Development of GIS Database for Infrastructure Management: Power Distribution Network System

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Abstract. Infrastructure management is an integral part of management in Universiti Kebangsaan Malaysia (UKM). One of the important infrastructures is the power distribution network system. Integration of Geographical Information System (GIS) in the power distribution system provides an upgrade in method to collect, store, and handle the data more professionally. Web-GIS application platform allows online data sharing for authorizing the users to get access to spatial and non-spatial data of the power system. Interactive online mapping provides three important modules that are viewing the module, statistical module and query module. These three proposed module is to help the user become more understanding of the related data. This paper describes how the process starting from data collection until the production of Web-GIS for online data sharing in the electrical distribution network system in UKM. The proposed online application integrates all the spatial data with complete power distribution information. This Geospatial system is able to enhance the management quality for a better sustainable campus.

1. Introduction

Infrastructure management has become an integral part of any organization, either in the private or government sector. The proper maintenance of the infra is crucial in order to properly serve the people and to avoid any accident. The infrastructure that deteriorates means a requirement of money and leads to an increase of cost of maintenance [1]. Every year's, budget allocation by federal or state government, they spent hundreds of millions of taxes payer money on the development and maintenance aspect to show how crucial is that to the nations. One of the crucial infrastructures that comply to the build of the campus of Universiti Kebangsaan Malaysia (UKM) is the power supply distribution infrastructure. Smooth, meaningful and productivity directly related to how well the...
management of the availability generated power to comply with the growing demand of the electricity [2].

As UKM moving forward to the digitalization era, a lot of equipment in the campus use the electricity such as machine in the lab, computer and also the basic need such as a lamp and air conditioner. The efficiency of the power transmitted cannot be achieved without proper record and monitoring of the distribution system. Any organization that plans to provide the optimum efficiency in day-to-day operations must know what asset it has, where they are, their condition and how they are performing [2]. The information about the physical assets is necessary in order to make a proper strategy in the decision-making process that will influence the operating level. Hence, to make sure there enough information in the decision-making process, data must be collected and neatly store so that the analysis that been carried out will increase the potential in operating level.

Geographical Information System (GIS) technology has a multidimensional approach in addition to being amenable to controlled planning, zoning of specific areas, preparation of land inventories, site suitability assessment, and socio-demographic analysis, it is generally utilized for mapping purposed [3,4]. GIS cover from the aspect of the database for inventory, map interacting viewing and several methods of analysis based on need. Based on this capability, the implementation of GIS in power distribution management is a suitable approach to increase the performance of serving to the end-user. Universiti Kebangsaan Malaysia (UKM) is trying to implement GIS and integrate it with any existing system at the moment [4-6]. However current standard operating procedure power distribution system, no existing system that can be integrate with, therefore, a new fresh system based on GIS is developed to create an upgrade to the conventional method in managing the system. The objectives of the study are;

- Data collection of location and attribute of each features in the power distribution network system in UKM.
- Development of the GIS geodatabase, and
- Developing the Web-GIS application for data sharing platform

2. Literature Review
The power distribution network is one of the main parts of the power system as it is connected to the load center [7,8]. The power distribution system in UKM consists of several components that started from the main substation that supply 33KV to the other substation in several parts of UKM through power cable before it supplies to the building. Geographical Information System (GIS) is a set of technology procedures designed to capture, store, manipulate, analyze, manage, present and disseminate spatial or geographic data for public or decision-makers [9]. GIS covers every part of any system in the spatial aspect starting from data collection until data analysis. Every component of the power distribution system can be map spatially by using GIS. The conceptual model of GIS provides a useful way to visualize it as a set of map layers or themes, all registered together to a common map base or geographic area [10].

GIS database or geospatial database contains information that displays a geographic surface that shows space and spatial data types in its data model and query language [11]. GIS database consists of two types of data that are spatial and non-spatial. Spatial data is data that represents the space and location of the feature and non-spatial data show information about the subject. Non-Spatial data usually in either qualitative or quantitative value.

The spatial data model categorized into two types vector data model and the raster data model. Vector data model represented in three form point, line and polygon. The point data model has coordinated
value, the line data model has distance information and the polygon data model shows the boundary of space [12]. The vector data model usually in shapefile format and suitable to represent features such as sub-station building and power cable line.

Raster data model sometimes referred to as an image, array, surface, matrix, or lattice [13]. The raster data model used in this project is the UAV image for the whole UKM. Raster data carrying advantage that it can be created and used without interpreting the represented phenomenon to mean that it can be created without excessive knowledge of the survey area [14]. In Web-GIS Application, the internet has become one of an integral part of daily human life and an essential medium to satisfy human need [15]. Several past years show that web map has become one of the important parts of the internet material that access by a lot of users [16]. Evolution of web map until nowadays lead by many open-source solutions such as Geoserver, Tomcat Apache, Udig and OpenLayers [17].

ArcGIS Online is an online platform that serves to store and design a Web-GIS application in the Cloud environment. Cloud computing is an evolving model with new aspects and capabilities, maintaining the data of cloud is dominant [18-19]. In the present field, cloud computing is employed for cloud users, depending on their premise cloud users can access and share data from anywhere, anytime [20]. ArcGIS online use a web-application builder to design the Graphical User Interface (GUI) for the web application that suits the user and shares it in the online environment. Figure 1 shows the conceptual diagram Web-GIS application work.

3. Study Area
Universiti Kebangsaan Malaysia is one of the established research universities in Malaysia, which is covers around 1,000 hectares (Figure 2). UKM cover a vast area enough to be said as a small town that has all aspect of facilities and infrastructure which serve around 20,000 population including staff and students.
4. Methodology
This research has four important phases where each phase contributes to the development of a GIS power distribution network system (Figure 3). The first phase is data acquisition, the second phase is data preparation and processing, the third phase is GIS database development and the last phase is the Web-GIS application, the development of the online application that enables data sharing for all levels of authorized users.

**Figure 3.** General methodology.
4.1 Data Acquisition
Data Acquisition divides into two sources which are survey data and remote sensing data. Survey data is ground survey work where the researcher went to the site to collect measurement consisting of information location coordinates and attribute information for the features. The instrument used in this process is the Global Positioning System (GPS) instrument.

In this project, the method of capturing data is from an aerial perspective which is using Unmanned Aerial Vehicle (UAV) image that captures the whole of UKM. The accuracy of the UAV Image is 5 cm resolution, which is higher resolution compared to the commercial satellite imagery. With this high accuracy image, each feature in the image can be identified clearly and any digitizing data acquired from this image can be categorized as accurate.

4.2 Data Preparation and Processing
This phase is a phase where all the spatial location data, coordinate, and attribute of each feature are converted into any GIS format. Data format in GIS consists of two types, vector and raster data format. The vector data format in this project represents the point location of the sub-station, polygon as the footprint of the building, and line for power line cable. Raster data format is in grid form either in cell or pixel form. The accuracy of this data format depends on its cell size that forms the resolution of the image. In this case, the resolution of the image is 5cm.

4.3 GIS Database development
GIS database or geospatial database contains all the features that already converted into GIS format. These features or layers are put in one set of datasets that contain the element of spatial projection, scale, and domain. The purpose of using geodatabase is the capability of storing bigger data that consume space, supporting attachment, feature-linked annotation, geometric networks and etc. The layer in a geodatabase is a design based on query analysis purpose so that the process of query the data will become easier. The data then shared as a service and store in the ArcGIS server before use in ArcGIS online for application use.

4.4 Web-GIS Application Development
Web-GIS application is an online base that enables online data sharing for the user. This part uses ESRI product ArcGIS online as the platform to design the Graphical User Interface (GUI) that will suit the user. ArcGIS online using the cloud as the medium to design, service data reader from ArcGIS server and store the full Web-GIS application. Web-GIS Application is in the cloud environment and the data that display in the application is stored in the UKM server.

4.5 GIS Database and Web-GIS Application
UKM has started to develop a GIS database for the electrical distribution network system for the whole campus since 2016 for maintenance and operation purposes. This GIS database then used to develop an online platform in the form of Web-GIS for dedicated users.

4.6 GIS Spatial Database for Power Distribution network System
Development of GIS spatial database required GIS software and, in this study, ArcGIS desktop software is used to create Geodatabase. Geodatabase or “.gdb” enables the user to design, store, and manage spatial and non-spatial data in a single environment. For this particular purpose, one dataset that contains several features for representing the elements or components for an electric distribution network was created. The features that exist in the datasets are a design based on the requirement of the system start from the main electrical substation 33KV until the electric is supply to each building for the whole campus of UKM. Figure 4 shows the design of geodatabase for the electrical distribution system for UKM.
Features or components that created in the geodatabase can be view or display in spatial or map manner in the ArcMap desktop version. The graphic representing includes how the feature is presented either in point, line or polygon format. This phase also allows the GIS operator to enter the attribute information for each of the spatial features in the system by entering the database on the attribute field. Figure 5 shows the features in dataset already being set in a suitable manner to represent all the component that exists in the system. Figure 6 shows the arrangement of the attribute field of the non-spatial data.
Web-GIS is one of the online platforms that enable the user to access spatial data without relying on specific GIS software. This platform provides a friendly environment for non-GIS users who has no idea how to use GIS software. The web-GIS usually design for a better environment and fast information retrieval. In this study, the web-GIS is designed by using operation dashboard themes that suitable for operating level and also decision-makers level. These dashboard themes can summarize selected information and display it using a certain widget. Figure 7 shows the design of the operation dashboard for the electrical distribution system.

![Operation dashboard theme](image)

**Figure 7.** Operation dashboard theme.

5. Result and Discussion
The analysis is a crucial part of the system to show how efficient the data is being retrieved by the user. All the data include spatial data and non-spatial data must be ready to serve the user. For this application, three important basic modules are provided, viewing module, statistic module, and query module.

5.1 Display Module and Statistic Module
The display module is the most basic module of any web-GIS. This module uses the operation dashboard to give optimum information display for the user. This module consists of 3 main components that are map, layer and statistic component. Map component shows the spatial or location of each feature, the layer component displays the layer data for each feature and the statistic component is the summarize of selected attribute information. Figure 8 shows the map component that can display the attribute information using display pop up function.

The statistic module displays the statistic or summary of selected data using an infographic widget. This widget can show the selected data either in number format, bar chart, pie chart, or line chart. For this application, the statistics are displayed in number format for the total distance of power cable, the total number of the compact sub, sub-station and location intersection point of power cable and other cables such as pipeline or telecommunication cable. Figure 9 shows the selected data show using an infographic widget in the application.
5.2 Query Module

Query module is one of the most important functions in any GIS application. The Web-GIS query module is a very powerful function because it can combine the spatial data and non-spatial data in one exercise. This tool has the capability to combine parameters between non-spatial data with spatial data so that it can show the location of its target. For example, in this application user can query the location of compact-substation based on its parameters such as “Lingkungan”, “Ring”, “Bangunan” and Blok. Users can either choose just one or two parameters or use all the parameters to search the location of substation needed. Figure 10 shows the parameter searching window and the result of the query session.
Figure 10. Query parameter window and results.

6. Conclusion
As for the conclusion, this paper highlights the importance of spatial elements or GIS in the power distribution network system in UKM. This development opens up a new dimension in power distribution management, starting from digital data storing, digital data sharing, and digital data analysis. This digital arena allows the data to be stored and handle with more professional manners and also reduces the risk of losing the data compare to the conventional method. Web-GIS application provides a new data-sharing method and platform for the user that can help improve efficiency in decision making and operation. Web-GIS application gives more interactive display to the user in order to provide more understanding of the data by giving several basic functions to the application such as infographic widget and query widget. In the meantime, more data is being collected to complete the whole UKM Power Distribution Network System so that the analysis that can be carried out from the data can be more accurate and reliable.

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References
[1] Hamimah Adnan, Zafrul Fazry Mohd Fauzi, Ismail Rahmat adn Azizan Supardi. (2012). Maintenance Management for Public Infrastructure for Malaysian Local Authorities. ARPN Journal of Engineering and Applied Sciences, 1514-1522.
[2] Ihiabe Y. Adejoh, Ajileye O.O, Alaga A.T, Samson A. Samuel and S.O. Onuh. (2015). Application of GIS in Electrical Distribution Network System. European International Jounal of Science and Technology, 81-95.
[3] Syed Nawaz-ul-Huda, Farkhunda Burke, Muhammad Azam, Shazia Naz. (2012). GIS for power Distribution network: A case study of Karachi, PAkistan. Geografia Online Malaysia Journal of Society and Space, 60-68.
[4] Aimi Nadira Mohd Safie, Khairul Nizam Abdul Maulud, Wan Shafrina Wan Mohd Jaafar, Abdul Aziz Ab Rahman, Faiz Arif, Muhammad Mukhlisin, Othman Jaafar. (2018). Auditing Road Maintenance Work using Unmanned Aerial Vehicle, Jurnal Kejuruteraan, 1(5) 2018: 23-27.
[5] Fifi Susanti Sjafri, Khairul Nizam Abdul Maulud, Wan Shafrina Wan Mohd Jaafarb Faiz Arif, Abdul Aziz Ab Rahman, Muhammad Mukhlisin. (2018). Development of Road Maintenance Inventory in UKM by using Aerial Images, *Jurnal Kejuruteraan*, 1(2) 2018, 65-75.

[6] Nor A. M. Nasir, Khairul N. A. Maulud & Nur I.M. Yusoff. (2016). Geospatial Analysis of Road Distresses and the Relationship with the Slope Factor. *Journal of Engineering Science and Technology*, 11(5), 655-665.

[7] Wireman. (1990). Maintenance Management: World Class Maintenance. *Industrial Press Inc.*

[8] K. Prakash, A. Lallu, F. R. Islam, K.A. Mamun. (2016). Review of power System Distribution Network Architecture. *Asia-Pacific World Congress on Computer Science and Engineering*, 124-130.

[9] Mohd Aizat Saiful Bahri, Khairul Nizam Abdul Maulud, Muhammad Amartur Rahman, Aslinda Oon Binti Ridzuan Oon, Adi Irfan Che Ani, Che Haffify Che Hashim, Hairi Karim, Muhammad Syahidi Hasbullah, Mohd Za’IM Aziz. (2019). Development of GIS Database and Facility Management System: Asset and Space in UKM. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 563-571.

[10] Yadav, S. K. (2013). GIS in Power Sector Management. *International Journal of Engineering Research and Technology*, 759-766

[11] Grace L. Samson, Joan Lu, Mistura M. Usman, Qiang Xu. (2017). Spatial Database: An Overview. *IGI Global*.

[12] Sabiu, N., Muhammed, S.N, Zakari, N. And Khalil, M.S. (2015). Vector Data Model in GIS and How it Underpins a Range of Widely Used Spatial Analysis Techniques. *Dutse Journal of Pure and Applied Sciences* 1(1), 122.

[13] Pingel, T. J. (2018). The Raster Data Model. In T. J. Pingel, The Raster Data Model (p. 1). Washington, DC: Association of American Geographers.

[14] Bugya T., Farkas G. (2018). An Alternative Raster Display Model. In Proceeding of the 4th International Conference on Geographical Information System Theory, Application and Management (GISTAM), 262-268.

[15] Skarlatidou A, Cheng T, Haklay M. (2013). Guidelines for trust interface design for public engagement Web GIS. *International Journal of Geography Science*, 1668-1687.

[16] Peterson, M. P. (2005). A Decade of Maps and the Internet. *The International Cartographic Association (ICA-ACI).*

[17] Abdelhalim Bendib, Dridi Hadda and Kalla Mahdi. (2016). Application of Webgis in the development of interactive interface for urban management in Batna City. *Journal of Engineering and Technology Research*, 13-20.

[18] Zarnab Khalid, Muhammad Rizwan, Aysha Shabbir, Maryam Shabbir, Fahad Ahmad, Jaweria Manzoor. (2019). Cloud Server Security using Bio-Cryptography. *(IJACSA) International Journal of Advanced Computer Science and Application*, 166-172.

[19] Muhammad Aqiff Abdul Wahid, Khairul Nizam Abdul Maulud, Muhammad Amartur Rahman, Mohd Aizat Saiful Bahri, and Othman Jaafar. (2018). Integrated Infrastructure Management Using Web-GIS Application, *Proceedings of the Pakistan Academy of Sciences: Pakistan Academy of Sciences, A. Physical and Computational Sciences*, 55 (3): 21–30 (2018).

[20] Sarmah, S. S. (2019). Application of Blockchain in Cloud Computing. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 4698-4704.