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Distribution and Monitoring of Electricity Using GIS in World Bank Housing Estate, Umuahia, Abia State, Nigeria

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ABSTRACT - Electricity plays a vital role in human existence and development. Man's growth and development on earth surface completely are hinged on energy and power. No meaningful development takes place without efficient and effective power and energy supply. The study looked at the role of Geographic Information System (GIS) in efficient and effective electricity distribution and monitoring in World Bank Housing Estate, Umuahia. Spatial database was designed. The study adopted GIS and Remote Sensing methods to acquire data and process the data. Spatial database was also created for the entities of interest in the study area. The attribute data generated from the oral interview were linked with the geometric data using ArcGIS 10.8.1. Various queries were performed with different results to guide the Decision makers involved in the day-to-day running of electricity supply activities in the study area. Network analyst tool of the ArcGIS software was also used to show that there is a significant difference between best and alternative routes taken between points as shown in the results generated. The study revealed that much of the energy supplied into the estate goes to illegal usage that could not be accounted for in terms of revenue generation and this affects the maintenance of power supply accessories in the area. It is recommended that a digital database for all the customers in the study area be created.

Keywords: Electricity Distribution, billing, revenue, database, queries, network

1.0 INTRODUCTION

Globally, current decade has seen significant progress in electrification across the developing world, where the greater majority of the un-electrified population resides thus making the share of global population with access to electricity rose from 83% in 2010 to 89% in 2017 and global population without access to electricity fell from 1.2 billion in 2010 to 840 million in 2017. Also, according to Sustainable Development Goal (SDG) indicator 7.1.1 report, the target is that by the year 2030, many challenges facing access-deficit countries were projected to have increased access to electricity to be up to 92% and these deficit countries in which Nigeria is among have expanded electricity access by less than 1% annually since 2010. This, however, increased but the electrification rate between 2010 and 2017 did not keep pace with population growth [1].

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Meanwhile, Population and Housing Census is the process of systematically obtaining and recording demographic, economic and social data, at a specified time, of the country's population. Compared to other surveys, in which information is collected from only a small sample of the residents, and from that conclusions are reached regarding the general population, the Population and Housing Census gets data from the entire population [2]. In addition, United Nations defines a population census as the total process of collecting, compiling, and publishing demographic, economic, and social data pertaining to a specific time to all persons in a country or delimited part of a country whereas as part of a census count, most countries also include a census of housing which is the process of collecting, compiling and publishing information on buildings, living quarters and building related facilities such as sewage systems, bathrooms, electricity, to name a few [2],[3].

According to the United Nations definition, four essential features of a census for population and housing are important that include the following; firstly, individual is enumerated separately; secondly, the census covers a precisely defined territory and includes every person present or residing within its scope. Thirdly, each person and each type of building and living quarters are enumerated with respect to a well-defined point of time. And lastly, the census is taken at regular defined intervals, usually every 10 years.

[3] also listed information to be collected on buildings to include building usage such as residential, commercial or industrial purposes, including the type of structure, the construction materials used for the outer walls and the year of construction. The type of information that is usually collected on living quarters includes the type and location (rural or urban locale) of the quarters, the number of rooms, the occupancy status and number of occupants, and the types of available facilities such as water, toilets, sewerage, bathing, cooking areas and lighting. Living quarters can be housing units or collective living quarters. Data on living quarters provide insights into the type and quality of

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housing that exist in rural and urban areas throughout the country. Meanwhile, electricity is a form of energy that occurs everywhere in nature, space and in living creatures; our present day world revolves around electricity. It lights up our homes, runs our factories, makes our life comfortable and provides us with entertainment.

Nevertheless, the fourth feature of UN on population census has not been prompt in Nigeria as the last census was conducted in 2006, but we depend on projected population for decision making for a while now. Therefore, building type (residential, commercial or industrial) necessitates the amount of energy (electricity) consumed. Also as the demand for energy continues to increase strongly; the gap between consumed electricity and power generated is still very wide. One of the ways to bridge the gap of ensuring effective performance, management, and maintenance and distribution network is through the creation of spatial database on buildings with emphasis on spatial location, status, state of supply using Geospatial technology [4].

The study area is World Bank Housing Estate located in Umuahia Urban, Abia State in the South Eastern part of Nigeria as shown in Figures 1. It is located between longitudes $7^{o}\ 20^{1}\ 30''$ and $7^{o}\ 39^{1}\ 0''$ East of the Greenwich Meridian; and latitudes $5^{o}\ 15^{1}\ 30''$ and $5^{o}\ 32^{1}\ 0''$ North of the Equator at the central part of Umuahia urban. It is bounded in the north by Ikot Ekpene road, in the south by Low-Cost Estate, in the east by Umuafia village, in the west by Aba road. It has approximately total area of 6,223.5m^2 and 1844 buildings.

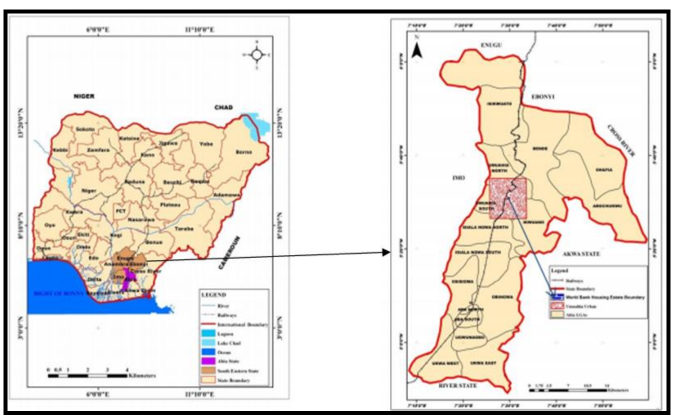

Figure 1. Map of the Study Area

2.0 MATERIALS AND METHODS

For most geospatial studies and research, data remain the foundation of every operation carried out. The first step was the design of a geospatial database that included view of reality, logical design, closely followed by data gathering and physical design phase with their respective schema. The vector data model approach was adopted in the conceptual database design phase. The transformer was conceptualized as point, roads as lines, buildings and the study area boundary as polygons. The data used are from primary and secondary data sources. Here, the materials used include observations from the field and personal interview about electricity billing was conducted; these served as primary data which were used to populate the database from the software used for the study. The Quickbird satellite imagery of Umuahia Urban obtained from GeoEye imagery collection served as secondary data set from where the roads, buildings and the study area boundary were extracted using head-on digitizing method. The boundary of the study area was masked using ArcMap 10.8.1. The building database had fields with building type, building status (indicating whether the building is occupied or not occupied), electricity information, water related information, location of each building were possible because the satellite imagery was orthorectified.

3.0 ANALYSES AND RESULTS

This section deals with the various queries performed on the database created for the entities in the study area and the results generated from each of them. The extracted entities from the imagery include the boundary of the entire Housing Estate which encloses the buildings and the roads linking the buildings for accessibility. The formatted map is shown in Figure 2.

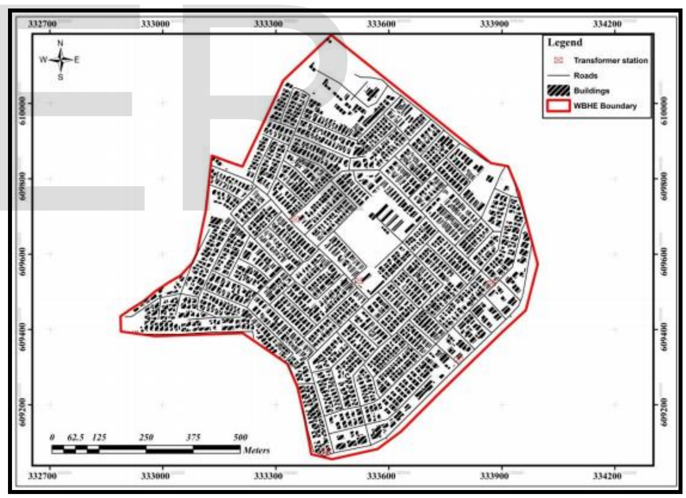

Figure 2. Composite Map of the Study Area

3.1 Database Extraction / Spatial Query

A database according to [5] is a repository for storing large amount of data. The database comes with a number of useful functions such as allowing concurrent use, supports storage optimization and data integrity, having query facility and optimization. The study centered on design and creation of a spatial database. The database was queried and various results were generated.

However, [6] opined that spatial querying is at the heart of what most users do with their GIS, relying on the fact that a data model allows spatial query to occur. It was believed that in the early days of GIS, topology were stored explicitly in tables in the database, and spatial queries were executed by making many hits, or reads, into those tables but due to advances in technological development in

Information Technology (IT), it was no longer necessary to store the topology in tables; executing the spatial queries are now through sophisticated indexing and searching procedures. Standard Query Language (SQL) was used to extract from the database.

Queries according to [7] are the most basic of analysis operations, in which the GIS is used to answer simple questions posed by the user. They observed that no changes occur in the database, and no new data are produced. The operations vary from simple and well-defined queries like what is where, and what is the relationship between objects. However, they allow for the use of geometry data types such as points, lines and polygons and that these queries consider the spatial relationship between these geometries. Nevertheless, either or both the spatial and attribute data may be utilized in the query to produce a result that can be either spatial, textual or both.

The findings from the study as a result of the database extraction otherwise called query are shown in Table 1. The total number of buildings digitized for the study was 1844. The table showed the single criterion and multiple criteria queries. The single criterion query uses one condition to extract from the database while the multiple criteria use more than one condition. Summary of the Queries' results are shown in Table 1.

Table 1. Summary of the Results from the Queries

S/N	Query Issued	Result	% of Total
1	"Metering Type" = "Prepaid"	6	0.33
2	"Power Source" = "Electricity/Solar"	2	0.11
3	"Status" = "Occupied" And "Connection Type" = "Illegal"	3	0.16
4	"Connection Status" = "Disconnected".	22	1.19
5	Occupation Status" = "Vacant" And "Connection Status" = "Connected"	25	1.36
6	"Connection Status" = "Connected" And "Water Supply" = "Borehole Water".	278	15.08
7	"Connection Status" = "Connected" And "Shop" = "Yes"	192	10.41

The prepaid metering is the best option in terms of electricity distribution monitoring and sustainability as it enables the operators to know the actual and eligible customers. It also helps in accurate revenue generation, utility maintenance, controlling of electricity loss as this can be seen in Figures 3a and 3b showing buildings with prepaid and postpaid meters in the day time respectively. Buildings with prepaid meters are more economical with the way they consume power by putting off all unused appliances and switching off the lighting bulbs in the day when they are not needed while the reverse is the case for the other consumers without meters.

Figure 3a. Building with prepaid meter

Figure 3b. Buildings with postpaid meters

One of the buildings is a mixed usage (residential and commercial) and the other is completely a residential building. It was proved during the study that they were connected illegally. This contributed to loss in revenue generation as stated by [8]. This also makes planning difficult since the eligible customers' consumption will not match the actual energy output. Few electricity bills were sampled through observation and interview from the study area as seen in figure 4a, 4b, 4c as of the time of the research. It was observed that the criteria for billing was not really ascertained because building with private borehole paid higher than building with commercialized borehole as seen in figure 4a and 4b.

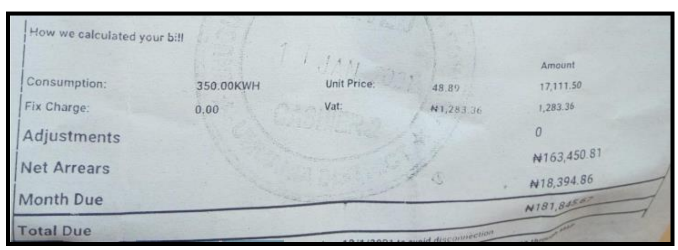

Figure 4a: Post-paid Building bill with private borehole

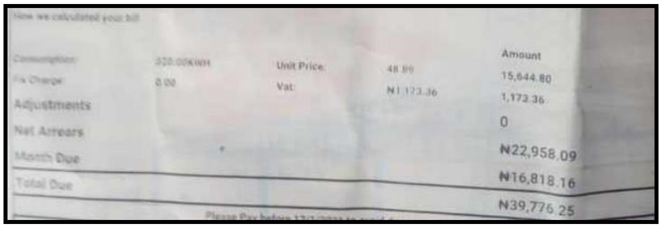

Figure 4b: Post-paid Building bill with commercial borehole

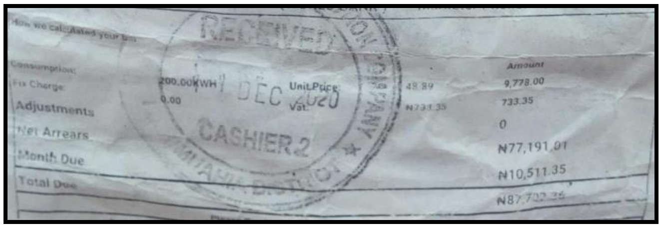

Figure 4c: Post-paid Building with no Borehole or Shop

3.2 Networking

[7] agreed that in GIS software systems, networks are modeled as points which can be street intersections, fuses, switches, water valves and the confluence of stream reaches: usually referred to as nodes in topological models, and are also modeled as lines like streets, transmission lines, pipes and stream reaches. Network topological relationships according to them defined how lines connect with each other at nodes. The relevance of network analysis to this study is to model the movement of the technicians along the streets from one transformer to another in case there are faults to be rectified. The network analyst menu in ArcGIS software was used to define locations of transformer 1 on Upstair Lane along Agbama Main Road in the southern part of the study area and Transformer 2 along Health Centre Road as indicated in Figure 5.

Figure 5. Diagram of the locations of the two transformers

Figure 6 and Figure 7 show respectively the best route between the two transformers and the direction window to follow along the generated route by the software. The operation is necessary if the technician is working on Transformer 1 and there is the need to work on Transformer 2 as shown in Figure 6. The total distance travelled is 789m (Figure 6) and the Best route map is shown in Figure 8.

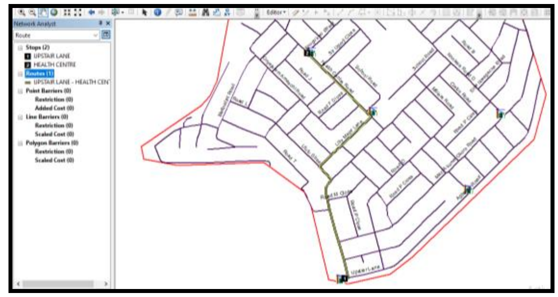

Figure 6. Best route between the Two transformers

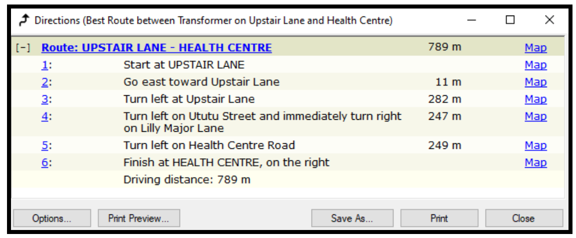

Figure 7. Direction window of the Best route between the Two transformers

On the other hand, there may be obstruction along the best route hence the need for an alternative route in other to get to the destination in the shortest possible time. A barrier on Road 'O' (Figure 9) created an alternative route (Figure 10) along which the technician can travel in other to get to the other transformer.

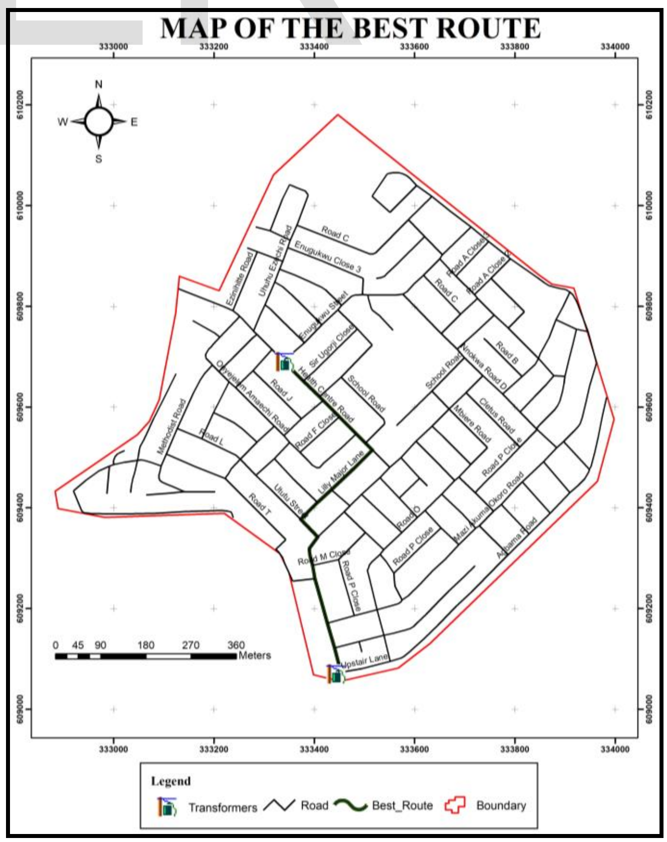

Figure 8. Map of the Best route

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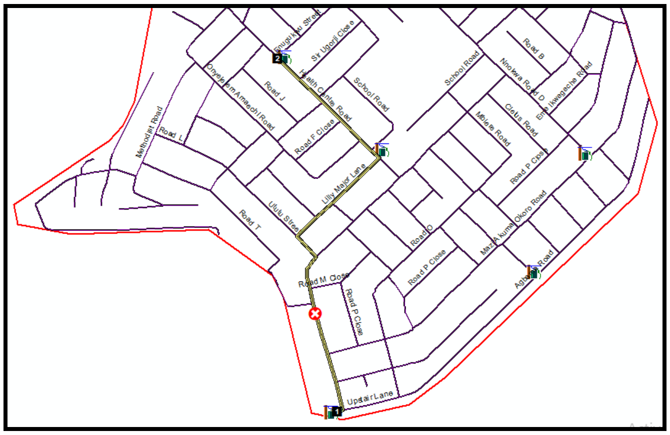


Figure 9. Barrier on Best Route

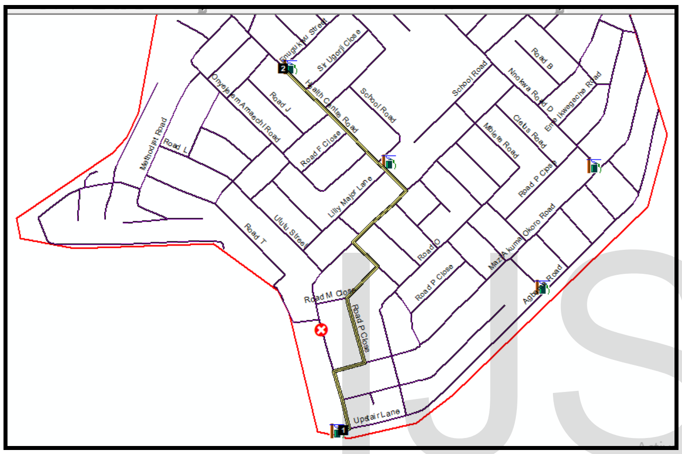
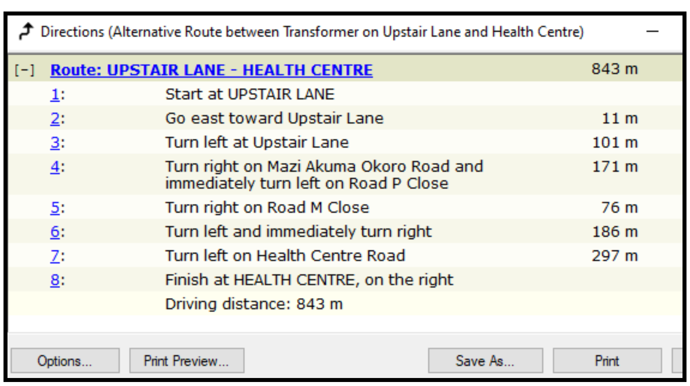


Figure 10. Alternative Route

The direction window indicated the travel distance of 843m (Figure 11) as against the best route travel distance of 789m (Figure 6). This is a difference of 54m longer than the best route travel distance. The formatted map of the Alternative route is shown in Figure 12.



Directions (Alternative Route between Transformer on Upstair Lane and Health Centre)

[-]	Route: UPSTAIR LANE - HEALTH CENTRE	843 m
1:	Start at UPSTAIR LANE	
2:	Go east toward Upstair Lane	11 m
3:	Turn left at Upstair Lane	101 m
4:	Turn right on Mazi Akuma Okoro Road and immediately turn left on Road P Close	171 m
5:	Turn right on Road M Close	76 m
6:	Turn left and immediately turn right	186 m
7:	Turn left on Health Centre Road	297 m
8:	Finish at HEALTH CENTRE, on the right	
	Driving distance: 843 m	

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Figure 11. Direction window of the Alternative route between the Two transformers

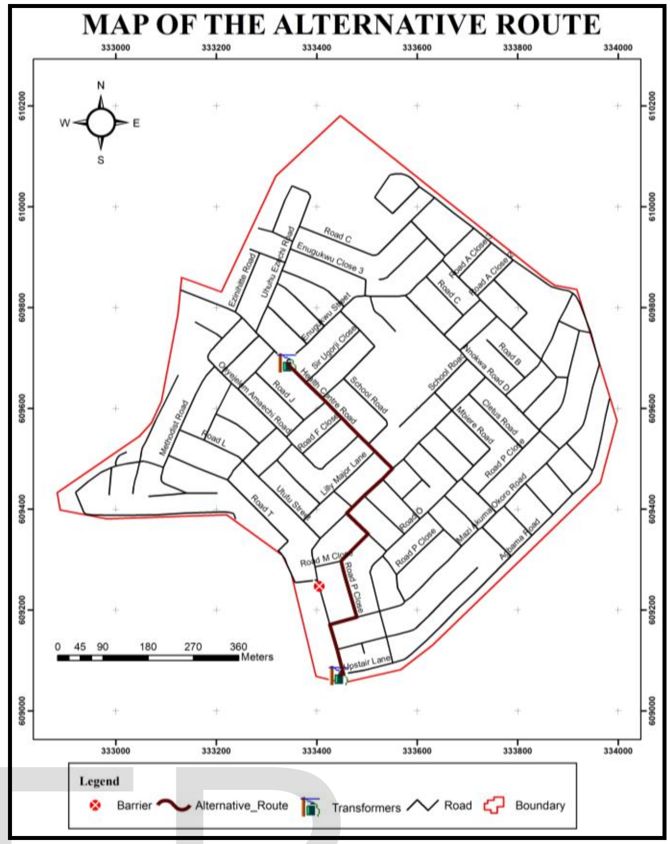

Figure 12. Map of the Alternative route between the two transformers

3.3 Limitations to the Study

The study intended to go a step further by looking at which buildings are connected to which of the transformers. Due to the nature of the illegal connections within the Estate, it was not possible to know which transformer to tag with which sets of buildings. The residents too were not ready to divulge such information because most are illegally connected. The electricity distribution companies are not willing to surrender such information to the researchers for fear of whether they might be exposed in their shady deals with the customers.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on the findings, losses in electricity distribution in the estate was as a result of its method of payment as Ninety Nine percent (99%) of the occupants are on post-paid method of payment and this method does not balance supply and consumption rates. Despite the post-paid method of payment, it was observed that people are sourcing for alternative means by installing solar powered energy and this will likely increase in the near future thus affecting the current distribution company revenue generation. Lastly, the house numbering in the estate was not properly done, thus making planning of the estate for infrastructure development difficult.

4.2 Recommendations

The following recommendations are made based on the findings. They are as follows:

1. The planning authority and agency assigned in the built environment should work together to enable them have compiled and published information on living quarters, buildings, and its related facilities.
2. Regular population and housing census in line with specified time schedule should be followed strictly in the country.
3. Metering of customer should be considered a right with enabling policy in order to check losses in electricity supplies to illegal customers as was seen from the study. Prepaid metering system will stop billing of buildings that are under renovation or vacant.
4. It was observed that the housing estate was not properly numbered. With proper population and building census, the distribution company can obtain such information from the agency saddled with that responsibility and create reliable geodata for customers. This will form the basis for customer enumeration with appropriate status.
5. From the study, it was observed that connected buildings are quite more in the night and weekends when operators are not on duty which has caused damages to electrical facilities especially transformers.
6. Finally, the distribution company should adopt Geospatial information based system which can aid in collecting each building's coordinates that will be attached to each building to serve as Electricity Identification Number (EIN) for easy access in the database.

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