The Impact of Surveying and Mapping in Transforming Ghana's Energy Sector; A Case Study of Electricity Company of Ghana (ECG) Asset Mapping Project.

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Key words: Asset, Electricity, GIS, Management, Map

1. SUMMARY

Reliable energy supply remains a critical factor for socio-economic thrives for most nations. Since the past decade, Ghana has experienced severe electricity supply challenges costing the nation an average of US $2.1 million in loss of production daily. The losses have been a drain on ECG's financial ability to pay power generators and distributors, pay employees and contractors made up of field engineers and technicians, repair and maintain their resources, and extend their service to unelectrified communities which had led to persistent and unpredictable power outages over the years.

A recent study conducted by the Africa Centre for Energy Policy (ACEP) alludes to these losses to illegal power connections, tampering with meters, and SHEP meters connected to the national grid without distributions agents' knowledge. However, through surveying and mapping initiative under the ECG Asset Mapping Project, Losamills Consult Limited has developed a geospatial solution that is helping ECG to identify illegal connections and tariff inconsistencies, improve revenue generation, develop accurate navigational maps for field operations, and ultimately ensure reliable electric power supply in Ghana.

The methodology involved three processes: (i) Capturing of field data of all ECG assets including meters, poles, pylons, transformers, customers' locations using Navcom LandPak GPS; (ii) data editing and attribute data standardization using ArcGIS; (iii) automating categorization of map features into AutoCAD using LSM Escript application. This project has been instrumental in arresting, prosecuting, and recovering huge sums of money from illegal connection offenders. In 2021 ECG identified 1,537 illegal connections across the country and recovered GH₵ 6.2 million from offenders.

2. INTRODUCTION

Access to reliable energy remains a critical driver for the socio-economic development of a country, making electricity a significant contributor to education, agriculture, health, and environmental sustainability (Sarkodie & Samuel, 2020). Consumption of electricity is extremely correlated with economic development and other indicators of modern lifestyle, with the presumption that electricity consumption offers a better life and well-being for people (Starr, 1972).

The Government of Ghana initiated the preparation of a National Electrification Scheme (NES) in 1989 as its principal policy to extend the reach of reliable electricity supply to all parts of the country over 30 years from 1990 to 2020. Then, national electricity access was about 23%, with less than 5% rural coverage. 46 out of 110 District Capitals existing then were connected to the national grid. The objective of the NES was to enhance socio-economic development nationwide, create jobs and improve living standards, particularly in the rural areas. (Kemausuor & Ackom, 2017). Electricity economic gains beyond Ghana include exporting power to neighboring countries of Benin, Togo, Cote d'Ivoire, and Burkina Faso (Owusu-Adjapong, 2018) Total electricity export in 2020 was 1,855.09 GWh according to Power Planning Technical Committee's report.

Electricity distribution in Ghana is done by the Electricity Company of Ghana Limited (ECG), and Northern Electricity Distribution Company (NEDCo). ECG is located in the southern part of Ghana, where the population is dense and electricity consumption is about 89% of total consumption in Ghana. The country had experienced severe electricity supply challenges costing the nation an average of US $2.1 million in loss of production daily from 2006 to 2016. This situation had developed even though installed generation capacity had more than doubled over the period; increasing from 1,730 MW in 2006 to 3,795 MW in 2016 (Center for Global Development, 2017). The Energy Commission of Ghana(2020) report indicated the total energy generated in 2020 was 19,716.59 GWh; this was made up of 7,293.23 GWh (36.99%) from hydro generation, 12,365.09 GWh (62.71%) from thermal generation, and 58.24 GWh (0.3%) imports. The total energy consumed, including losses, was 19,716.59 GWh representing a 10.23% increase over the 2019 consumption of 17,887 GWh.

.The electricity supply challenges can be attributed to several factors, including a high level of losses in the distribution system, which is mainly due to the obsolete nature of distribution equipment and the non-payment of revenue by consumers (Center for Global Development, 2017). Other factors are revenue losses due to illegal connections and poor tariff assignment, which makes it difficult for distributors to recover the cost of electricity. According to a study conducted by the Africa Centre for Energy Policy (ACEP), electricity distributors lose more than GH¢1.3 billion annually due to power theft in Ghana.

Geographical Information System(GIS) on the other hand has proven to be a powerful decision support tool for electricity network distribution analysis, monitoring, and asset management with a demonstrated example from India (Rai & Singh, 2016). GIS can effectively manage information on the distribution of electricity to customers and information describing the attributes of each customer including their location, meter types, tariffs, and several meters. Geodatabase provides an easy and quick way of retrieving information for planning and management purposes. For instance, if ECG needs to install a meter for a new customer, the geodatabase assists them in precisely identifying the closest LV network to connect the service line and planning the length of electrical cables or number of poles to be used based on the proximal distance of pole to new customer facility.

3. LITERATURE REVIEW

Electricity like many energy systems is essential for the growth of any developing country. Electric power shortage is one of the major obstacles that hinder the spread of development across these countries and cause societal disparity. Innovative spatial technology and GIS solutions provide a viable alternative to solve many problems in the electric power system (Sekhar, et al., 2008). For instance, the research work by Rai & Singh (2016) on electrical asset database helped Bhadohi city, India to identify the types of electrical poles, the total number of transmission substations, the total number of transformers, and the length of electrical power cables. It further established the trend of customer increment between 2011 and 2015 which provides valuable information for the power management authority in Bhadohi city to assess their performance, obtain a precise estimation of current equipment on the ground and make an informed decision for future electrical network extension plans.

Without any doubt, GIS technology supports fast, accurate, and reliable data management. It provides a timely, accurate, and easy way for information retrieval, which is vital in taking prompt and accurate decisions (Shah, et al., 2019; Verma, et al., 2009) necessary in electricity asset map management.

The distributions of electrical energy to end-users in most urban areas are faced with diverse spatial problems, particularly with the use of the analog system. An electricity asset map of the electrical network and customer database is critical for planning, load management, power loss reduction, better revenue generation, and enhanced management standards (Ihiabe, et al., 2015).

However, the quality of any spatial database hinges on data input accuracy, completeness, and consistency (Veregin, 1999; Devillers, et al., 2005; Beard & William, 1993) to ensure that it is reliable for analysis and planning. Yadav (2013) remarks that GIS map data for electricity distribution and related databases requires a continuous update to keep the information current. Data accuracy ensures that distance measurement, spatial identification of map features, and attribute information are valid and reliable (Chrisman, 1991).

4. AIM AND OBJECTIVES

The main aim of the project was to map all ECG assets, and customer information to increase revenue generation, perform routine field operations, identify illegal customers, and ultimately improve service delivery. The specific objectives were as follows;

i. Map all ECG assets, customer location, and attribute information using the GPS land surveying method.
ii. Map all navigational details including routes, water bodies, and landmark features
iii. Establish electricity asset map geodatabase in shapefile format.
iv. Produce electricity asset map in AutoCAD format.

5. STUDY AREA

The study area selected for this research is the Takoradi District in the Western Region, Ghana. It lies between longitude 0°25'31.17"W and Latitude 5°32'3.44"N. The total study area is about eighty-four square kilometers (84km$^{2)}$.

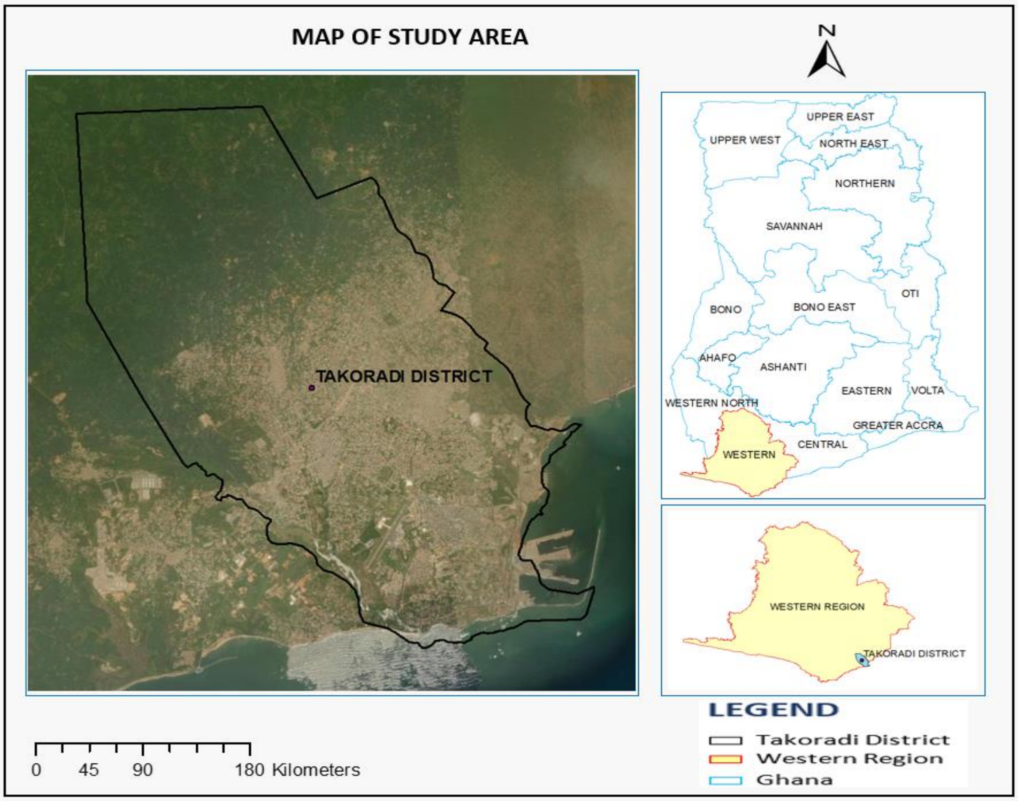


Figure 1: Map of Study Area

6. MATERIALS AND METHOD

6.1 Software and Equipment Used

Table 1: Table representing software and equipment used

Software	**Remarks**
ArcGIS 10.2	It was used for spatial data analysis, editing, updating, and exporting attribute details of electricity meter attribute into CSV for further analysis in Microsoft excel.
AutoCAD Desktop	It was used for producing AutoCAD maps in DWG format
LSM Escript	A customized python script application developed by Losamills Consult Limited to run shapefile data into AutoCAD DWG format with ECG's thematic layer symbolization standard.
GIS 360	Conversion software was used to convert kmz of Navcom GPS field survey output into shapefiles.
Microsoft Excel	It was used to analyze attribute information of customer meter attributes to identify potential duplicates and errors for correction on the ArcGIS platform.
Google Earth	It was used to analyze captured field map data to identify left out details such as buildings, road networks, and landmarks for field revisit survey and update.
Equipment	
Navcom LandPAK GPS and Controller	Set of land surveying instruments used to capture field data.
Computer	It was used to run all software and related electricity map data.

6.1 Data Requirement

- Customer buildings locations with meter attribute details
- Electrical network map including transformers, Pylons, LV and HT poles, and Substations
- Navigational details such as Waterbodies, route networks, and landmarks features.
- District boundary map

6.2 Method

i. Reconnaissance Survey

The project team obtained the various district boundary maps from ECG, to carry out effective field reconnaissance. This phase helped in planning the work before setting off for the field survey such as carefully planning the routes as well as mobilizing resources for the survey.
In this process, the team visited all the appropriate stakeholders such as the Police Unit, Chiefs, and opinion leaders in the district as part of the community entry requirement and sensitization.

ii. Field Data collection using GPS Survey

Collecting of all map data was done using Navcom LandPAK GPS with a horizontal accuracy of up to 5cm which met the requirement of the project. To ensure that the standard accuracy was achieved for X and Y coordinates, each Navcom GPS was calibrated using a stable point of departure approved by the Survey and Mapping Division of the Lands Commission, occupying control for not less than thirty (30) minutes.
ECG provided the district map that had been subdivided into blocks and rounds which was used as a boundary reference for mapping.

iii. Data processing

Processing of the kmz surveyed field data of electrical distribution network and customer location details were converted into shapefile for further analysis and editing on the ArcGIS 10.2 platform. The editing process involved removing duplicates of features, correcting attribute information names, and updating left-out details. To ensure data completeness, the edited map within ArcGIS was converted to kmz for overlays analysis on google Maps to identify any potential data gaps such as buildings, route networks, water bodies, and landmark details. For effective correction management of customer meter attribute information, it was exported as a CSV file from ArcGIS for analysis in Microsoft excel.
The finalized ECG asset map with various layers such as structures, meters, poles, transformers, substations, pylons, routes, and streetlights was categorized and symbolized based on ECG's specification. Using the LSM Escript application, electrical map output was converted to AutoCAD DWG format. All maps were saved in UTM Zone 30N and Ghana Metre Grid.

7. RESULTS AND DISCUSSION

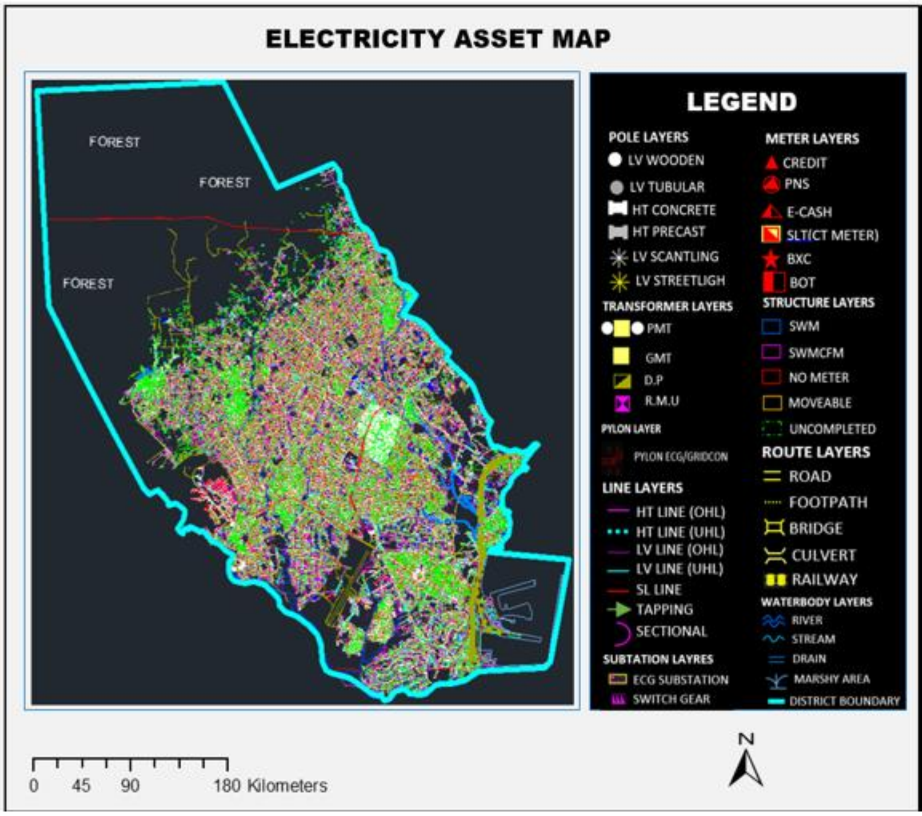
Error! Reference source not found. shows the electricity asset map of the Takoradi District of Ghana. It indicates information about electrical network distribution, customer information, and navigational features. The electrical network is made up of LV, HT, and Scantling poles; LV, HT, Pylon, and Tapping lines; Pylolons, Transformers, Primary substation, Distribution panels, Ring Main Units, and Streetlights. Customer information includes the location of customer buildings (Structures), attribute details, and meter information. Navigational features include route networks, water bodies, farms, forests, cemeteries, lorry stations, and football fields.
The map shows 22499 poles, 1347364 meters of line conductors, 165 pylons, 266 transformers, and 1 primary substation.

Location and distribution of electrical network resources are valuable information for planning network extension, connecting new customers and unelectrified communities to the nearest electrical resource in the area.

The result also indicated a total of 83,199 Structures (buildings) and 77,125 meters in the district. Out of the total number of structures in the study area, 36.7% representing 30,525 had a meter and 15.7% representing 13,088 had no meter but tapped from structures with a meter,0.6% representing 469 had no meters but had a direct supply from the network (illegal connectors) and 47.0% representing 39,117 were unconnected to ECG's electrical network.

Meters represent a direct commercial component for ECG. Monetary charges are assigned to customers' meters based on power use and tariff type. The asset map can identify and help ECG recity tariff anomaly. For instance, where customers acquire a meter for residential activity and change their activity to commercial use, it incurs a financial loss to ECG due to inappropriate tariff assignment. More so, all structures with a service line but no meter are grouped as SWSBNM(Structure With Supply But No Meter). This group represents potential electricity users who use the ECG service for free. Identification of illegal connections helps ECG to prosecute offenders and recover a substantial amount of their losses.

Detailed quantities for various layers such as structures, poles, transformers, and meters are found in Table 1.



LV-Low voltage **HT**-High Tension **SWM**-Structucture With Meter **SWMCFM**-Structure Without Meter Connected to Structure with Meter **NO METER**-Structure without connection **MOVEABLE**-Structure such as kiosk and container that can be relocated **UNCOMPLETED**-Structure under construction **SWSBNM**-Structure With Supply But No Meter **GMT**-Ground Mounted Transformer **PMT**-Pole Mounted Transformer **D.P**-Distribution Panel **RMU**-Ring Main Unit.

Figure 2: Electricity Asset Map

Table 1; Table showing quantities of electrical assets

METERS			STRUCTURES	
Type	**Count**		**GROUP**	**Count**
Prepaid	76,607		SWM	30,525
Credit	399		Moveables	21,550
SLT(CT Meter)	119		SWMCFM	13,088
			No Meter	10,118
			Uncompleted	7,449
			SWSBNM	469
Total	77,125		Total	83,199
POLES			**TRANSFORMER**	
Type	**Count**		**Type**	**Count**
HT/LV	196		PMT	75
HT	1,269		GMT	191
LV	13,205		Total	266
Scantling	7,829			
Total	22,499		**SUBSTATION**	
			Type	**Count**
LINES			Primary Substation	1
Type	**Lenght/m**		ECGS	1
HT	75,531		Total	2
LV	521,723			
SL	705,681		**PYLONS**	
Tapping	18,969		**Type**	**Count**
Pylon	25,460		Pylon	165
Total	1,347,364		Total	165
STREETLIGHTS				
Type	**Count**			
Mono	2,980			
Bio	369			
Trio	5			
Quad	6			
Total	3,360			

Figure 3 shows a map of electrical network distribution. The electrical network is made up of LV, HT, and Scantling poles; LV, HT, Pylon, and Tapping lines; Pylolons, Transformers, Primary substation, Distribution panels, Ring Main Units, and Streetlights. The LV and HT lines are 11KVA and 33KVA conductors whilst the pylon lines are 161KVA and 330KVA conductors.

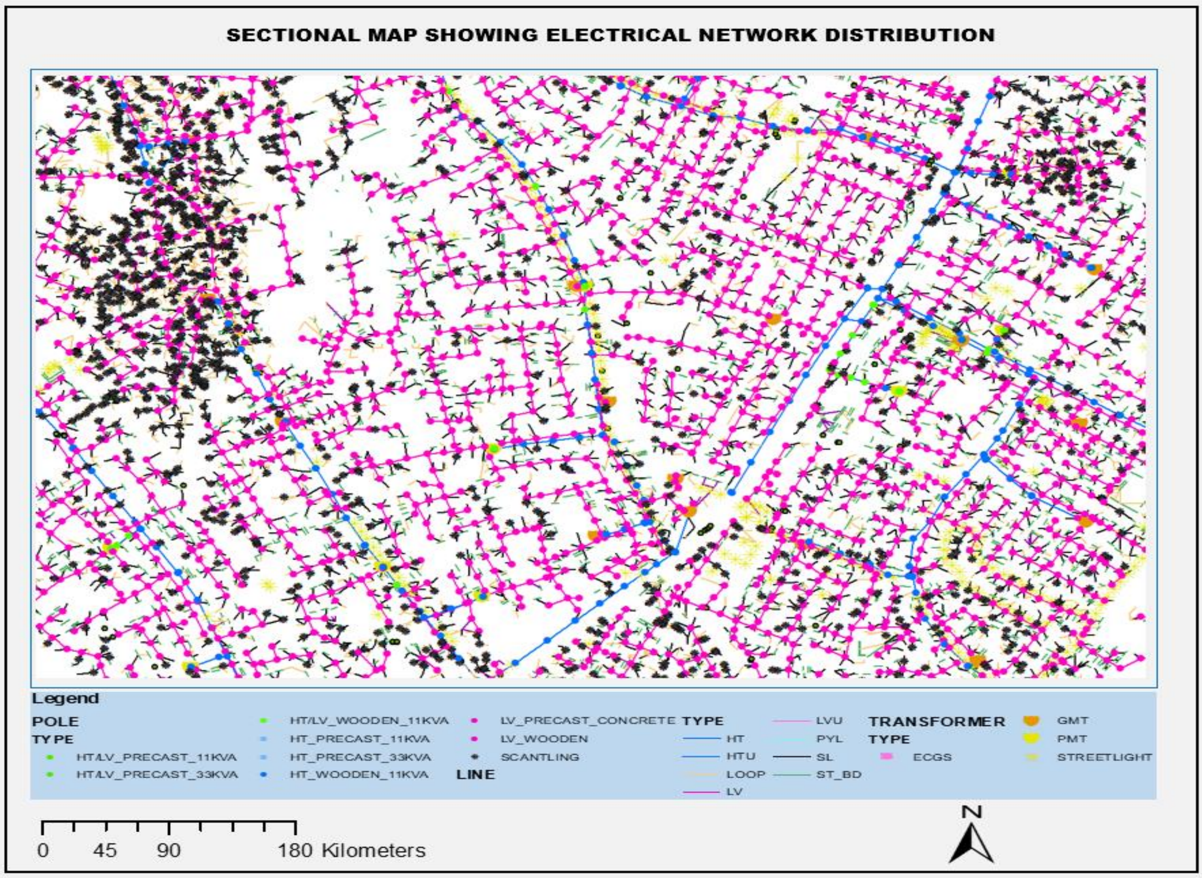


Figure 2: Sectional Map showing Electrical Distribution Network

Figure 4 shows a sectional map of customers’ connection to the electrical network and demonstrates the navigational property of the map with road features and landmarks. The navigational nature of the map supports ECG’s key field operations such as installing new equipment, distributing bills to credit customers, disconnecting payment default customers, and operating faulty equipment.

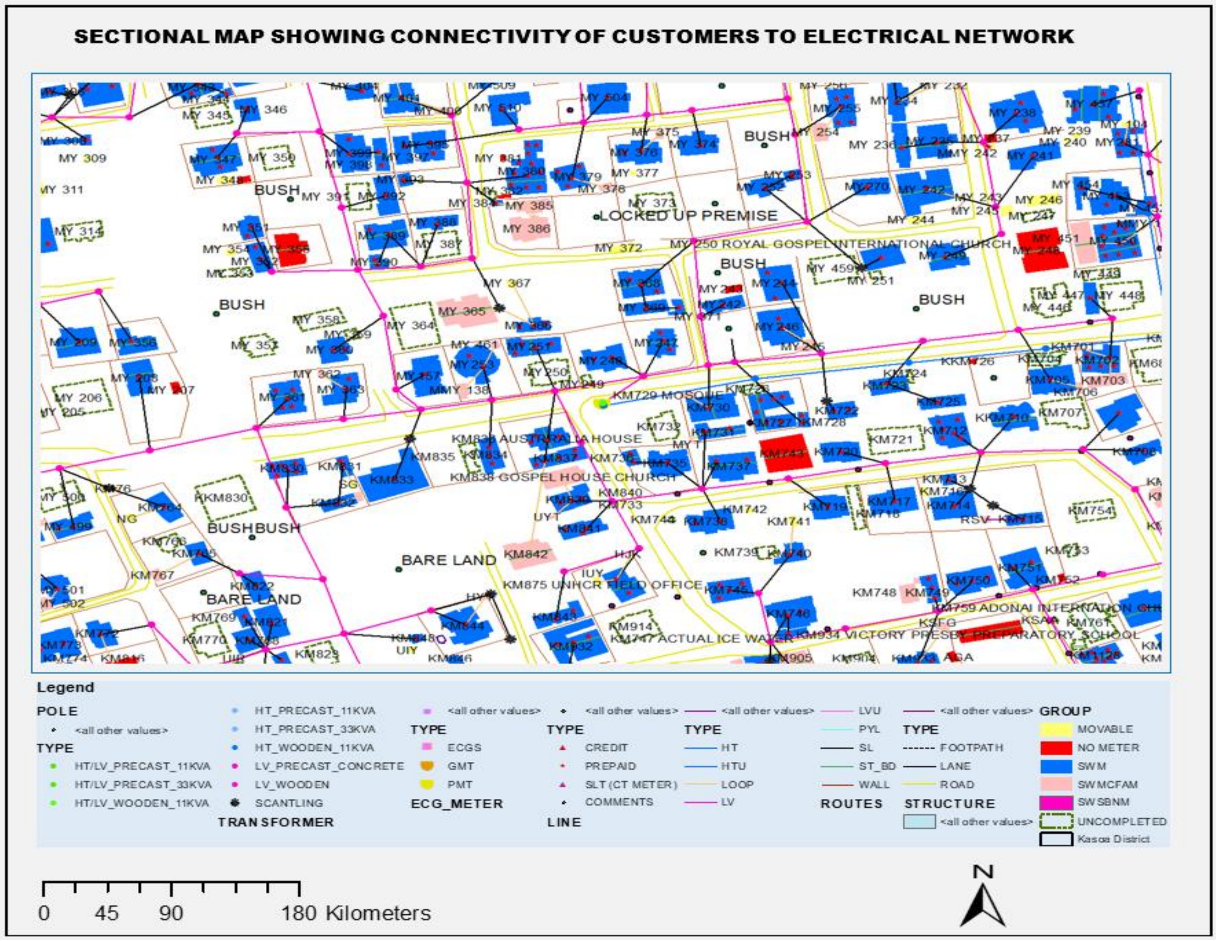


Figure 3: Sectional Map showing Customer connectivity to Electrical Network

Figure 5 indicates that structures with IdsA303 and A300 have direct service line supply from the network but have no meter which denotes an illegal connection.

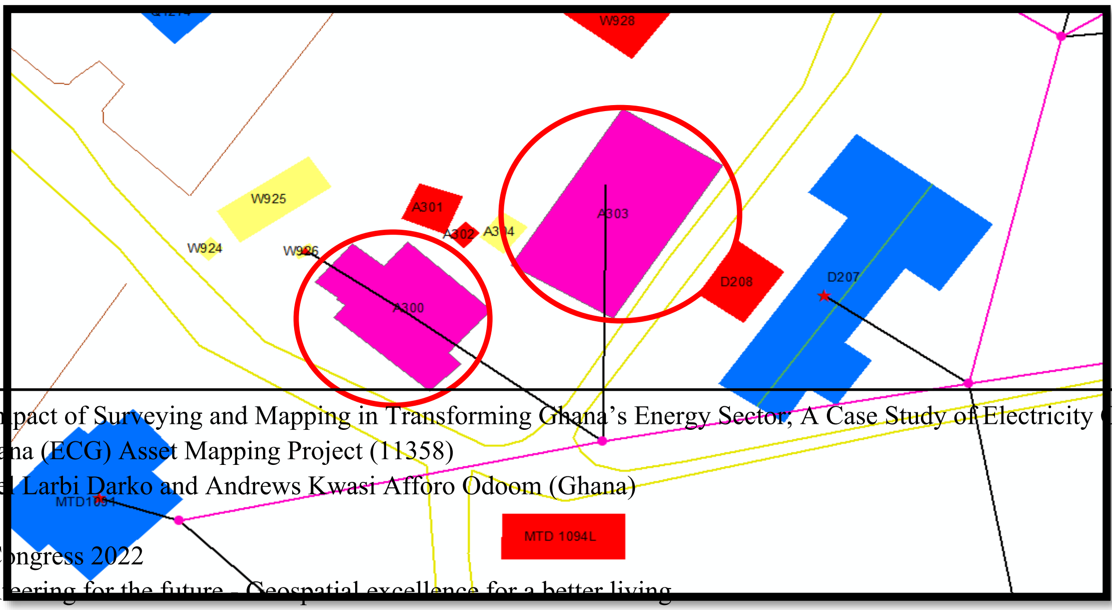


Figure 6 shows an unelectrified community with the dominance of uncompleted houses. This is suggestive of the development of a new community that would need electricity. This knowledge is essential for ECG to extend its network within an unelectrified community, in

Figure 4: Map result demonstrating sample of illegelly connected customers

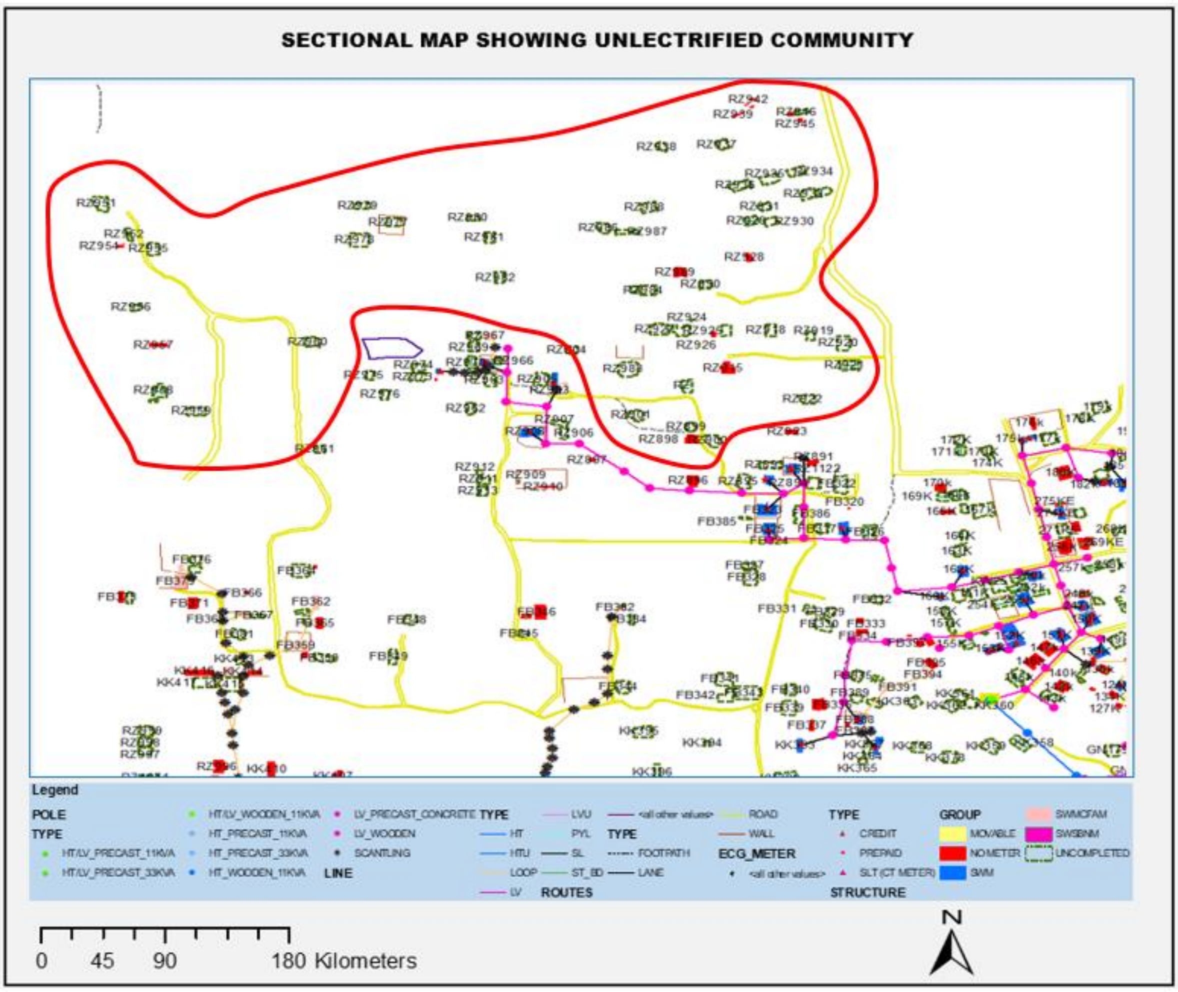


Figure 5:Sectional Map Showing Unlectrified Community

Figure 7 shows a sectional map that demonstrates the usefulness of the map to compute a precise estimation of resources like several poles and the length of electrical cables needed for connecting a new client or an unelectrified community to the electrical network. For example to connect R2983 to the network the closest pole is 228.8m away. This avoids the overestimation of resources by field engineers and makes planning easy.

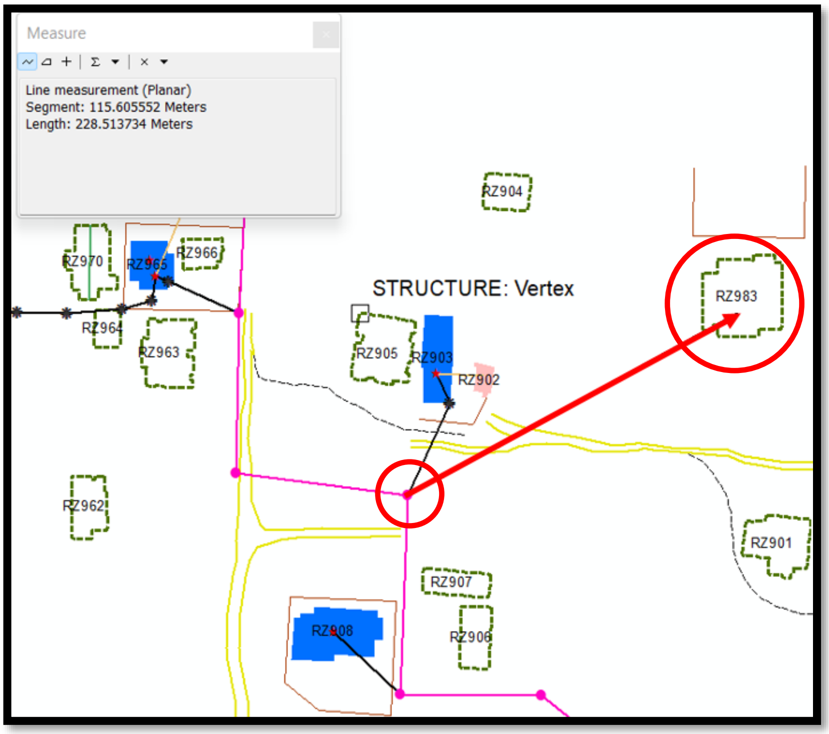
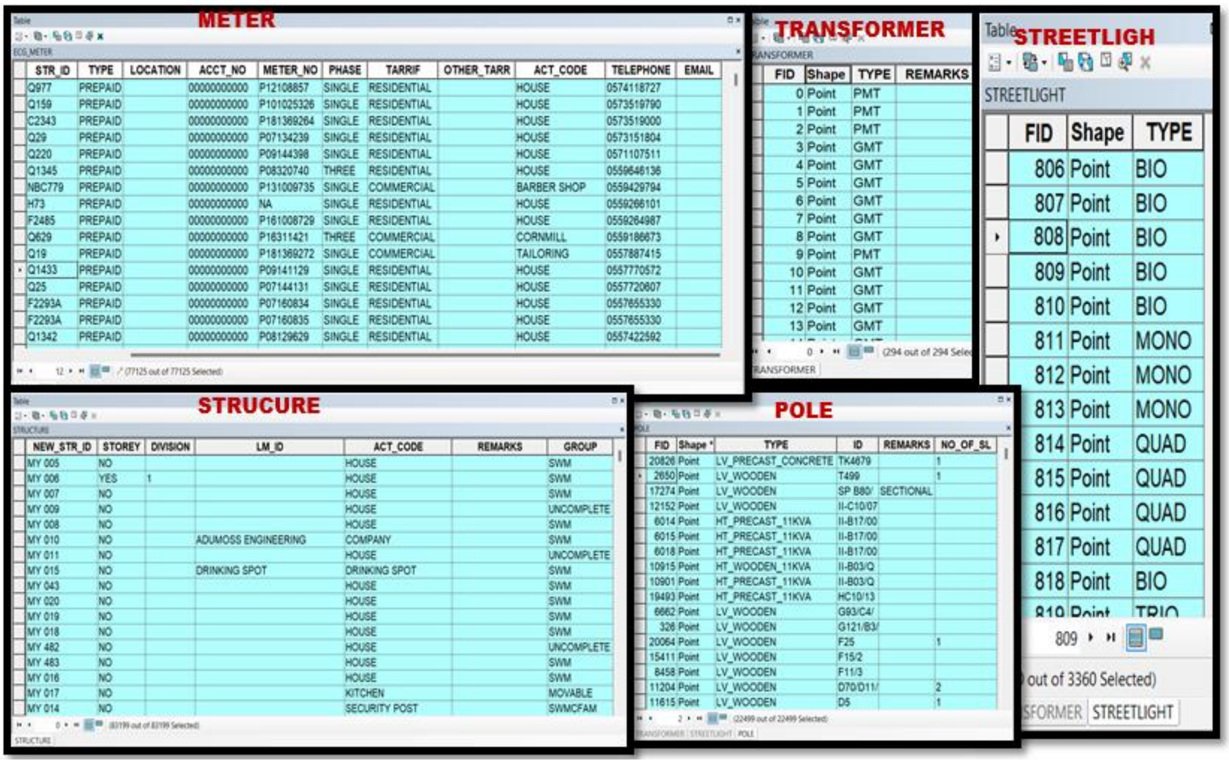


Figure 6: Estimating resources for connecting a new customer

Table 2: Table Showing Attributes of map layers

Table 2 provides sample attribute information for various layers. Analysis of activity code and meter tariff can be useful for detecting and resolving tariff issues. For example, if a



STRUCTURE whose activity code is a factory (commercial activity) but has a METER with a residential tariff, it raises an alert for potential tariff problems for rectification.

8. CONCLUSION

An electrical asset map provides an easy, fast, and reliable platform for retrieving information, planning field operations, optimizing opportunities for revenue generation, and improving power supply service to consumers. The ECG asset map project has demonstrated the ability to identify the illegal connection, offer a navigational function that supports the planning and execution of field operations, and correct inconsistencies in meter tariff assignments. The benefit to close gaps for financial losses and create opportunities for revenue increment allows ECG to maintain its equipment, pay power producers and workers, and ensure sustainable energy supply to consumers.

A remarkable advantage of a digital electrical asset map is that it offers a smarter alternative to the analog system of managing electrical assets data and customer information. The obvious trade-off is that digital maps are effective for error detection and correction, suitable for numerical and non-numerical information processing, and quick means for information retrieval and analysis.

However, the effectiveness of an electrical asset map like any geodatabase management system relies heavily on data accuracy, completeness, and consistency. It requires a quality control system at every stage during the data process including the method of spatial data collection, software for data editing, and expertise of the technical data management team. ECG's operations are such that there are continuous changes to electrical network architecture, meters, and customers. This is mainly because ECG installs new meters for customers daily, installs new electrical equipment in response to network load augmentation needs, and extends the network to unelectrified communities. Hence, to maintain a complete database for reliable analysis and planning, constant and periodic update of map data is important.

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BIOGRAPHICAL NOTES

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Ing. Surv. Samuel Larbi Darko is the founder and CEO of Losamills Consult Limited, a mapping, and engineering company in Ghana which undertakes surveying and other geo-informatics assignments. Currently, he is the President of the Licensed Surveyors Association of Ghana (LiSAG). He has over 35 years of experience in land survey and digital mapping services, as well as delivering and managing complex projects. Samuel is responsible for charting the strategic direction of the company, in support of our local and international growth plans. Overseeing the commercial and technical roadmaps for Losamills' ever-expanding suite of high-quality mapping products. Samuel has a passion for technical innovation and is a regular speaker at international conferences and trade shows. He holds degrees in MSc Integrated Map and Geo-information Production (ITC, Netherlands), BSC Geomatic Engineering (Kwame Nkrumah University of Science & Technology, Ghana), Graduate Diploma in Law (University of Law, UK), Training in GPS Surveying (Trimble Navigation Ltd, UK), ArcGIS I&II (ESRI, USA), and System Development for Project Managers (ISS, Singapore).

His past working experiences include Executive Director (Sambus Ghana Limited) and Assistant Staff Surveyor (Survey Department Division, Lands Commission)

Co-Presenter

Andrews Kwasi Afforo Odoom is the GIS Business Manager of Losamills Consult Limited. He is a highly experienced geospatial professional with a technical, operations, and management background who thrives on developing GIS processes and products. His skills base spans geospatial analysis, spatial modeling, database management, data quality control, and project management. He loves working closely with customers, tailoring geospatial solutions to meet their specific requirements whilst delivering valuable business insights. He holds a degree in MSc. Geographical Information Systems (University of Brighton-UK), BSc Geomatic Engineering (Kwame Nkrumah University of Science & Technology, Ghana), Executive Mastery in Project & Contract Management (GSGL, Ghana), and Certificate in ArcGIS Pro Training (ESRI, USA)

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