random distribution at 0.01% significance level with 0.215604336939 ratio. Only 5 (19%) of the transformers complied with the safety standard of siting transformers at least 10m away from the main road. 2 (7%) of the transformers violated the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) standards of 25 years in service. The study therefore recommends that transformers should be provided in the newly built up areas of Karji and Water Intake by KAEDCO. It also recommends that transformers located within 10m buffer zone across the major roads in the study area should be relocated away by the KAEDCO. This will promote safety of the road users and the general public. Future installations should also comply with the standards.

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1 Introduction

Nigeria has been experiencing inadequate power supply for decades. The privatization of the distribution companies over the years has not improved the supply of electricity nationwide. Previous administrations have made an adequate supply of electricity their priority to boost industrial activities and the economy of the country. Apart from population growth and advancement in technology, electricity consumption has increased, and this has led to the expansion of the distribution network (Abana, 2018). Consequently, bringing private investors to take over the distribution of electricity, as practiced all over the world, is a good idea.

The power sector is crucial to national development. Any country carrying out developmental reforms must give priority to the power sector (Chatta, 2015). Generally, the crucial role played by the power sector in the economic development of a nation cannot be overemphasized (Awosope, 2014). As such, industrial growth, agriculture, infrastructure, and virtually all sectors of the economy are dependent on a reliable power supply. Nigeria ranks among the lowest in total net electricity generation globally (Abana, 2018). Power generation has been a problem for the country, with successive administrations budgeting huge amounts of money to overcome the challenges.

Power transmission process involves certain stages, which include conveying generated electrical power from the plants to distribution stations, and subsequently to consumers (Yildirim & Nisanci, 2010).

Although adequate electricity supply is critical for nation-building, power failures and load shedding are the characteristics of electricity supply in Nigeria (Kareem, 2006). Basic human activities now require the use of electricity. Depriving people of electricity these days is tantamount to castration (Musa, 2009). According to Sule (2015), poor electricity supply is caused by multiple challenges affecting the generation and distribution of electricity. Some of the problems associated with electricity distribution in Nigeria include poor maintenance, mismanagement, inadequate funding, and corruption (Stanley, 2012). This is evident in virtually all the sectors of the economy.

Electricity supply in Nigeria is seasonally dependent and generally unreliable. It is believed that there is a better supply during the wet season (Ponnle et al., 2011). In the northwestern part of the country, there is a significant improvement in access to electricity from 36.6% to 42.2% as of 2013 (Guzomakem, 2015). However, despite the improvement, almost every Nigerian now has a generator to cater to their electricity demands (Okoendo, 2011). This

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has led to the country spending about N17.9 billion annually to import generators to cover the shortfall in electricity supply.

The apparatus used to convert alternating current from one voltage to another is the transformer. Although they may be "step-up" or "step-down", they are designed to work on the magnetic induction principle. Transformers are not evenly distributed in Nigeria (Abana, 2018), and as a result of that, the rate of utilization of each one may be high. Furthermore, the transformers used in distribution are of different capacities, sizes, and functions. However, no matter the capacity or size, they play a very critical role in the distribution phase (Chatta, 2015). Jasni et al. (2017) asserted that the adequate supply of electricity depends on the condition of the transformers, as they are the backbone of the power supply. However, capital assets used in electricity distribution continue to deteriorate as a result of neglect, theft, and vandalism, especially in rural areas (Olivia Phillip International Consulting, 2013).

Today in Nigeria, the sub-stations and injection stations are over 40 years old, and the electric transformers used in the distribution are very old, putting the transformers in serious ageing problem (Okoro & Chikuni, 2007). Overload and poor maintenance are other factors responsible for the breakdown of electric transformers (Sulaiman & Ali, 2011; Ijewere, 2006). Change in land use pattern (eg, Residential to commercial) can cause overloading of the existing transformers, causing their malfunction (Caven, 1998).

Due to the population growth and the spatial expansion in Narayi ward, the demand for an adequate supply of electricity is just as it is the case in the entire country (Salihu et al., 2014). However, despite the importance of the issue mentioned above, no study has focused on analyzing the spatial distribution of transformers, their compliance with NERC standards in Narayi ward, Chikun Local Government Area. This study, therefore, was aimed at analyzing the spatial pattern of distribution of electric transformers, creating a geodatabase, and checking their compliance with NERC, ANSI/IEEE standards.

2 Materials and methods

2.1 Study area

Narayi Wards lies between latitude 10°27′49′′ and 10 °29′9′′ North of the equator and longitude 7°26′27′′ and 7 °27′53′′ east of Greenwich Meridian. The ward shares a boundary with Patrick Yakowa Road to the east and Barnawa to the west. It is bordered by the River Kaduna to the north and Television (Unguwan Yelwa) to the south. There are two (2) seasons in Narayi ward, the first is the rainy season, and the wettest month is August. The average rainfall here is 1,300mm. The second is the dry season, which starts from September to February annually.

Narayi ward experiences high temperatures all year round, which is a characteristic of the tropics. The mean daily temperature in the area can be as high as 34 °C between the months of March and May. The temperature could be as low as 20 °C during December to January. This low temperature is intensified by humidity due to the dry Harmattan wind.

The vegetation type is the guinea savannah zone based on vegetation classification. The vegetation here suffers from anthropogenic disturbance through the cutting down of trees for fuel wood, cultivation, and construction works. Narayi ward lies within the plains of Hausaland, which slopes gently towards the desert, and the streams drain north–east toward Lake Chad. The plains reach an altitude of about 71m in the southern part and gradually decline in altitude northward (Mortimore, 1970).

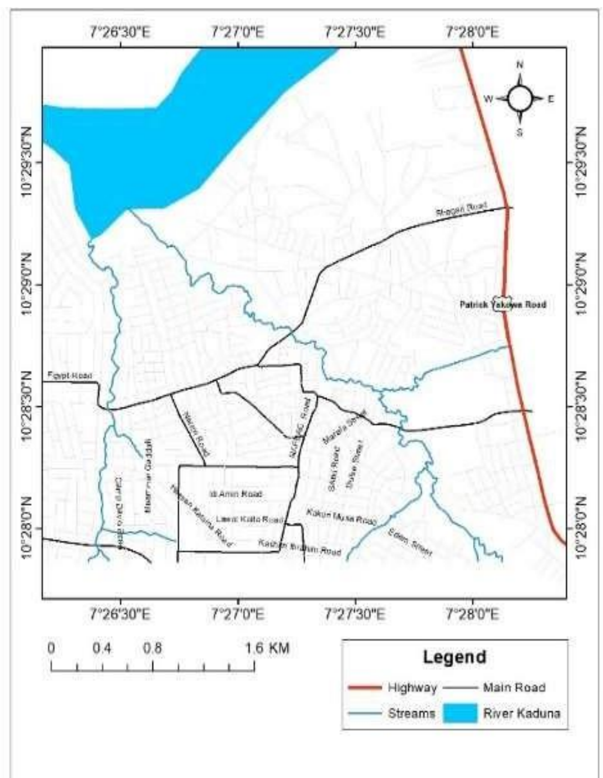


Figure 1: Narayi Ward, Chikun Local Government Area

2.2 Reconnaissance Survey

A preliminary survey was conducted by the researcher in order to be more familiar with the study area. During this phase of the research, a visit was paid to the KAEDCO officer in Chikun LGA, 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.

2.3 Data Sources

Absolute location (Geographic Coordinates) of the existing electric transformers in Narayi Ward was obtained using a handheld GPS device (Garmin 78S) with the aid of 117 KAEDCO technical staff at the Narayi Business Unit. Data on the conditions and characteristics of the existing transformers were obtained from the KAEDCO Business Unit. Information such as the functionality of the transformers, average loading, and year of installation was collected. 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.

2.4 GIS Analysis

The data obtained were analyzed as follows, based on the set research objectives:

- The collected coordinates (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 transformer map using ArcGIS 10.3 software.
- 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 the 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).
- A geodatabase was created for both the spatial and attribute data of the electricity distribution transformers in Narayi ward, 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 a 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.
- 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) Distribution 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.
- The years of service were obtained by simple arithmetic applied to the record obtained from the KAEDCO Narayi 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 a maximum of 25 years of transformers in service, and Transformers that have spent 25 years and beyond in service were identified by querying the 'DATE_COMM' field of the geodatabase and shown on the map.

3 Results

There is a total of 27 public transformers accounting for 93% of the overall transformers in Narayi ward. Transformers in this category have different capacities, mostly ranging from 300kVA to 500kVA. They are purchased, installed, and maintained by the distribution company (KAEDCO) for the general public in the areas located. They are spatially distributed across all parts of the study area in varying patterns due to the mixture of the urban land uses. This is because the areas are mostly made up of residential buildings occupied by middle- and lower-income earners, who do not use personal transformers dedicated to their own use but rather rely on public ones.

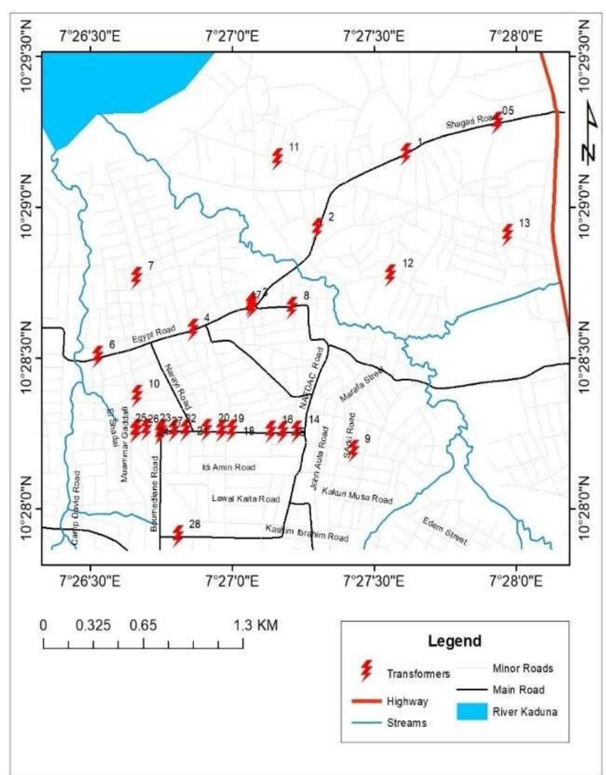


Figure 2: Location of Public Transformers in Narayi ward

There are a total of 2 dedicated transformers accounting for 7% of the overall total of distribution transformers in Narayi ward. The two transformers are located in the NAFDAC Premises.

Table 1 shows the distribution of transformers in Narayi ward according to their capacity.

Capacity (kVA)	No	Percentage %
50	13	45
300	5	17
500	10	35
33k	1	3
Total	29	100

Transformers with 50kVA are mostly pole-mounted across newly built-up areas of High Cost and a few others sited at 9mobile, Airtel, Glo, and MTN masts. There are those with 300kVA, which are sited at NAFDAC buildings as well as residential areas. Transformers with 500kVA were mostly located in public residential areas. The 15V transformers are located within the KAEDCO substation in Narayi, and they make up the Injection Station for the Business Unit.

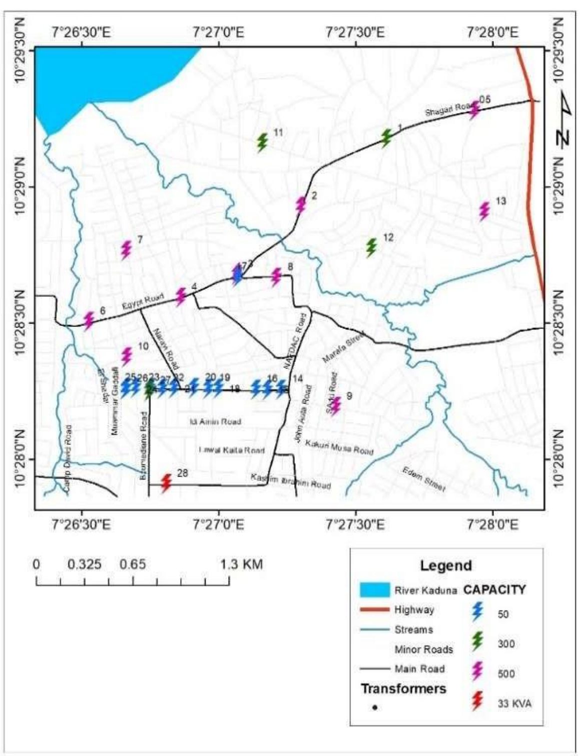


Figure 3: Spatial Distribution of Transformers in Narayi Ward by Capacity

3.1 Spatial Pattern of Location of Transformers in Narayi Ward

Nearest Neighborhood 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 Narayi ward. The result shows clustered points at a 0.01% significance level with the Nearest Neighbour Ratio (NNR) of 1.020928 (See Figure 4).

Figure 4).

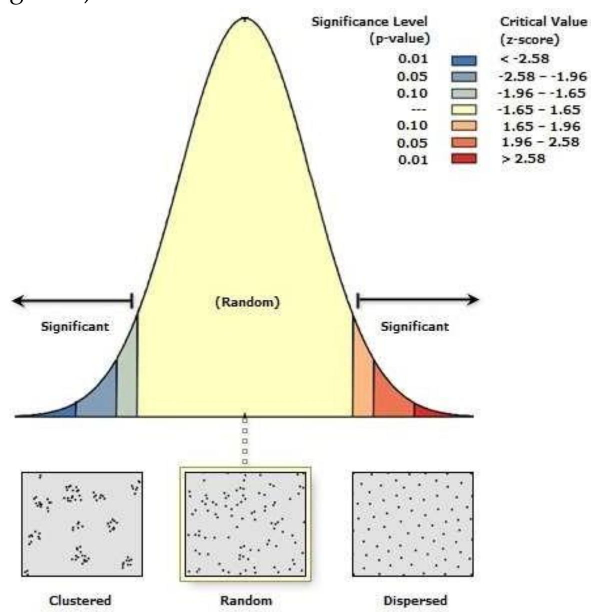


Figure 4: The Distribution Pattern of Transformers in Narayi Ward

Given the z-score of 0.215604336939, the pattern appears to be random.

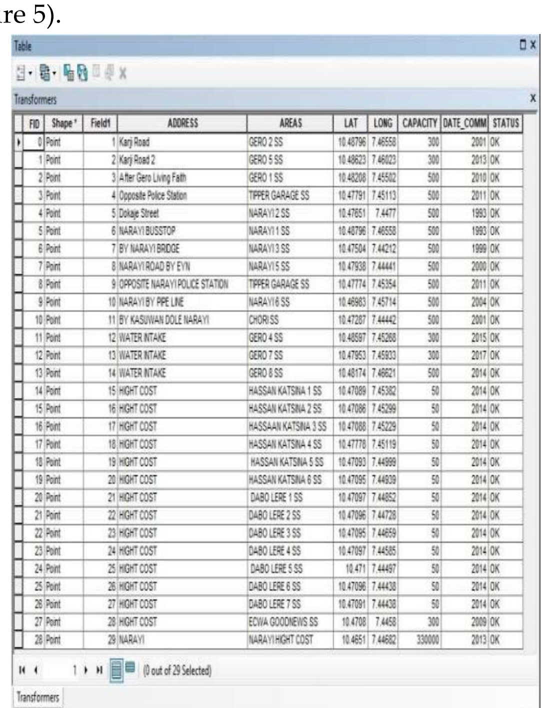
Average Nearest Neighbor Summary

Observed Mean Distance:	219.0507 Meters
Expected Mean Distance:	214.5603 Meters
Nearest Neighbor Ratio:	1.020928
z-score:	0.215604
p-value:	0.829296

Based on the average nearest neighbor summary results, the observed mean distance from one transformer to another is 219.0507m, resulting to a random distribution. This is just a little above the expected mean distance of 214.5603m, which results in a regular distribution pattern. The random nature of the transformers' distribution is a result of the mixed nature of the various urban land uses, which is responsible for the differences in electric power demand and supply, which also affects the location of electricity distribution facilities. For instance, most of the 50kVA transformers are found within the new residential area of High Cost, and a few others are sited at mobile tower masts.

3.2 Geodatabase of Transformers in Narayi Ward

A geodatabase plays a key role in GIS analysis. It provides the opportunity for information on objects to be stored, manipulated, retrieved, and updated over 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 a 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 over time. The geodatabase contains both spatial and attribute data (See Figure 5).



Table

Transformers

FID	Shape *	Field1	ADDRESS	AREAS	LAT	LONG	CAPACITY	DATE_COMM	STATUS
0	Point	1	Karji Road	GERO 2 SS	10.48796	7.46558	300	2001	OK
1	Point	2	Karji Road 2	GERO 5 SS	10.48623	7.46023	300	2013	OK
2	Point	3	After Gero Living Faith	GERO 1 SS	10.48208	7.45502	500	2010	OK
3	Point	4	Opposite Police Station	TIPPER GARAGE SS	10.47791	7.45113	500	2011	OK
4	Point	5	Dokaje Street	NARAYI 2 SS	10.47651	7.4477	500	1993	OK
5	Point	6	NARAYI BUSSTOP	NARAYI 1 SS	10.48796	7.46558	500	1993	OK
6	Point	7	BY NARAYI BRIDGE	NARAYI 3 SS	10.47504	7.44212	500	1999	OK
7	Point	8	NARAYI ROAD BY EYN	NARAYI 5 SS	10.47938	7.44441	500	2000	OK
8	Point	9	OPPOSITE NARAYI POLICE STATION	TIPPER GARAGE SS	10.47774	7.45354	500	2011	OK
9	Point	10	NARAYI BY PIPE LINE	NARAYI 6 SS	10.46983	7.45714	500	2004	OK
10	Point	11	BY KASUWAN DOLE NARAYI	CHORI SS	10.47287	7.44442	500	2001	OK
11	Point	12	WATER INTAKE	GERO 4 SS	10.48597	7.45268	300	2015	OK
12	Point	13	WATER INTAKE	GERO 7 SS	10.47953	7.45833	300	2017	OK
13	Point	14	WATER INTAKE	GERO 8 SS	10.48174	7.46621	500	2014	OK
14	Point	15	HIGHT COST	HASSAN KATSINA 1 SS	10.47089	7.45382	50	2014	OK
15	Point	16	HIGHT COST	HASSAN KATSINA 2 SS	10.47086	7.45299	50	2014	OK
16	Point	17	HIGHT COST	HASSAAN KATSINA 3 SS	10.47088	7.45229	50	2014	OK
17	Point	18	HIGHT COST	HASSAN KATSINA 4 SS	10.47778	7.45119	50	2014	OK
18	Point	19	HIGHT COST	HASSAN KATSINA 5 SS	10.47093	7.44999	50	2014	OK
19	Point	20	HIGHT COST	HASSAN KATSINA 6 SS	10.47095	7.44939	50	2014	OK
20	Point	21	HIGHT COST	DABO LERE 1 SS	10.47097	7.44852	50	2014	OK
21	Point	22	HIGHT COST	DABO LERE 2 SS	10.47096	7.44728	50	2014	OK
22	Point	23	HIGHT COST	DABO LERE 3 SS	10.47095	7.44659	50	2014	OK
23	Point	24	HIGHT COST	DABO LERE 4 SS	10.47097	7.44585	50	2014	OK
24	Point	25	HIGHT COST	DABO LERE 5 SS	10.471	7.44497	50	2014	OK
25	Point	26	HIGHT COST	DABO LERE 6 SS	10.47096	7.44438	50	2014	OK
26	Point	27	HIGHT COST	DABO LERE 7 SS	10.47091	7.44438	50	2014	OK
27	Point	28	HIGHT COST	ECWA GOODNEWS SS	10.4708	7.4458	300	2009	OK
28	Point	29	NARAYI	NARAYI HIGHT COST	10.4651	7.44682	330000	2013	OK

(0 out of 29 Selected)

Transformers

Figure 5: The Attribute Table of the Geodatabase of Electricity Transformers in Narayi

The spatial data include the coordinates of the transformer point locations stored in terms of Northings and Eastings. This data is a very important element of the geodatabase because it provides information about the geographical location of the individual transformers in Narayi Ward. Some of the attribute data built in the geodatabase include: type of transformer, year of installation, service years, address, feeder, and capacity. Data on all these variables are important, and being in the geodatabase, they can provide additional information about the transformers at any time needed. With these in the database, a query can be made to display the actual locations of either all or a particular category of transformers (See Figure 6).

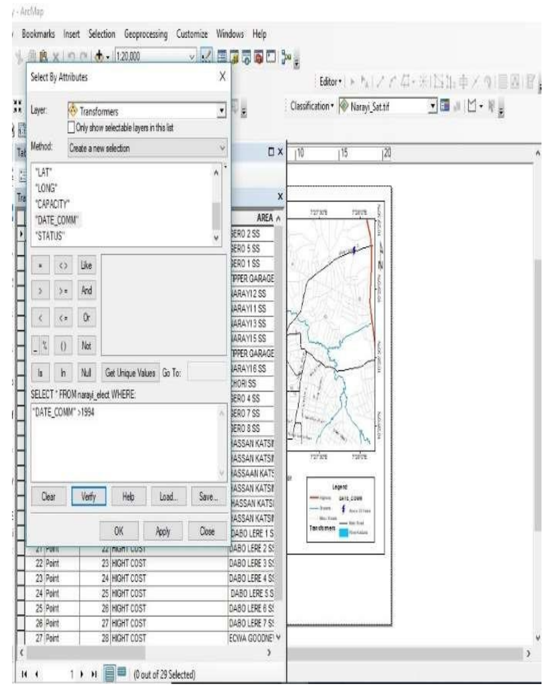


Figure 6: Screen-print of Geodatabase Query Processes

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 bridges the gap left by Omilabu et al. (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 have 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.

3.3 Compliance with NERC (2016) Standards for Siting Transformers

A Safety clearance of 10m buffer zones were created around each transformers in Narayi Ward 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 7). These transformers were located less than 10m away from the main roads.

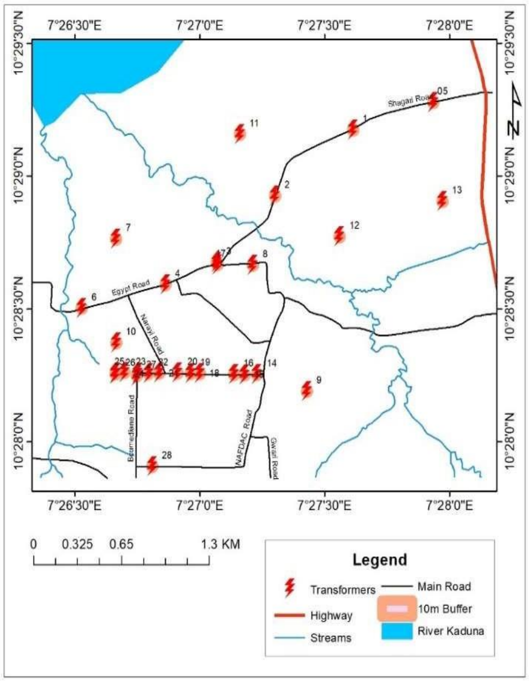


Figure 7: Transformers Sited within 10m Buffer from Major Roads

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

3.4 Transformer Service Life

Electricity transformers have the capabilities, under normal operating conditions, to serve far beyond their expected years of disposal, but the consequences of engaging very old transformers are enormous. These may include deterioration of insulation materials, power outage, fire incidents, 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 the Interior and Bureau of Reclamation (2005) and also reported by Shomolu (1994), is 25 years. Figure 8 reveals the result of the query operation carried out on the geodatabase to map out the transformers that have spent 25 years or above in service within Narayi Ward.

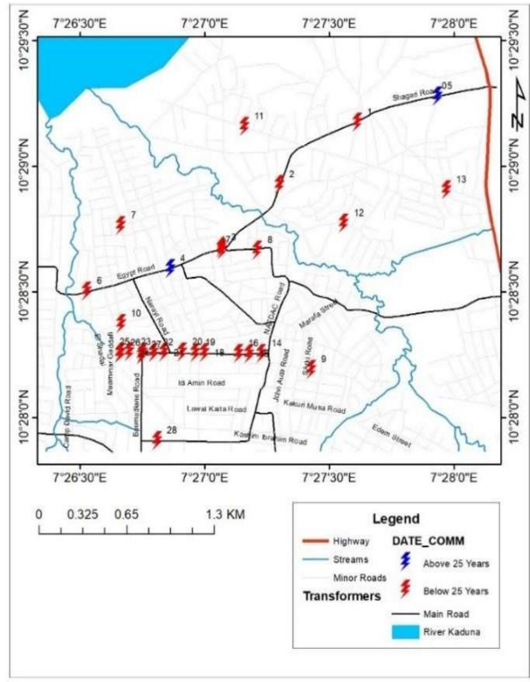


Figure 8: Query Operation showing the Locations of old Transformers (25 years and above)

Appendix 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 Narayi ward. These transformers were identified from the geodatabase created.

4 Conclusion

In conclusion, the spatial distribution of electricity transformers in Narayi ward is random in areas where there are concentrations and a mixture of urban land use activities. The geodatabase created contains useful data that can always be manipulated, retrieved, and updated over time. Also, 5 (19%) of the transformers complied with the safety standard of siting transformers at least 10m away from the main road. Two 2 (7%) distribution transformers have served beyond their useful life span of 25 years, and 16 (34%) are located within the 10m buffer zone across the main roads of the study area.

5 Recommendations

The study recommends that:

i. KAEDCO should deploy more transformers for an efficient power supply. Regular maintenance should also be carried out on the existing transformers.
ii. Transformers located within the 10m buffer zone close to major roads should be relocated. Any future installations should also comply with the standard.
iii. Transformers that are in service for more than 25 years should be replaced with new ones to avoid

sudden breakdown in distribution.

iv. KAEDCO, as a distribution company, should also build a comprehensive geodatabase of all its assets to improve information collection and analysis. This will help in decision-making.

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