



Integrated Infrastructure Management Using Web-GIS Application

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Abstract: The aim of this research is to build a web application using Geographic Information System (GIS) Technology and at the same time can assist the university in managing infrastructure asset. Infrastructure assets information which is stored using conventional methods such as in paper form; paper maps; and drawings are not reliable anymore. However, this information can be used by converting them into a geospatial data format. Furthermore, a geodatabase is created to store all the information. Spatial data and attribute data are connected to each other in the geodatabase. ArcGIS Desktop is an application to create, manage, edit, manipulate, visualize and publish geospatial data. The publish service will be used in ArcGIS Online and act as a medium to customize a webmap application. The web-map application is capable to provide and visualize the spatial and non-spatial information of each infrastructure asset. In addition, assets information can easily be shared among the university management and with the advantage of GIS mapping, the information can be understood by everyone. The research investigates the infrastructure asset management using ArcGIS Online and how it can improve the conventional method of asset management.

Keywords: ArcGIS Online, Geospatial, Infrastructure management, Web application, UKM

1. INTRODUCTION

Universiti Kebangsaan Malaysia (UKM) is one of the oldest universities in Malaysia and it is almost 50 years old. Within the last 50 years, a lot of new development and improvement has been done to provide better services to its community and the organizations. Infrastructure management is an aspect that is very important for an organization like UKM. Such organizations which provide services and in this case education services would need a proper workflow in managing all its infrastructures. Without a proper workflow in managing infrastructure assets, the organization tends to lose profit and also the customers, in these contexts the students of the university. As mentioned by E. Too [1], L. Hardwicke [2], and Mandele et al [3], economic growth also depends on the imperative role of the infrastructure assets. Therefore, massive

attention is required to have good infrastructure assets management because of the big roles its have within the organizations.

An asset is a store of value and one that creates benefit for the organizations. It is something that business possesses and deploys to create some future benefit. Cash, inventory, property, plant, and equipment are all considered business assets because they have value and can give benefit to the organizations [4]. Hastings [5] define asset management as the set of activities that are associated with identifying what type of assets are needed, identifying funding requirements, acquiring assets, providing logistic and maintenance support systems for the assets, and disposing or renewing assets. Asset management is a strategic and integrated set of processes to gain lifetime effectiveness, utilization and returns from physical

assets. In addition, infrastructure asset is a multiplex structure with extremely important and essential elements for an organization [6]. By understanding asset management, it will help organizations to manage the complexity of the infrastructure assets information.

Information Technology (IT), however, is the prime enabler of success in managing asset for organizations. This day, IT utilized for asset management is required to provide an integrated view of lifecycle information. Such an integrated view not only provides for the decentralized control of asset management tasks but also allows for holistic and informed decision support. A critical aspect of IT adoption is to find the strategic fit between the way an organization manages its assets and the technologies selected to aid in its execution [7]. This is supported by Hastings [5], IT in asset management has three major roles. IT is utilized in the collection, storage, and analysis of information spanning asset lifecycle processes. Secondly, IT provides decision support capabilities through the analytic conclusions from analysis of data. Thirdly, IT provides an integrated view of asset management through processing and communication of information and thereby allow for the basis of asset management functional integration. Generally, it means that the ultimate goal of using information systems for asset management is to create information enabled an integrated view of asset management. These inter-related components of asset management would benefit from what GIS technology can be offered nowadays [8,9].

Spatial and information system capabilities of GIS technology have been long recognized in assisting asset management. Baird [10] state that, GIS has become an obvious choice of the solution in asset management because of the extended use of asset information with spatial information. Spatial information capable answering all the questions about locations, patterns, trends, and condition [11]. This is supported by Campbell et al [12], taking the point of knowing what and where the location of the assets is where GIS comes to be acknowledged. A system with spatial integration is capable to analyses a complex data structure based on spatial location, such as visualize data using a map using various relation to show the proximity, adjacency, and others spatial relationship. For decades, most assets information was confined to use on desktop-based

PCs and could not be easily accessed or shared with other organizations. Nowadays, GIS technology also capable to host the asset information and shared the information across not only computers but in any mobile devices at anywhere and anytime. This is possible because of the new emerging technology, science and mathematics which influencing the approaches and understanding of the importance of asset management.

Nevertheless, the traditional method is still widely used in asset management, many organizations required their staffs to record down all the information in a paper form and later transferring the information into the digital database in tabular format. Meanwhile, human errors might happen during the process of transferring data of non-digital format as handwriting in a report form, it can get smudged or unrecognizable, typos and unintentional mismatches among data can occur as well [13]. This is very common mistakes when transferring information between different formats. However, this issue cannot be overlooked, technical staffs may not see the problem when such an incident occurred, but this kind of information is very important for the management. Management of an organization needs a lot of information and details in order for them to make decisions. Small errors in the information might produce a big impact on their decisions. Other than that, management also need to get the information in a very simple way but precise and the information need to be easy to understand, also the information can be access anywhere and anytime.

Therefore, GIS technology and its web applications technology can be a new approach for solving the issues of storing assets information using geodatabase and to make the information can be shared with other organizations. In addition, the information can be visualized with spatially related information which other asset management application does not have. GIS application will only help the organization to reduce the workload of their workers and also keep the updated data in their geodatabase. Samiullah [14] mentioned that GIS is very effective tools that can save time and resources. Besides, when the assets are linked to a geographic location and visualize it on a map, it can be a powerful decision-making tool [15]. In addition, GIS provides an efficient platform for better management of assets and outages, planning

and analysis, improving customer service, and increased the accuracy of data. This paper will briefly discuss the process of building a geodatabase that stores asset information, also how to publish the information and make it available online using web GIS application.

2. METHODOLOGY

This study was conducted to customize web applications using ArcGIS Online – WebApp Builder to visualize the information of infrastructure in UKM and also to integrate the information of all infrastructures with GIS geodatabase. The study will cover UKM, Bangi area and the focus are the buildings, roads, sewages, pipelines, and garbage bins as shown in Fig. 1.

Web GIS applications should be able to provide an informative solution to users. Combining the database that keeps all the information of the infrastructures and a geodatabase that contain the

spatial information of the infrastructures and to visualize in one application would be the main task of this study. The study is divided into four phases as a guideline and each phase needs to be done according to the guideline in order to ensure the objectives can be achieved. Fig. 2 used to show the workflow of the study.

3. DATABASE DESIGN

A geodatabase is a place where all the spatial data and non-spatial data are stored. A geodatabase will be developed to occupy the needs of UKM’s infrastructure management. The planning and design should take place before database development phases. This is to ensure that the databases can operate like it needs to be. Besides, a good database is important to support all operations and analysis [15].

There are three sub-phases in database design which are conceptual, logical, and physical.

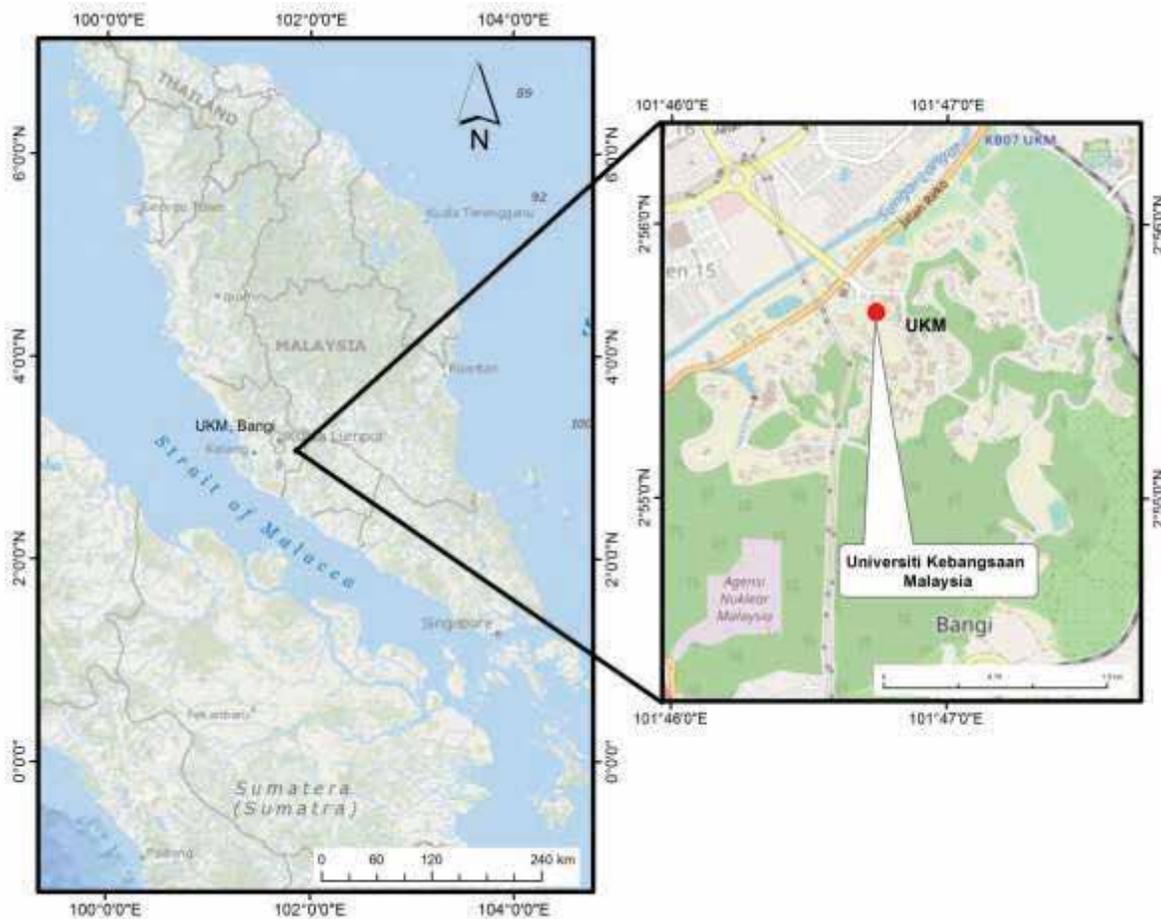


Fig. 1. Study area (UKM, Bangi)

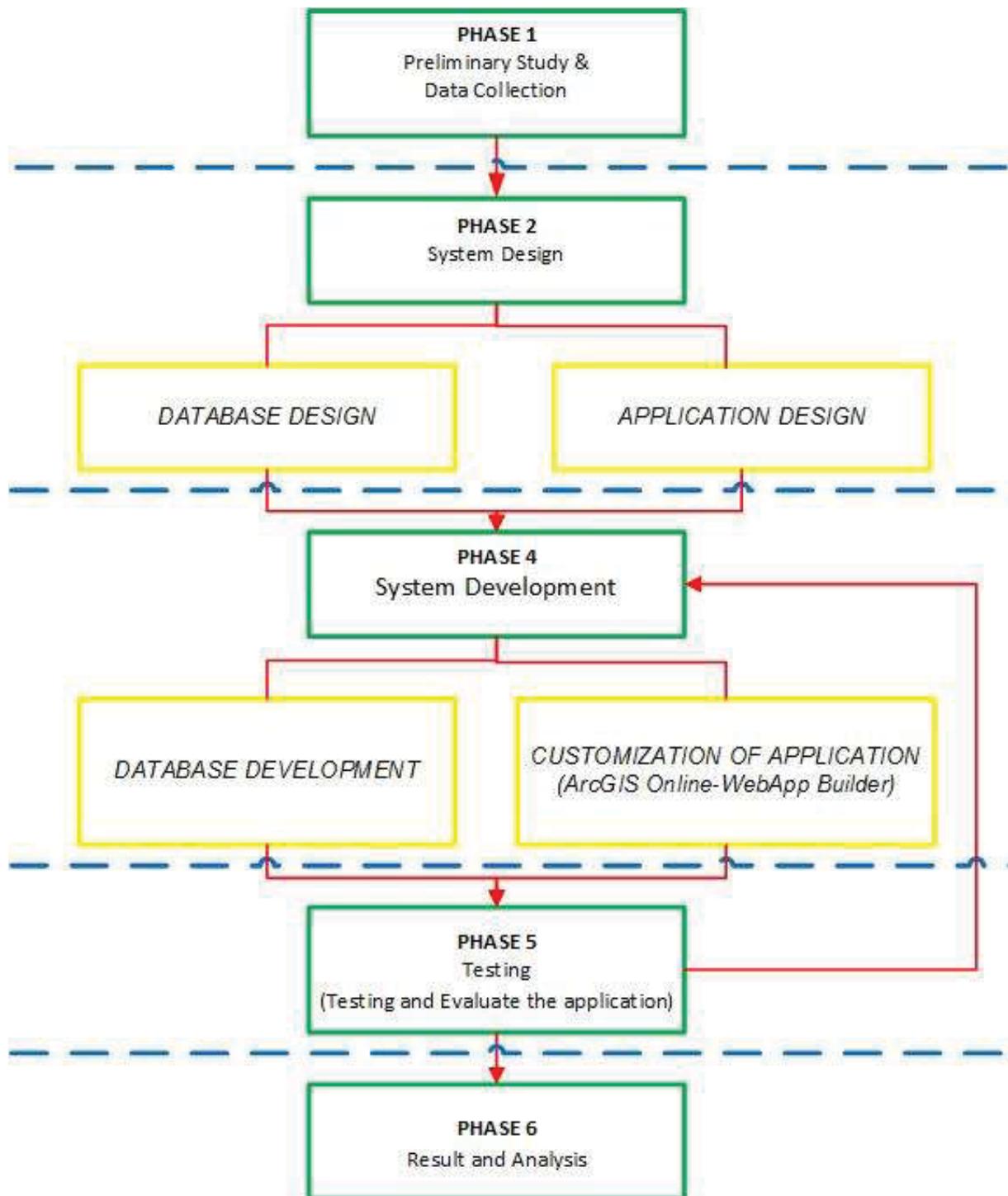


Fig. 2. Study framework

3.1 Conceptual

Conceptual design is a very important process in database design. This process will describe the data model for the application and also the overall scheme of the database. The database will be hosted in ArcGIS Online cloud service where the services will be shared to an authorized person only. This is

to ensure the data security. Open Street Map (OSM) basemap is used as a basemap for this application, this is to reduce the time for data processing while loading the web applications. By using ESRI's basemap layers, the process of uploading the basemap is simpler compared to uploading user own basemap. The service hosted can be access at the same time by the multi user as shown in Fig. 3.

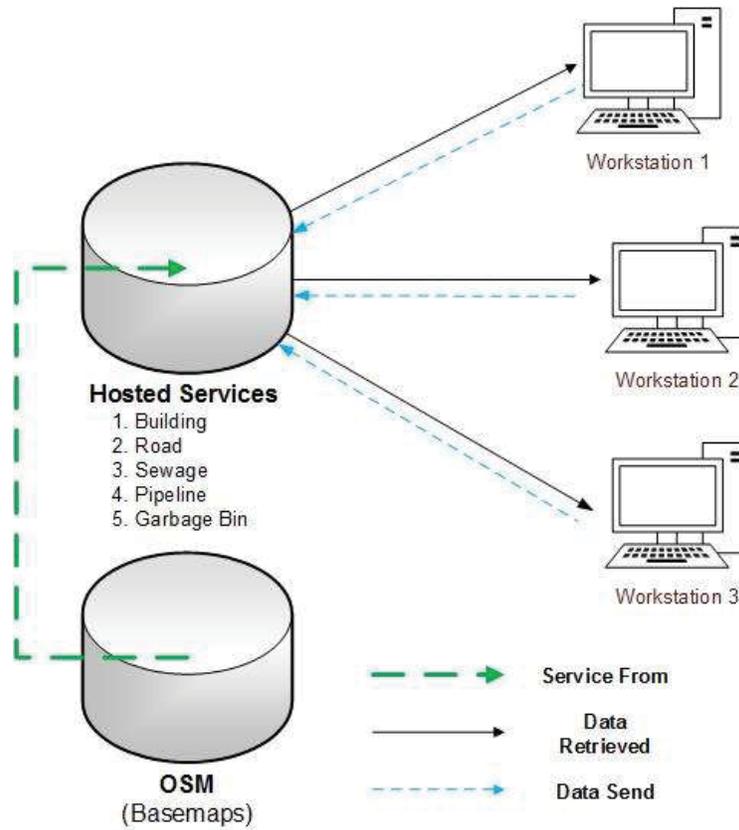


Fig. 3. Conceptual design

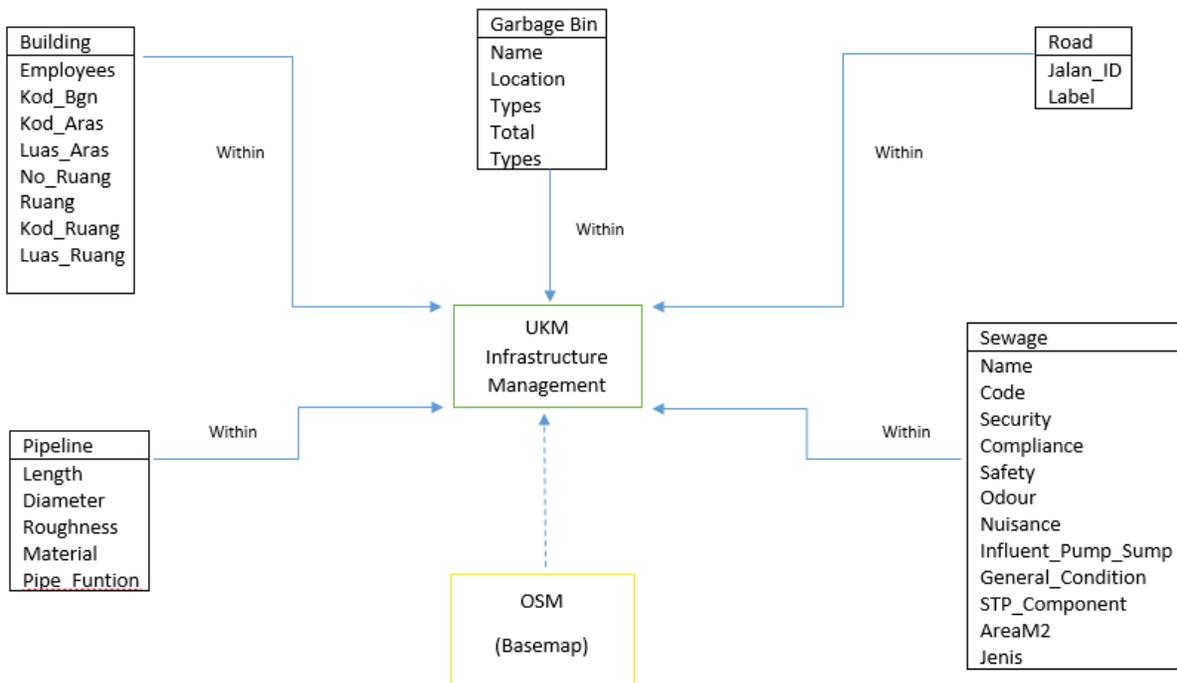


Fig. 4. ER Diagram for UKM infrastructure database

3.2 Logical

The logical design is the end users view of the data environment. End users are the people who use the application programs as well as those who designed and implemented them. The data storage is shown in the entity relationship logically as shown in Fig. 4. In logical design, the high-level data model of conceptual design is changed into a Database Management System (DBMS) data model.

3.3 Physical

The physical model requires the designer to match the conceptual model's characteristics and constraints to those of the selected hierarchical, network or relational database model. Because the physical design depends on the specific database software, it is said to be software dependent [16]. Fig. 5 shows the Geodatabase developed for UKM infrastructure management using Arc Catalog.

4. ARCGIS ONLINE

There are a lot of methods and techniques have been developed to provide a better process for infrastructure management. However, most of these applications were developed to work as a standalone system and with limited functionality such as inventory and condition data management [17]. This limitation makes the process inefficient, time-consuming and tends to produced errors when

interpreting the information.

ArcGIS Online technology is a convenient method to use for publishing spatial data online [18]. It is a collaborative, cloud-based platform that allows members of an organization to use, create, and share maps, apps, and data, including authoritative basemaps published by ESRI. Through ArcGIS Online user will get access to ESRI's secure cloud, and use it to manage, create, store, and access data as published web layers, and because ArcGIS Online is an integral part of the ArcGIS system, user can use it to extend the capabilities of ArcGIS for Desktop, ArcGIS for Server, ArcGIS apps, and ArcGIS Web APIs, and ArcGIS Runtime SDKs.

4.1 Publish a Service

As mention above, geodatabases are prepared in ArcGIS Catalog and Desktop. The geodatabase or offline data such as polygon, line, point and raster need to be published to be available online. Hosted service will be published in the organization account which is "Universiti Kebangsaan Malaysia". There are two types of services are available which are tiled map and feature service.

Tiled map service work like a cache map service. The entire map will be drawn in several different scales and stores copies of the map images. As a result, each time user request for the same service

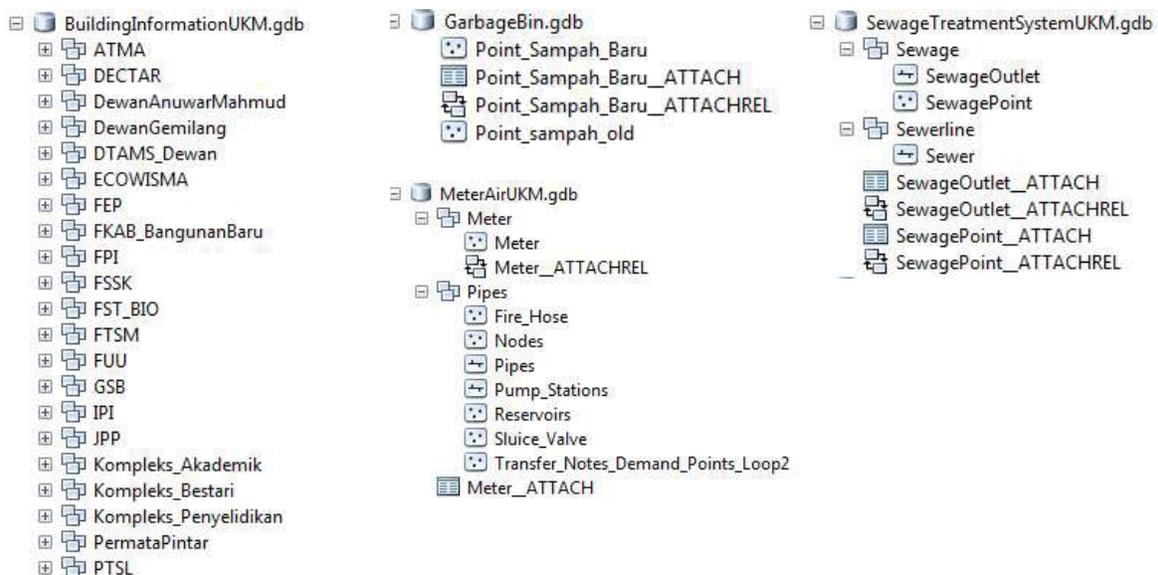


Fig. 5. Physical geodatabase of UKM infrastructure

the output will be quicker because it only needs to recall the caches rather than drawn the map again. Feature service allows the user to alter the data such as edit, add, delete, and update the data. Tiled map service does not have this service because the service is published as images of the data.

There are building, road, pipeline, sewage and garbage bin services and each has one GIS web applications. As mention above, the map of each data is prepared in ArcMap and the service will be published from ArcMap. It required an Internet connection. The user needs to sign in and use the same organization account. Once the process to publish and host feature layer in ArcGIS Online is complete user can see the services in organization account and proceed with creating a map and share it as web map and web applications.

4.1 Create and Share Map

In this phase a map will be created to be used to build a web app. Starting with a basemap, configuring the data, and customizing the application settings. Finally, all the maps information will share with all members in the group created before. The layer that published before will be added to a new map. The default basemap used were standard ArcGIS Topographic basemap. For this map, OSM maps are chosen as the basemap.

As mention above, the web applications will be created a base on the type of infrastructures. Each

type will have different web map. Fig. 6 shows one of the web maps of the garbage bin. All web map will be used the same basemap. Next, the user adds the feature layer and configures the symbology and how the attributes will look to the end user.

5. RESULT AND DISCUSSION

ArcGIS Online already provides templates that can be used for the web applications and the user also can choose to build new applications using Web App Builder. Web App Builder offers a lot of choices in configuring the appearance, settings and functionality of the web application. This is more convenient methods to create a new application with a different identity from the given templates.

The web application used visual and compositional themes offer in the Web App Builder and following widgets layer list, attribute table, print, zoom slider, measurement, home, scalebar, coordinate and filter are added to provide more options for the user. Once the web applications are ready, it has an option where it can be shared among the organization members. Only an authorized member will have access to the web application because of the data security issues. The following are the results of each infrastructure asset management based on their type of infrastructures.

As shown in Fig. 7-11, each application using OSM basemap respectively. The user can view the attributes each feature by selecting the feature, and

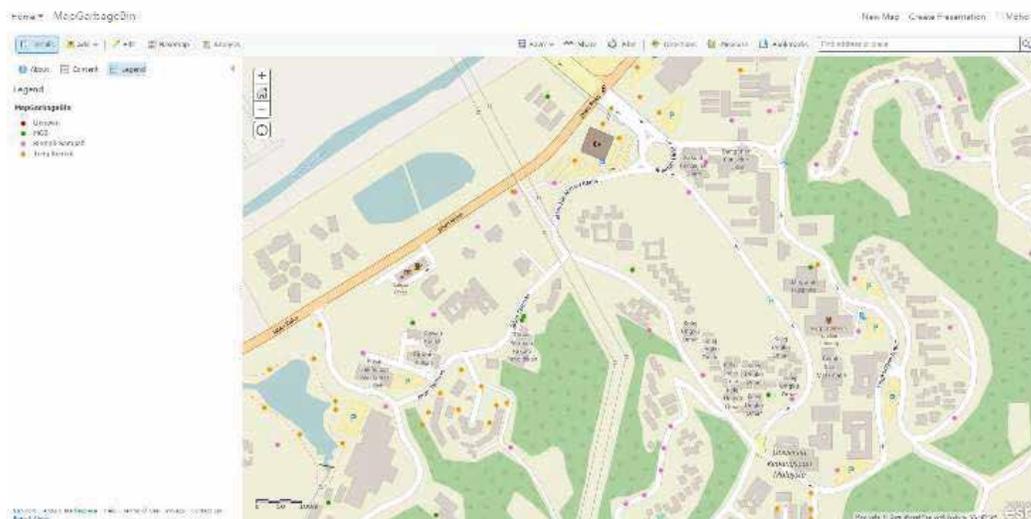


Fig. 6. Garbage bin web map

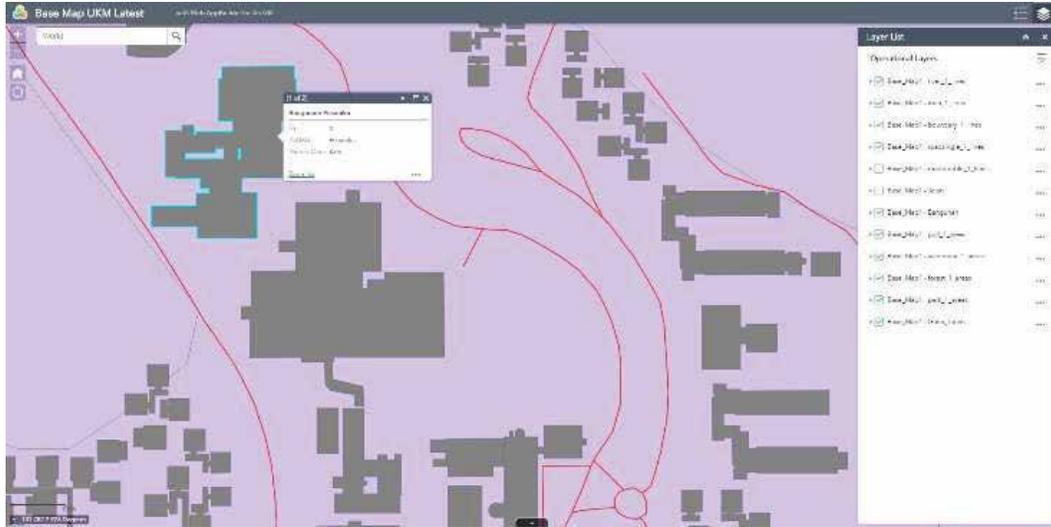


Fig. 7. Building web applications

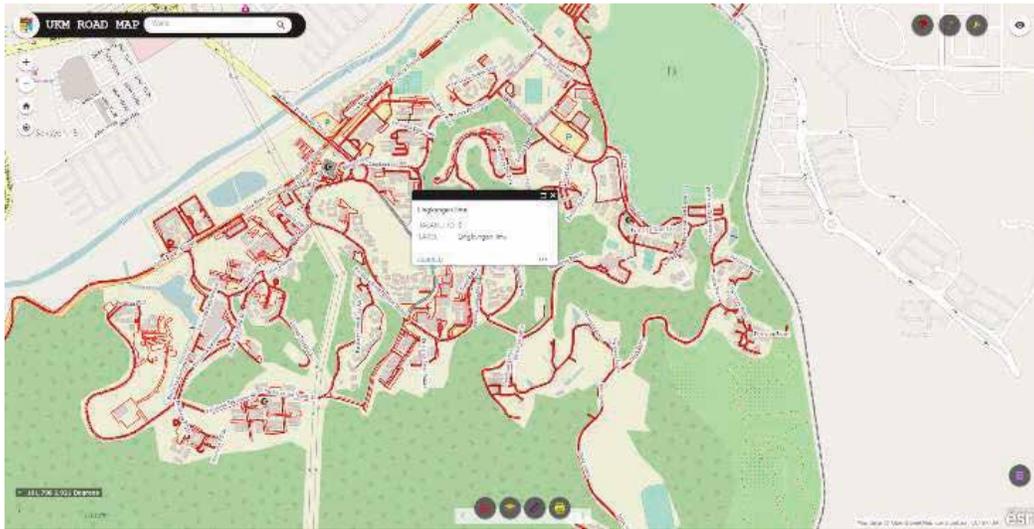


Fig. 8. Road web applications

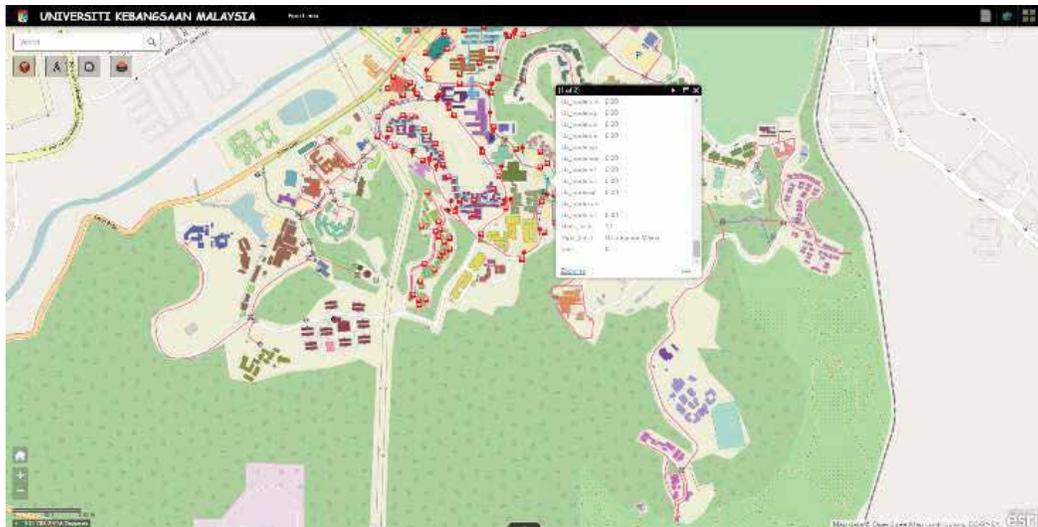


Fig. 9. Pipeline web applications

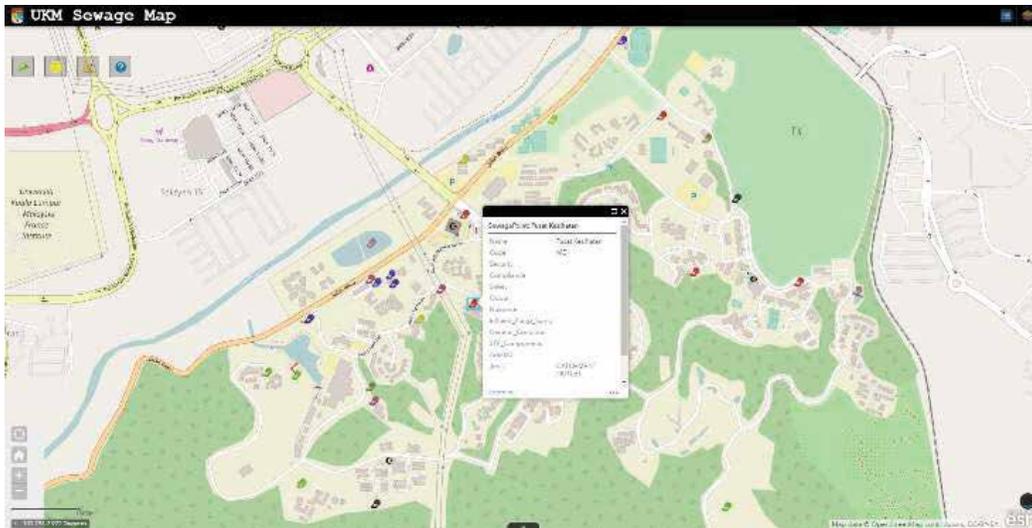


Fig. 10. Sewage web applications

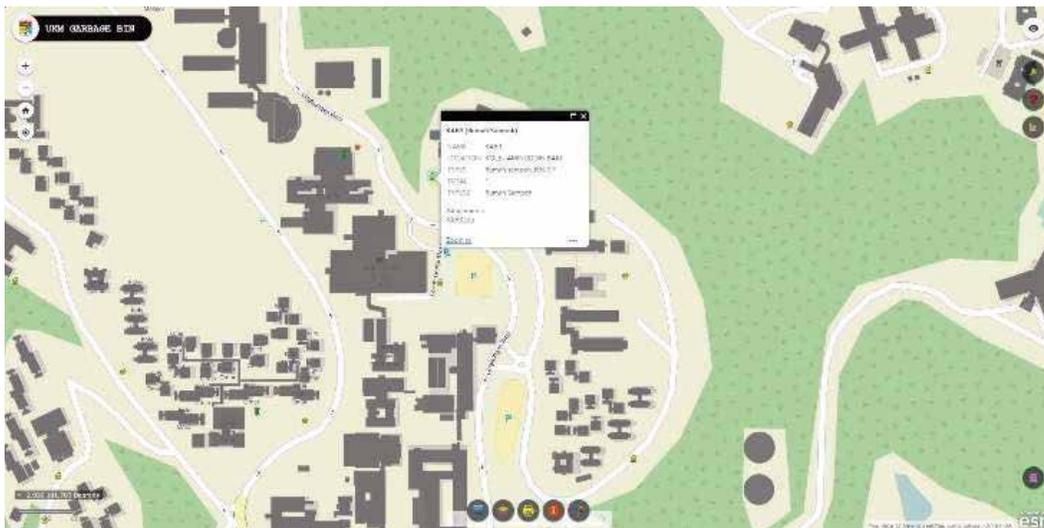


Fig. 11. Garbage bin web applications

attributes windows will come out and list out all important information. Through this application, the user will not only have the information of the asset and will be able to identify the location of the asset from the map view. The choices of the basemap also vary and the user has the option to choose which better suit the application.

Every steps and process in developing the web applications require absolute attention which starts from the data collection and preparation, second designing and developing the geodatabase, third configuration before publishing the data, fourth customization of the web applications and lastly publish the web applications. Any steps or processes

that not follow the right methods will affect the next flow of the process. However, there is still a lot of improvement that can be done to maximise the effectiveness of the application but through this research hopefully will give the ideas on how GIS can aid asset manager and the university.

6. ADVANTAGES OF ARCGIS ONLINE

ArcGIS Online has proved to be a good option that quickly and user-friendly application to represents spatial data. Multi users can also access the data simultaneously from anywhere anytime. The user can also add attachments such as pictures and PDFs. The services that hosted can also be used in others

web map and web applications at the same time.

7. CONCLUSION

The present study was to introduce a new method to be used for infrastructure management of UKM using ArcGIS Online web applications. ArcGIS Online has been chosen because of the capabilities of the application in providing a good platform for the user to customize and configure the applications based on the user needs. The process of storing and visualizing the information of the infrastructure becomes more convenient and efficient. Moreover, useable to access the latest data and share it among the members of the organization.

A good infrastructure asset management will always benefit the organization in many ways. It will also be a great help to management in making better planning and decisions for the better future of the organization and its customers.

8. ACKNOWLEDGMENTS

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