Integration of Web-GIS and Remote Sensing in Power Pole / Line Asset Management System for PNG Unitech Campus

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Abstract

The use of GIS and Remote Sensing (RS) technologies, integrated with database management systems to manage electrical assets, is important to any electrical service provider, as it significantly reduces their workload while increasing the effectiveness of the utility's operations. This research was done to explore the feasibility of establishing an asset management system for Papua New Guinea's sole provider of electricity, PNG Power Limited (PPL), using the Papua New Guinea University of Technology (PNGUoT) as its locale. Due to PNG's diverse and complex geographical environment, the difficulty of power distribution within an area makes it challenging for the existing database system (MS Excel) to manage PPL's electrical assets effectively. This has highlighted the need for GIS and information technologies to work in coalescence to effectively manage, communicate and disseminate information on PPL assets, which can aid in better decision-making for planning, monitoring, and budgeting purposes. The rapid advancement of GIS, RS and IT technologies has made it much easier to understand the complex dynamics of utility management. This paper demonstrates the application of GIS and RS utilizing approaches derived from web GIS development methods to create an interactive and user-friendly web-based asset management systems for specific electrical assets such as Power poles, Power lines and Transformers located on PNGUoT campus in Lae City.

Keywords: *Asset Management Systems, power distribution, IT technologies, web GIS, power pole, power line, Lae City.*

1. Introduction

The Electricity Utility sector is vital in the development of any city. Parkpoom (2013) and Kanmani (2014) has argued that the sole purpose of any Electricity Distribution Utility (EDU) is to be dedicated to delivering energy to consumers by meeting the customers' energy demands. EDU comprises electrical assets such as power stations, high voltage transmission lines, transformers, feeders, electric poles and lines including others that constitute the electrical distribution system. EDU requires an effective and efficient means of being monitored and managed to enhance the operations, as well as extend the life of its assets and (or) to notify if there is any need for potential asset failure. Accordingly, for an asset management system to be effective, an electricity utility requires accurate information to constantly update its assets inventory. However, the complexity of the electricity power distribution system of an area may make it difficult to accurately collect data; hence, the need for incorporation of geospatial technologies like Web-GIS and RS to resolve such issues. This research was done to utilize a Web-based GIS incorporating Remote Sensing technologies to create an interactive map as an asset management system for PPL assets.

2. Nature of the problem and research questions

According to the PPL Information Handbook (2016), PNG power is responsible for generating, transmitting, distributing, and retailing of electricity all over Papua New Guinea. Like other electricity utilities around the world, PPL has a Supervisory Control and Data Acquisition (SCADA 2018) System that controls distribution network operations, monitors, gathers and processes real-time data, directly interacts with assets and records events into a log file.

The SCADA (2018) functions in such a way that it monitors the power distribution within the assets from the source and the power station to the substations (load centers) and from the substations to the load points (consumers), to detect any electrical faults that result in a blackout (open switch) where the system will notify the operator. The distribution of power within assets is only monitored by the SCADA (2018) system while the information about the attributes and conditions of these assets including spatial information is managed using Microsoft Excel spreadsheets.

It is critical to cognize that electricity generated from the power station is carried using high voltage transmission lines over an extensive area to load centers. The power is then reduced by transformers to be apportioned into grids and distributed by feeders to various load points (i.e., residences, building complexes, industrial areas, etc.). Over time the attribute information of assets' power-poles, power lines and step-down transformers will be difficult to manage using MS Excel when dealing with multiple spatial locations. Microsoft Excel in this instance lacks better data management and organization, complex querying and most importantly, use by multiple customers simultaneously. Assets such as power-poles and power lines are especially important; however, it is difficult to keep track of the conditions of these assets. As a result, many power outages are caused by deteriorating power poles and faulty power lines.

The purpose of the underlying research was to establish a Web-GIS power-pole and power-line asset management system since it holds both spatial and non-geospatial attributes for each power-pole and power line as well as transformers and can be shown on a digital map. The map also depicts the distribution pathway of the electricity that flows from the step-down transformers to each power pole, where required energy is transmitted through the low voltage power line to residential and academic facilities. Hence, this paper attempts to answer some research questions to contribute to the knowledge of Electric Utility Asset Management systems.

2. Materials and method

2.1 Study Area

Due to the complexity of electric power distribution in cities, the underlying research project that spurred interest in this paper was specifically targeted at developing a Web-GIS suitable for managing power distribution system within the PNGUoT Campus in Lae City (Figs. 1 and 2). PNGUoT campus is located within the vicinity of East Taraka that is 8 to 9 km outside of Lae City (Fig 1) in the Morobe Province of Papua New Guinea. Lae is considered as the industrial hub of the nation and is well known for its all-year round rainy season; the industrial and geographical aspects of the city give an optimum location for PNG's only Technological University in the Pacific region outside Australia.

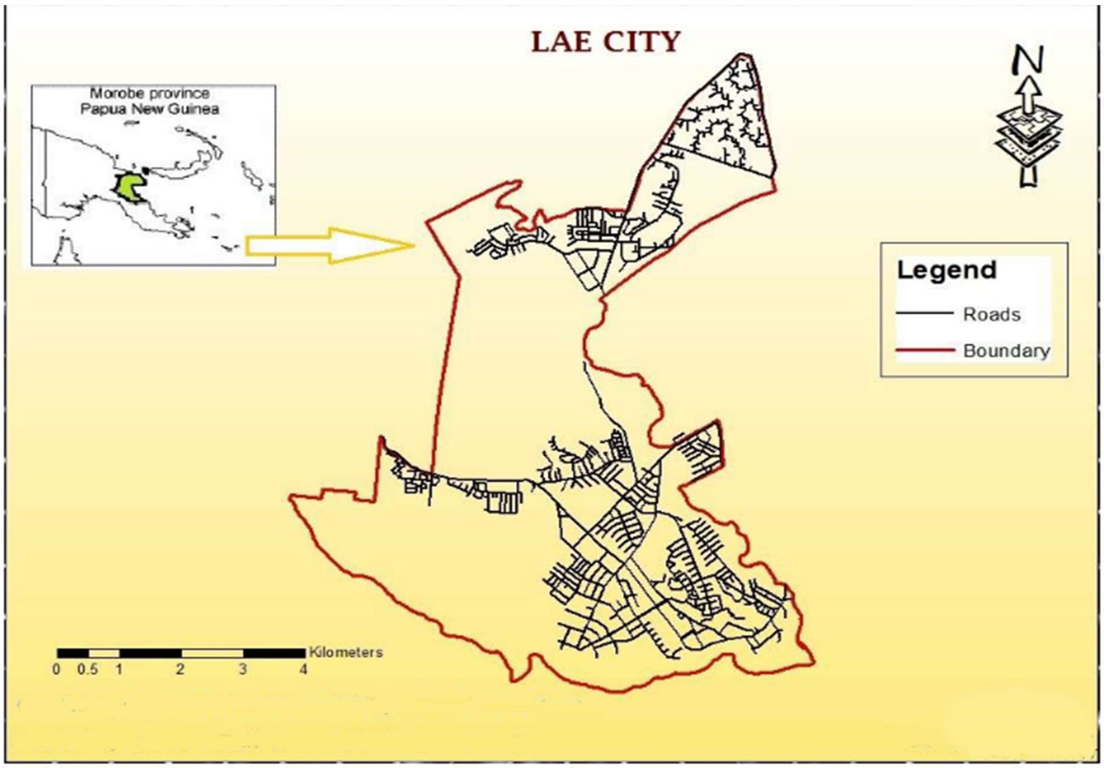


Figure 1: Map of Lae City Showing Existing Road Network

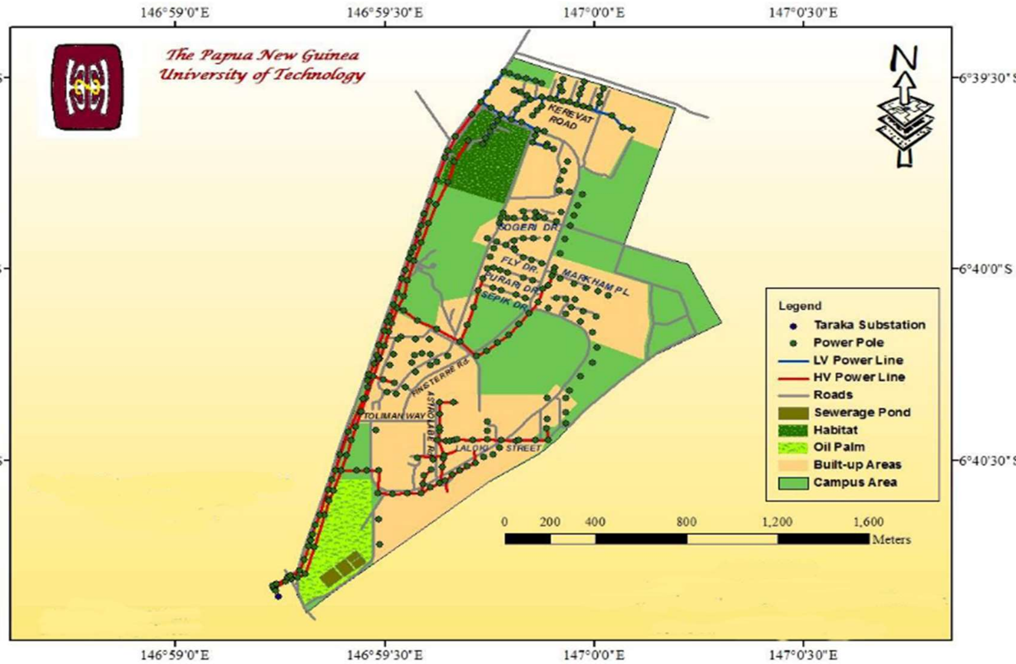


Figure 2: Map of the Study Area: PNG University of Technology (PNGUoT) Campus, Lae

2.2 *Workflow* Structure

The research was done in six (6) stages as shown in the asset management workflow diagram (Fig 3).

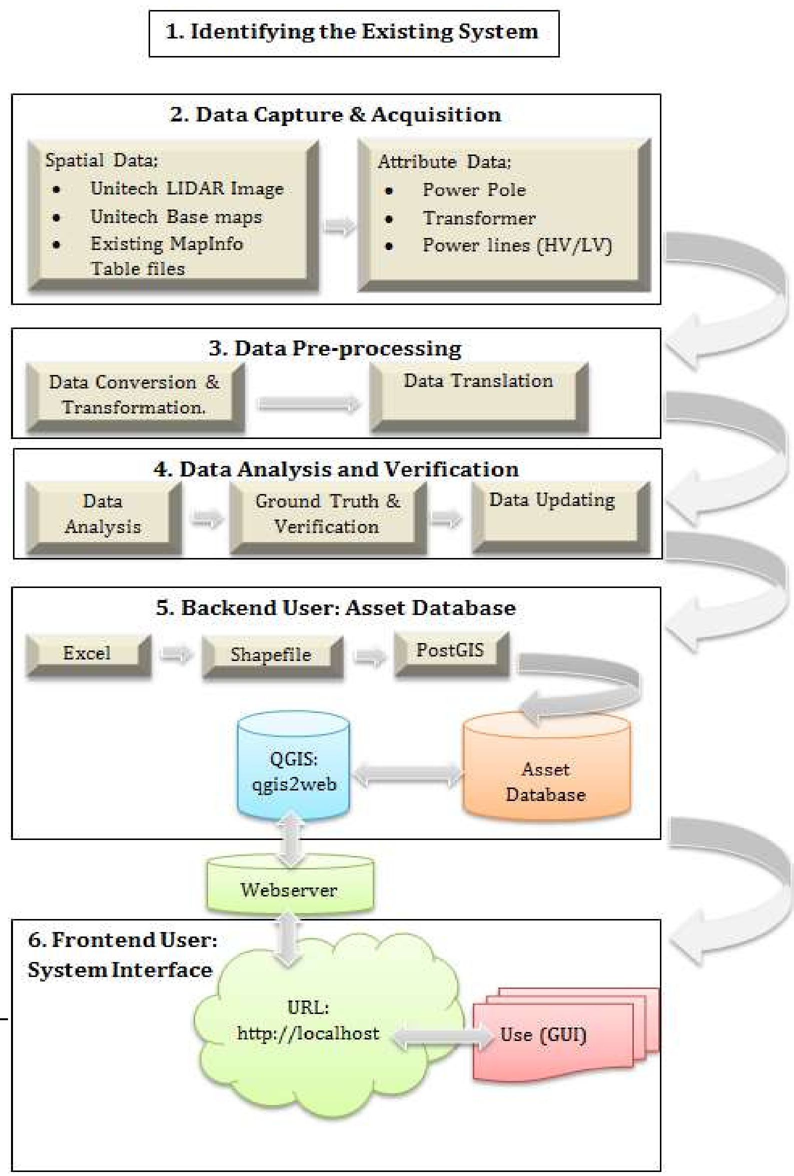


Figure 3: The workflow diagram of the research

2.3 Identifying Existing Systems/Operations

Interviews conducted by our team with key PPL officials at the Lae Power Distribution Centre revealed that all load centres use Microsoft Excel (MS Excel) to manage information about the physical and electrical attributes of the assets and are archived at the PPL headquarters located in Port Moresby. They also confirmed that that "MS Excel was not effective enough to maintain and monitor all information due to the distribution of power over a large area." Hence, this created the opportunity to develop a Web-based GIS management structure to be integrated with the existing PPL system (MS Excel) to improve assets monitoring and reporting functions.

2.4 Data Acquisition

The spatial and statistical inputs required for this research utilised remote sensing data and other in-situ techniques obtained from collateral data respectively. The research used a high-resolution LIDAR image which was captured in 2013, to extract spatial information. The data referencing system for the LIDAR image was set at WGS 1984 datum, using the Universal Transverse Mercator (UTM) projection system. Due to the exceedingly high spatial resolution of the image (20 cm), it was possible to digitize the existing power-pole and power-line infrastructure within the PNGUoT campus.

The statistical (attribute) data was provided by PPL in excel format and MapInfo table files. It contained both qualitative and quantitative information. Qualitative data deals with nominal measurements such as the names of features because the information is clustered according to the types or classes that are qualitatively distinguishable (i.e., Power-pole, Powerline and Transformer). Quantitative data is both in ratio and ordinal forms; ordinal data deals with grouping by rank based on some quantitative measures; for instance, the power-pole condition can be ranked as 'particularly good, 'good' and 'poor'. 'Ratio' is the highest level of measurement that includes an absolute starting point that emphasizes entity value, distance and coordinates and is associated with numbers (i.e., integers, dates, decimals, etc.).

2.5 Data Pre-processing, Translation and Verification

The LIDAR image was re-projected to WGS 1984 datum to maintain local PNG Mapping standards. All other vector spatial datasets were translated from MapInfo table files to ArcGIS Shape files and QGIS file formats. All statistical datasets were screened and checked for data completeness. The statistical datasets covered power-poles, High Voltage (HV) power lines and Low Voltage (LV) power lines. Verification of the spatial data was conducted during the ground-truthing exercise. A base map of the PNGUoT campus (Fig 4) was printed and checked for accuracy to use for the field verification exercise. It took a total of four days to do the ground-truthing based on the criteria-set in Table 1.

Table 1. Criteria used in Ground-Truthing

Objective	Criteria
To complete HV/LV power-line datasets	HV and LV lines were determined by these parameters/factors. • HV lines run above the LV lines • HV= 22Kv and LV=240V • LV always supplies power to the residential areas • HV supplies power to the Academic facilities and student halls of residences
To complete HV/LV power-line datasets	Determine the existence of individual power poles and transformers • Identify the flow of the power line

On the base map, the locations of the poles were compared to their physical locations on the ground and where they did not exist, they were omitted. The poles omitted were based on the premise that they were wooden poles that were damaged, hence they were removed to pave way for rerouting of the power lines to satisfy consumers' demands. Where there are more consumers (houses) the electricity demand is high.

Once all spatial and statistical datasets were verified and checked for completeness, accuracy, and consistency they were all uploaded into an ArcGIS environment. The datasets were then updated using three (3) phases. Omitted poles indicated on the map were deleted from the existing dataset, thus updating the power-pole attributes. Since power line is denoted by a polyline, it must have a starting point and ending point (which is from one pole to another); therefore, the power line attribute was updated using two tools in ArcGIS. The identify tool was used to determine the attributes from the starting pole from which the line started to the ending pole. Based on that the pole attributes such as the pole_id and feeder_id were determined for the power line since the power-pole acts as the parent entity from where the power line originates. The Measure tool was used to measure the distance of the power line from one pole to another.

Combining the HV and LV attribute tables into one entity to be denoted as 'Power-lines' by digitizing over the existing HV lines to incorporate the LV lines, since they both cannot be joined or combined in MS Excel.

Figure 4: The base-map of the Papua New Guinea University of Technology campus

Figure 5: The data verification map of the PNGUoT campus

2.6 Asset Database Design (Back-end user)

The required database system utilized a Relational Database Management structure; the logical phase shows the data elements and the relationship between these elements and can be referred to as the model of data storage theory (DB Schema). This schema (Fig. 6) indicates that the power-pole acts as the parent entity that the transformers and powerlines need to exist.

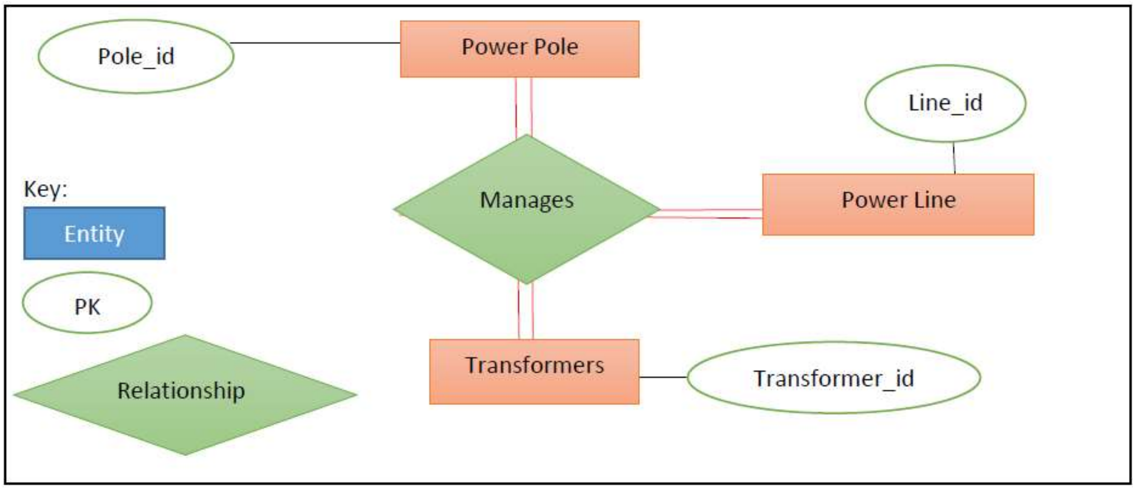


Figure 6: The database schema of the research

The database was created using PostgreSQL and PostGIS; hence, when the data was converted from MS Excel and MapInfo table files to ArcGIS shapefiles, which made it possible to create a spatial database in PostgreSQL. This is because the software recognises the related geography and geometrical relationships between the objects within the database. The PostGIS extension was also added as a plug-in into PostgreSQL to add spatial functions for optimization and spatial capability purposes (Fig 7).

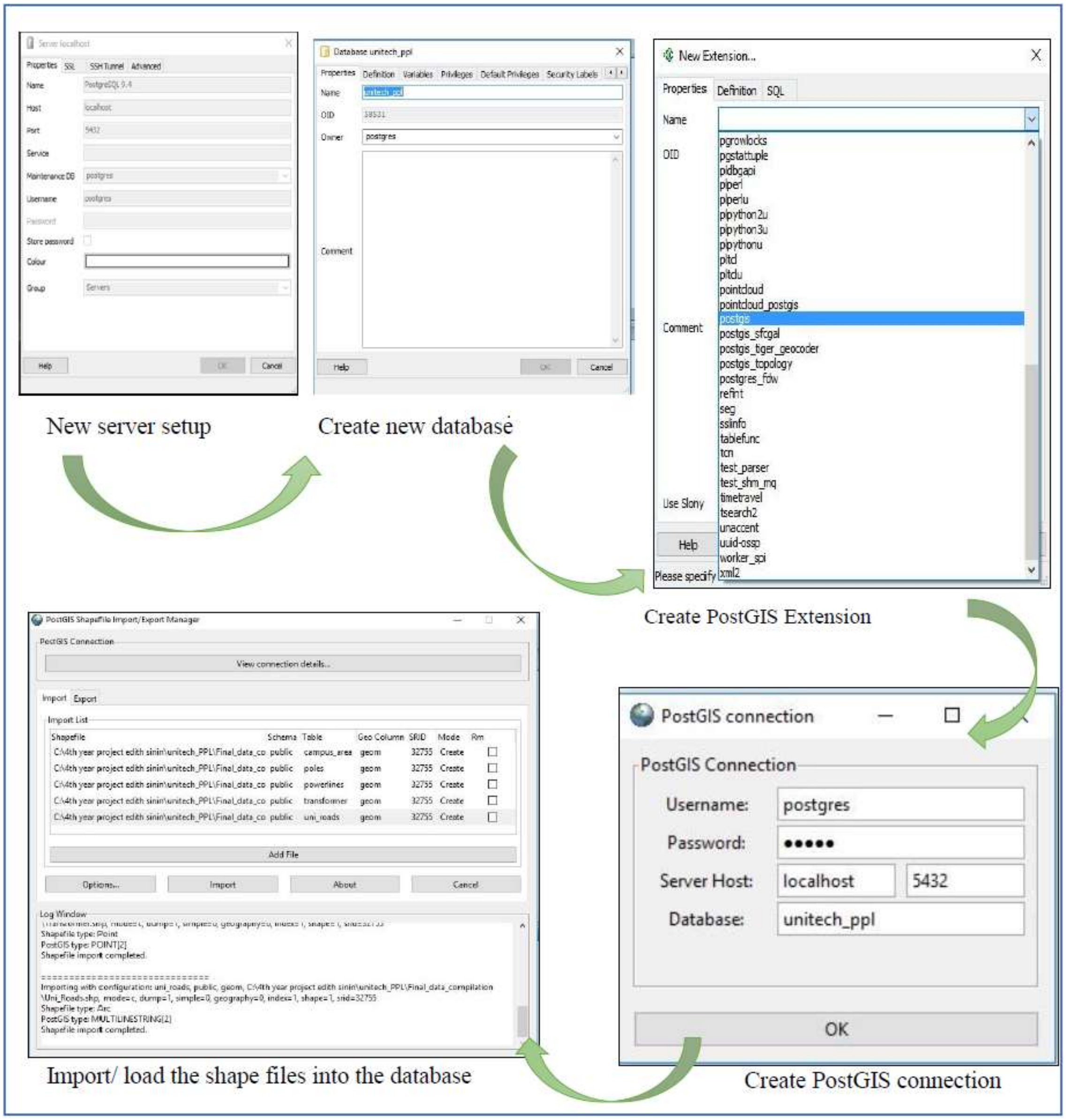


Figure 7: Loading of data into PostGIS

An Entity Relationship Diagram (ERD) as shown in Fig. 8 was created to query the database. The graphical query builder was used to build the ERD in PostgreSQL. Once the ERD was established the database was assessed by running queries either as single attribute queries or multiple table queries as shown in Figs 9 (a) and (b). Moreover, queries can be done using the MacEachren Cartographic Cube to identify potential user requirements.

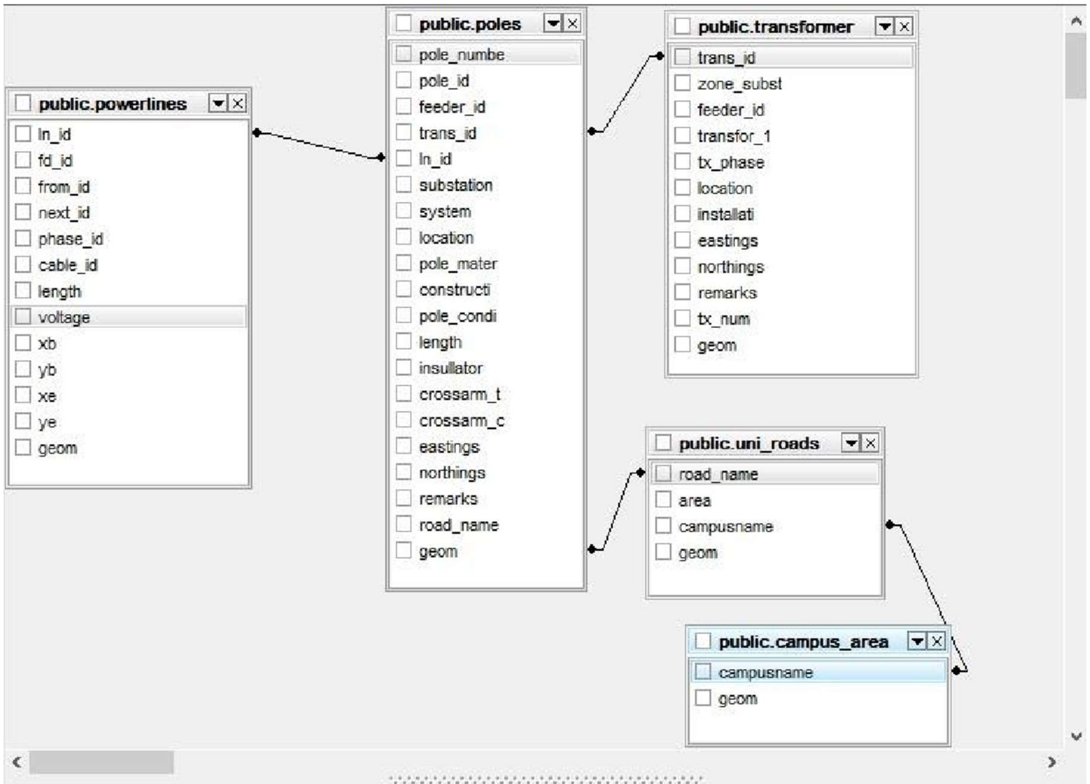


Figure 8: Entity relationship diagram

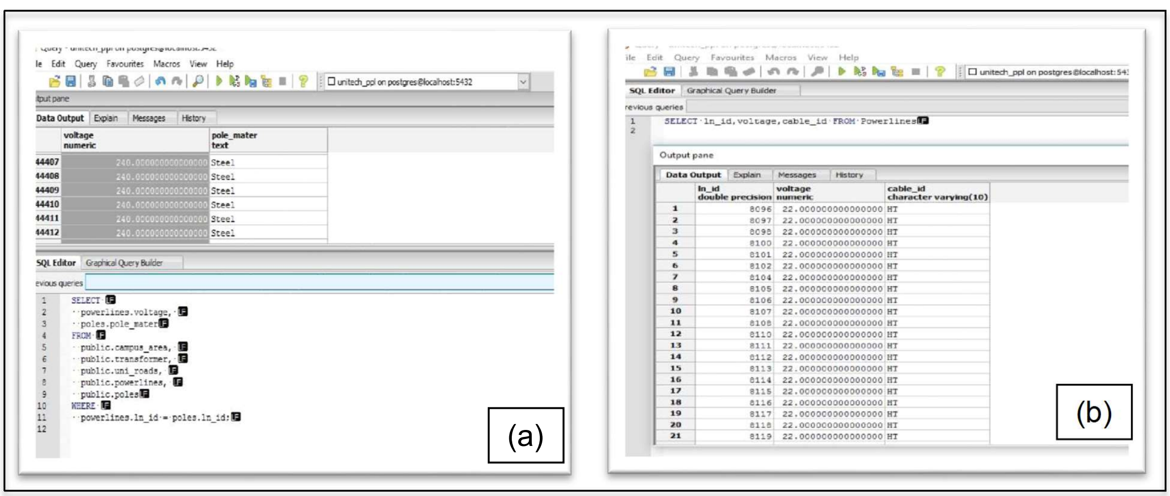


Figure 9: Query by multiple tables (a) and multiple queries by a single table (b)

2.7 Asset Management User Interface (Front-end user)

The research had to determine a method to convert Geospatial datasets (e.g., shapefile) into a format that can be read over the internet. This was done in three phases:

i. Importing PostGIS tables into the QGIS environment

QGIS automatically prompts the user to enter the required credentials used in PostGIS. When the credentials are entered, it brings you into the workspace from which the "Add PostGIS layers" option is selected from the browser. After it is selected, a dialogue box is opened; this is where credentials are also entered to connect with the PostgreSQL server where the database is stored. Upon entering the credentials, the PostGIS tables can be added into the dialogue box from which "import" was selected and the coordinates were added accordingly. This now allows the tables to be opened in QGIS as layers.

ii. Creating and publishing map using qgis2web plugin

In the workspace, the layers were styled to the desired colour of each layer (points, lines, and polygons), each point layer size was increased to a readable size and the line weight for each polyline was also increased. For example, the "Uni_Road" attribute table was opened by which a new column was added as "image." In this column, basic coding was done to highlight the image corresponding to each road (i.e., adding image for Fly Drive: <img src = "C:/4th year project edith sinin/unitech_ppl_website/System/qgis2web_1568876133.79/pictures/Fly drive.JPG" width="300" height="250").

The project properties for the interactive map can now be set using Open Geospatial Consortium (OGC) oriented capabilities. Firstly, the Web Map Service (WMS) provides three (3) functions like GetCapabilities, GetMap and GetFeatureInfor, these capabilities support the creation and display of web maps from various sources. Secondly, the Web Feature Service (WFS) allows clients to update and retrieve geospatial data coded in GML. This specification defines interfaces for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform. Lastly, the Web Coverage Service (WCS) simply allows for the specification of the WMS interface to allow access to geospatial coverage.

The qgis2web plugin was utilized to provide basic interactive map functions such as zoom in, search, measuring and adding layers. For this online system, leaflet was preferred because it was deemed to have more map functions. Finally, to make the background of the interactive map appealing, Open Street Map (OSM) was used to overlay all layers. Finally, the web map was exported into an HTML file to be accessed online using HTTP on a computer platform.

iii. Interactive map customization and interface design

The interface was further customized by adding photographic images to improve its authenticity. Dreamweaver was used to design the interface such that links to database queries and interactive maps established were still intact. Furthermore, the online system was provided a security password and username and a system policy was created to secure and properly acknowledge the organization that provided data.

2.8 System Testing, Maintenance and Publishing

Dreamweaver provides an avenue to locally test the system before declaring the system acceptable, since it is an online system, and several factors were considered during the testing. Accessibility and usability are the attributes that any user requires to use it. Error checking is simply to check if the online system site has broken links and to fix them. For browser compatibility, the system can preview pages of different browsers and platforms. Most importantly, the user can check if the system achieves the objectives of creating a simper user-friendly and interactive asset management system.

Dreamweaver also provides an opportunity to identify differences in layout, colour, font sizes, default browser, and window size that cannot be predicted in a target. Internal testing was done from time to time when links were created and edited due to time limitations. However, for this project due to data confidentiality, this online system was not published to a webserver for the public to access it and to conduct external testing to get feedback from different users on their views about this online system.

3. Results

The online power-pole and power-line asset management system was set up successfully; this system interface is composed of two main system interfaces as detailed in the results. Fig.10 shows a snapshot of the login user interface enabling restrictions to authorised access only.

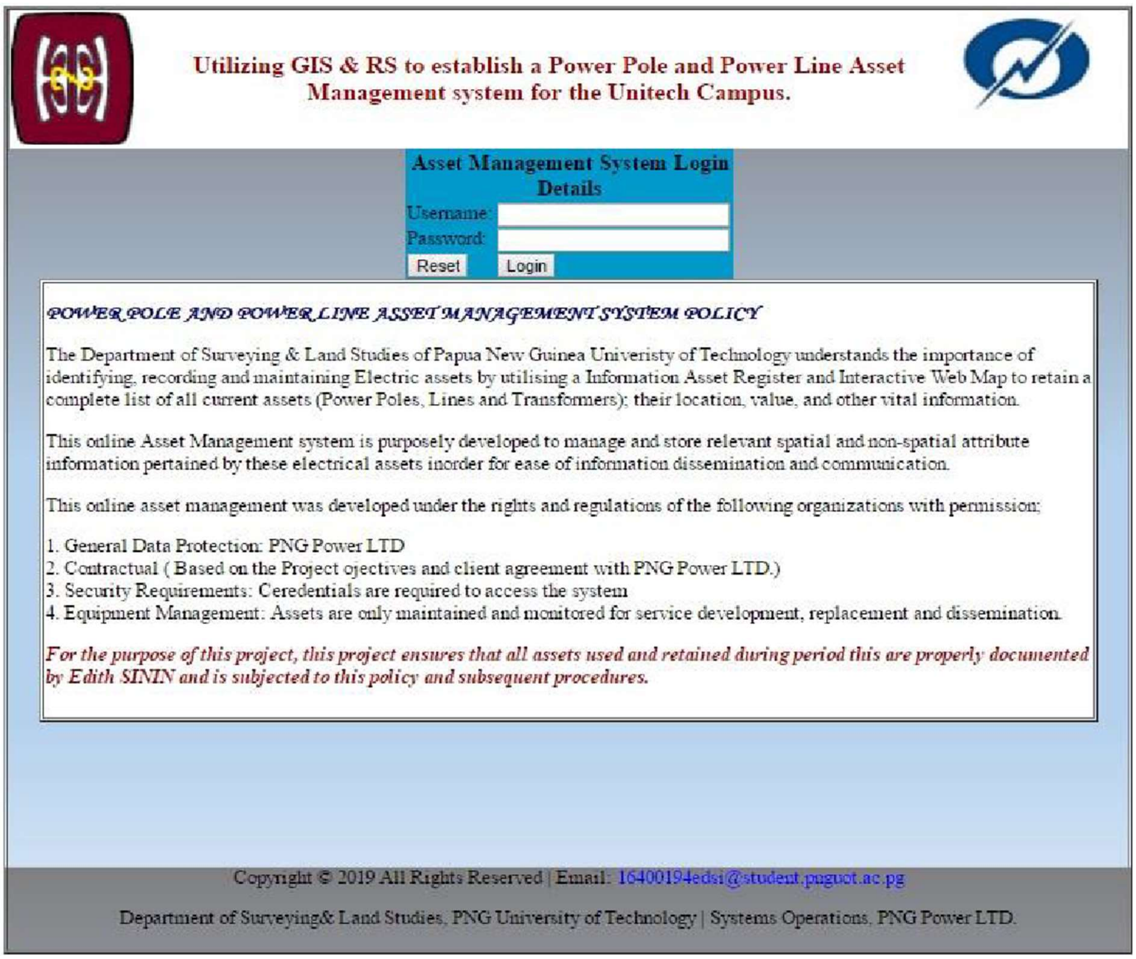


Figure 10: System policy interface

This online system was implemented in collaboration with the Department of Surveying and Land Surveying of the PNGUOT and PNG Power Ltd. A system policy was outlined to specify system requirements and security requirements to protect the integrity of the data. Moreover, a username and password were incorporated to provide data security for the online system.

3.1 Web-Mapping (Main System Interface)

The main system interface as shown in Fig. 11 was customized by adding links that contained asset datasets that were queried from the database and were exported to html files.

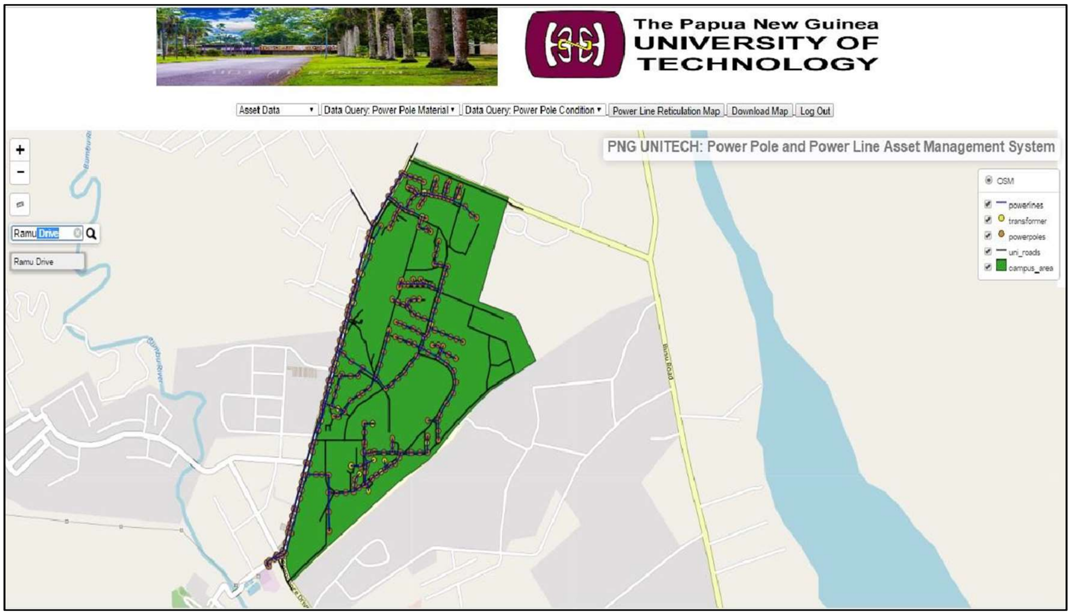


Figure 11: The main system interface

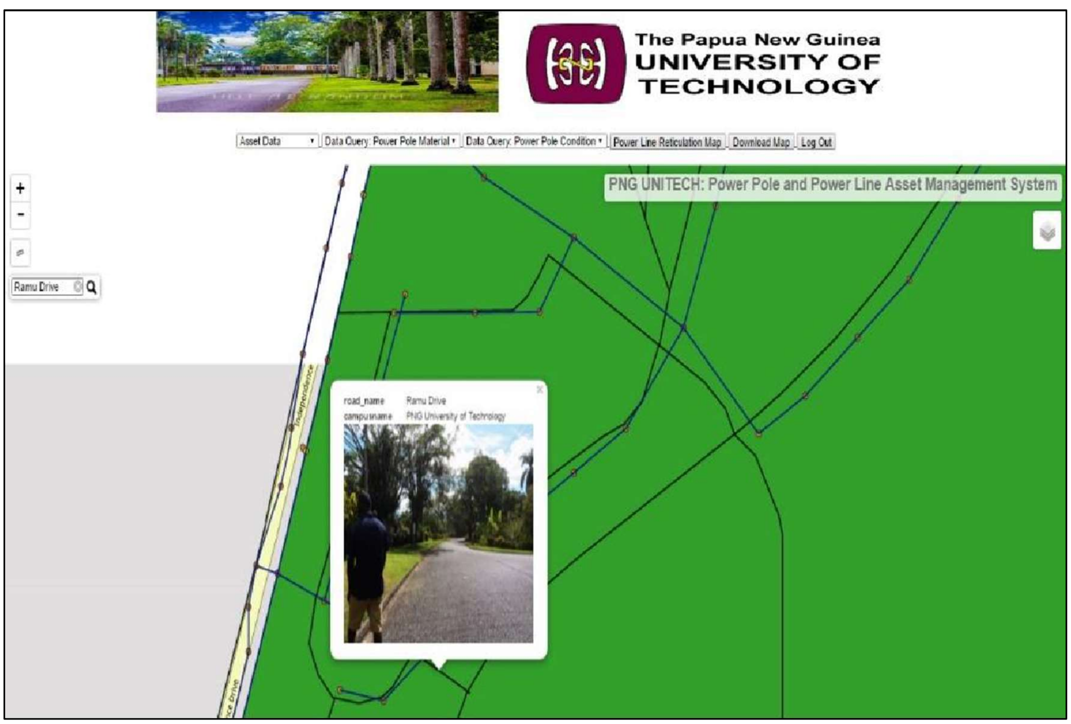
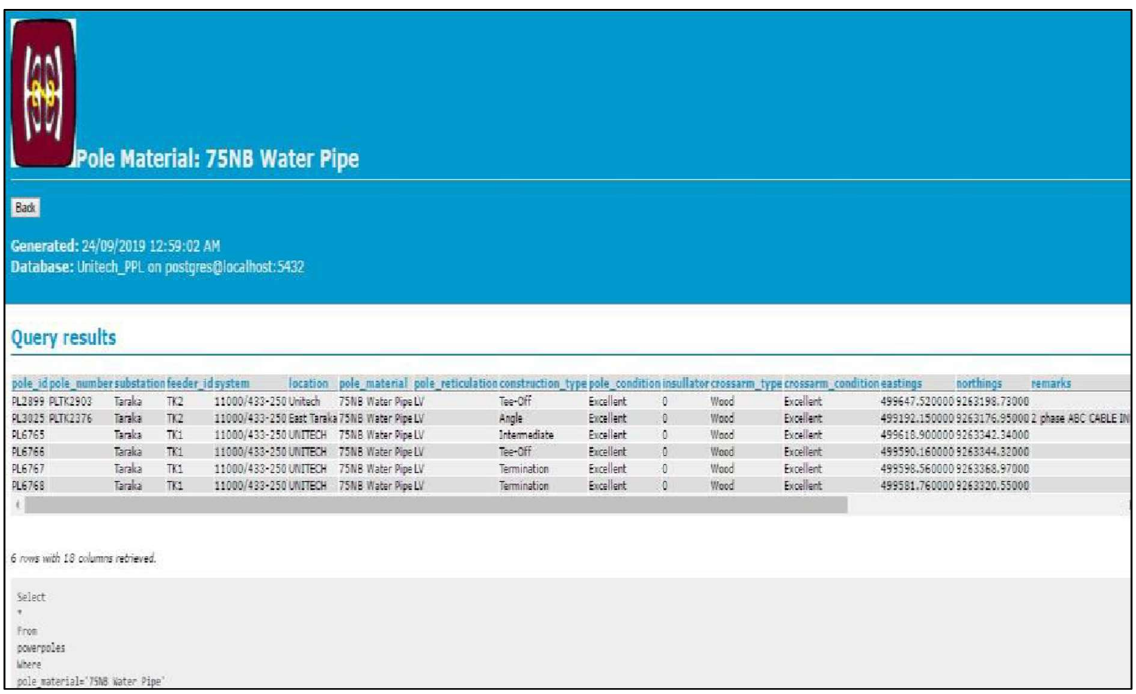


Figure 12: Search function interface

Once the user clicks on the road, a pop-up image is shown indicating the road name and campus name that are also complemented by an image for better visualization as shown in Fig.12. When the road name or street name are entered in the search bar, it automatically zooms into the road. From where the user can proceed to view the road's image. It can also allow the user to click on the power lines, power poles and transformer along that road. The drop-down menus in the main panel may be used to show query out-puts made in PostgreSQL. The query outputs can be shown either as statistical data in html format (Fig. 14) or as maps in pdf format (Fig. 15).

Figure 13: Main drop-down menus



Pole Material: 75NB Water Pipe

Back

Generated: 24/09/2019 12:59:02 AM
Database: Unitech_PPL on postgres@localhost:5432

Query results

pole_id	pole_number	substation	feeder_id	system	location	pole_material	pole_reticulation	construction_type	pole_condition	insullator	crossarm_type	crossarm_condition	eastings	northings	remarks
PL2899	PLTK2903	Taraka	TK2	11000/433-250	Unitech	75NB Water Pipe	LV	Tee-Off	Excellent	0	Wood	Excellent	499647.520000	9263198.73000	
PL3025	PLTK2376	Taraka	TK2	11000/433-250	East Taraka	75NB Water Pipe	LV	Angle	Excellent	0	Wood	Excellent	499192.150000	9263176.95000	2 phase ABC CABLE IN
PL6765		Taraka	TK1	11000/433-250	UNITECH	75NB Water Pipe	LV	Intermediate	Excellent	0	Wood	Excellent	499618.900000	9263342.34000	
PL6766		Taraka	TK1	11000/433-250	UNITECH	75NB Water Pipe	LV	Tee-Off	Excellent	0	Wood	Excellent	499590.160000	9263344.32000	
PL6767		Taraka	TK1	11000/433-250	UNITECH	75NB Water Pipe	LV	Termination	Excellent	0	Wood	Excellent	499598.560000	9263368.97000	
PL6768		Taraka	TK1	11000/433-250	UNITECH	75NB Water Pipe	LV	Termination	Excellent	0	Wood	Excellent	499581.760000	9263320.55000	

6 rows with 18 columns retrieved.

```
Select
*
From
powerpoles
Where
pole_material='75NB Water Pipe'
```

Figure 14: Statistical data in the application browser window

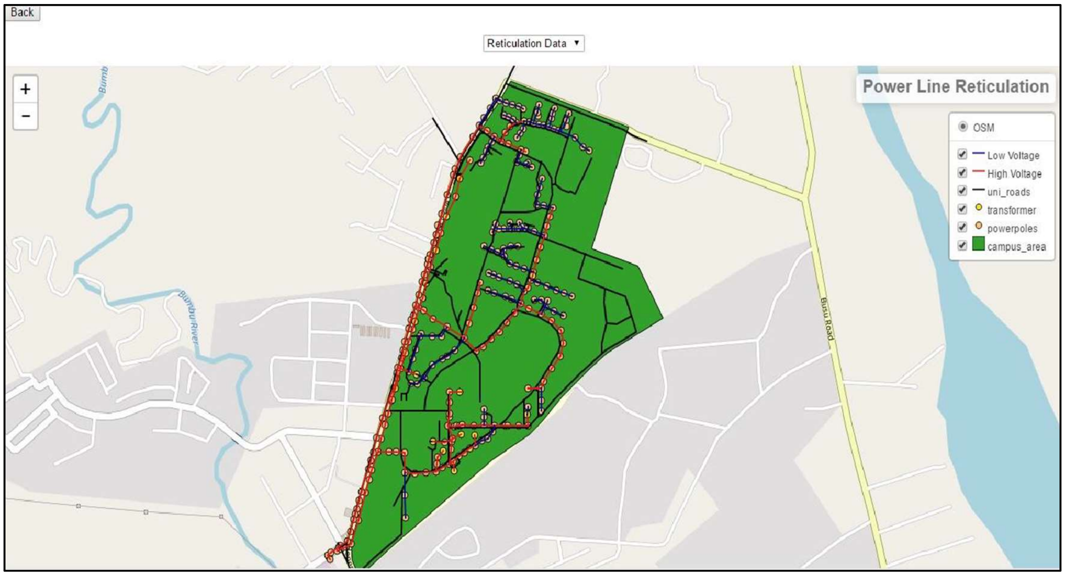


Figure 15: Map showing the Power Distribution System in the PNGUoT Campus

The Pop-up shows attribute information relating to the power-pole, powerline, or transformer when you click on them individually in the map-view of the Asset Management Application. This is shown in Figs. 16 (a), (b) and (c) respectively.

Figure 16: (a) Powerline, (b) Power-pole and (c) transformer attribute information

Though the research was completed; unfortunately, it was not published to a web server to be accessed by others with the understanding that the dataset used was confidential and cannot be disseminated without the consent of PNG power LTD. The accomplishment of this research has resulted in the achievement of all objectives and their purpose. Table 2 summarises the research questions and their respective outcomes.

Table 2. Analysis of results

Research Questions	Outcomes
How to apply interoperable web-GIS software that allows geospatial information to be disseminated and communicated using the internet?	QGIS is an open-source software that is OGC compliant and has an inbuilt server that aids the creation of an interactive map to communicate Geospatial information.
How to create an integrated geo-spatial database system?	PostGIS and PostgreSQL was used to create the geospatial database
Is it possible to create a user-friendly and interactive web mapping asset management system for the Transformers, Power-pole and Power lines within the PNGUoT Campus?	User friendly: ● Simple navigational aids ● Simple user interface ● Informative Interactive: ● Zoom function ● Unbroken links ● Search function ● Measuring function ● Information pop-ups ● Image pop-ups ● Legend (add layer function)

4. Conclusion and recommendations

The most important aspect of this online system is that complex information can be simplified into a pictorial format which is the interactive map. The stored attribute information can also be displayed and communicated if there is an internet connection. Geographical Information Systems (GIS) have diverse capabilities that can be used to solve day-to-day problems if the system is implemented and managed appropriately. As highlighted in this paper, GIS was integrated with municipal utility assets by combining spatial, statistical and image data, and storing these complex datasets into a simple interactive web map.

The question that should be asked is how can this online system be beneficial to PNG Power? This online system was designed and developed to be a user-friendly system for storing and disseminating information that can help PPL in better decision-making in Network operations and planning of Power Distribution, such as: 1) the asset management can be utilized for risk assessment mapping to locate poor conditioned power poles and lines that need to be repaired immediately to avoid black outs or other electrical faults. 2) The Asset Management System can help PPL in updating information instantly since the asset management system may be accessed anywhere using the Internet. 3) Most importantly, other centres can access this information online without the use of email since it is time consuming to send large data files.

Acknowledgments

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