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Development of a GIS Database for a Water Pipe Distribution System at UTHM Pagoh

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Keywords

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Abstract

The development of a Geographic Information System (GIS) database for the water pipe distribution system at Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh addresses key challenges in managing infrastructure. This study focused on creating a Geographic Information System (GIS) database for the water pipes at UTHM Pagoh Campus, managing the water pipe distribution system is challenging due to outdated methods and and inefficiencies, with reliance on paper maps causing operational issues and data handling difficulties. The main goal was to improve how the infrastructure is managed by combining different types of data into one system This upgrade boosts efficiency in maintenance, helps allocate resources more effectively, and enhances decision-making through detailed 3D visualizations and accurate mapping of pipe materials and maintenance records. The objectives are to develop and digitize the database, as well as to perform the GIS database validation. The database includes detailed information on pipe materials, sizes, and maintenance records, making it easier to manage resources and plan maintenance through a comprehensive digital map of the network. Using QGIS software, the project successfully created a user-friendly visual representation of the pipe network, aiding strategic planning and maintenance. This new system improved water utility management, emergency responses, and reduced environmental impacts. A digital map of the pipe network was created to help with resource allocation and maintenance planning. This new system made managing the water utilities more efficient, improved emergency responses and reduced environmental impacts. By using GIS technology, the project improved the current water pipe management system at UTHM Pagoh, providing a strong tool for maintaining and planning infrastructure.

1. Introduction

The development of a Geographic Information System (GIS) database for the water pipe distribution system at Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh addresses key challenges in managing infrastructure. Traditional methods often rely on incomplete data and manual processes, making maintenance and resource allocation inefficient. This project combines spatial and non-spatial data into a comprehensive GIS database, making data management more efficient, supporting better decision-making, and enhancing spatial visualization.

This system makes it easier for people to make decisions by offering lifelike 3D visualizations, bringing together building details, geographic insights, and inspection info more seamlessly, and making it a breeze to find the data you need [1]. GIS data falls into two main categories: spatial and non-spatial. This data can be handled, modified, analyzed, and shown to multiple users. This process allows for thorough and structured solutions [2]. The database includes detailed information on pipe materials, sizes, and maintenance records, allowing for the mapping of the distribution network to improve resource allocation and proactive maintenance. By digitizing the water distribution system, the project aims to improve infrastructure management, boost emergency response capabilities, and support environmental impact assessments. Water supply companies are now finding it essential to incorporate GIS technology to create an efficient, sensible, and practical GIS system for managing water supply networks. By doing so, they can enhance the operational and supervisory capabilities of these networks, achieve smart management of urban water supply systems, and elevate the overall management and service standards of the water supply network [3].

1.1 Geographical Information System (GIS)

In the era of Industrial Revolution 4.0, the digitalization of the world is accelerating, driven by the widespread use of the internet [4]. Geographic Information System (GIS) technology has become essential for managing modern infrastructure. It can integrate, analyze, and visualize both spatial and non-spatial data. This is especially useful for managing complex systems like water distribution networks, where traditional methods often struggle due to incomplete data and manual work.

The use of GIS is transforming the planning and design of water resources by combining remote sensing data with AI and hydrological models. This integration provides detailed information and visualizes it through maps and symbols, simplifying the management of issues like droughts and floods [5].

1.2 Problem Statement

At Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh Campus, managing the water pipe distribution system has been quite a challenge due to outdated methods. Relying on paper maps often leads to missed details, data loss, and difficulties in handling and updating. These issues result in poor asset management, slow emergency response, and a lack of predictive maintenance.

To overcome these problems, UTHM is looking to modernize its approach by implementing a digital map utility system using advanced GIS technology. This new system will make planning, monitoring, and maintaining the water infrastructure easier, leading to a more efficient, resilient, and sustainable system that will benefit everyone in the UTHM community.

1.3 Objectives

The objectives of this study are:
1) To develop a database for water pipe distribution.
2) To create a digital map for water pipe distribution.
3) To perform a validation of the GIS database design.

1.4 Scope of Study

This study will be conducted at UTHM Pagoh, as shown in Fig. 1. This study used the data from map utilities from the Facility Management Department of UTHM Pagoh using the software QGIS.

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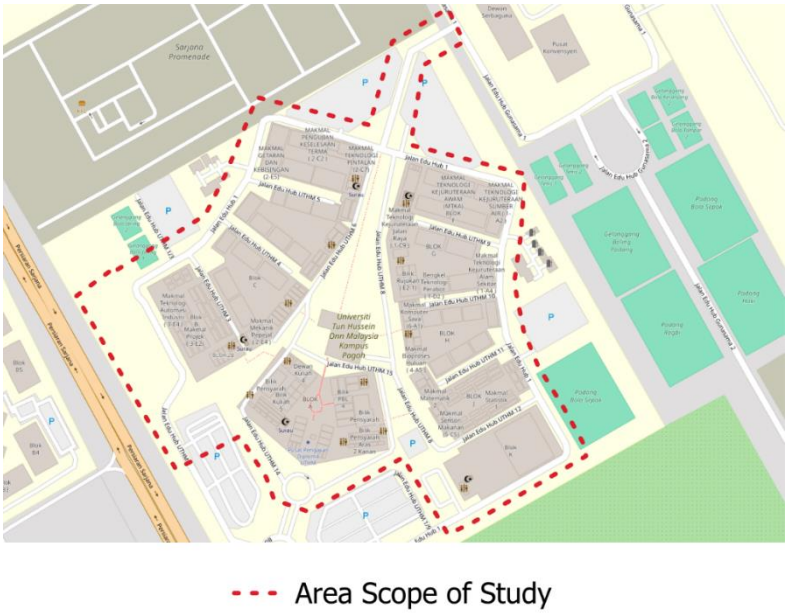

Fig. 1 *The Area Scope of Study*

2. Method

The flowchart of this study represented in Fig. 2. Spatial data from UTHM Pagoh Facility Management, such as pipe sizes, lengths, and valve locations, and feedback from staff on digital record-keeping effectiveness was collected. This data was processed and synchronized using maps. A detailed GIS database schema, represented by an ER-Diagram, was illustrated that contains entities for storing information such as type of pipe, diameter, length, and average depth. The software that have been used is QGIS software which is open-source geographic information system. This database facilitated the development of a digital map for better resource allocation and maintenance planning. The study ended with a summary of findings and suggestions for enhancing water distribution system management.

2.1 Development Software

2.1.1 QGIS Software

This study use the QGIS Software. Fig. 2 shows the interface of the software.

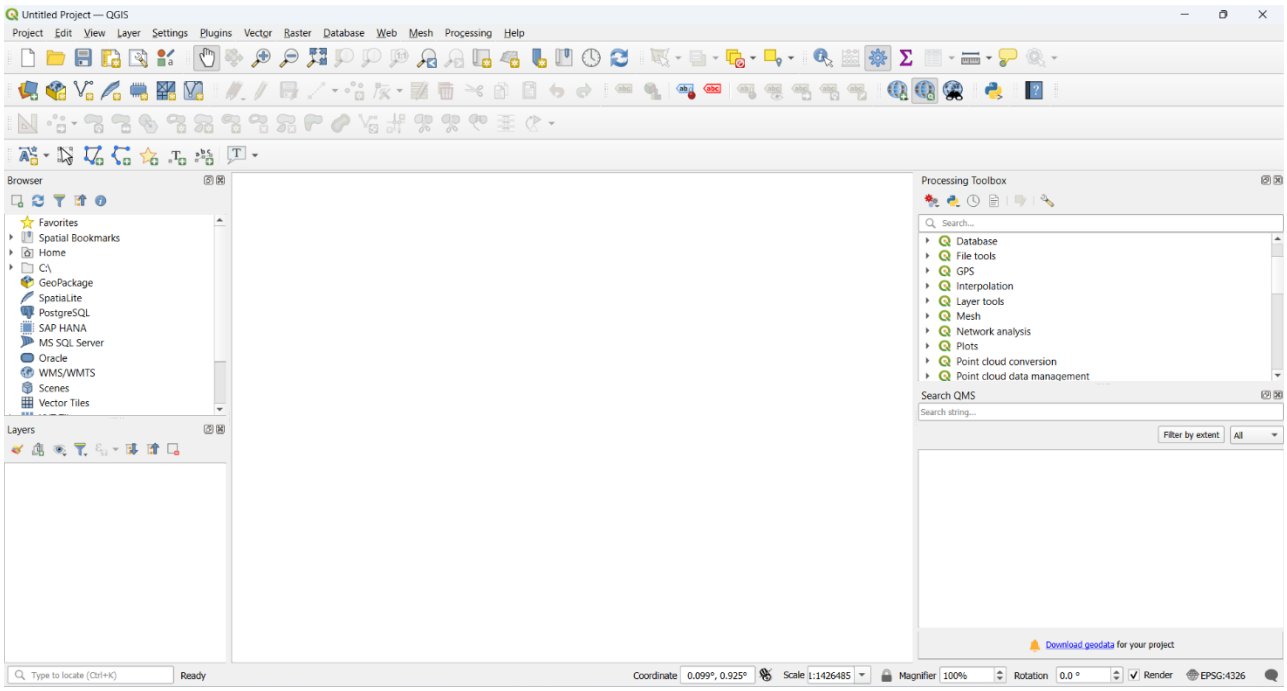

Fig. 2 *The Interface of QGIS Software*

2.1.2 ER-Diagram

The database model for this study was developed as shown in Fig. 3. From QGIS Training Manual, normalization is the process of organizing a database to eliminate redundancy to make it more efficient for general queries and preventing issues like insertion, update, and deletion problems that can affect data integrity.

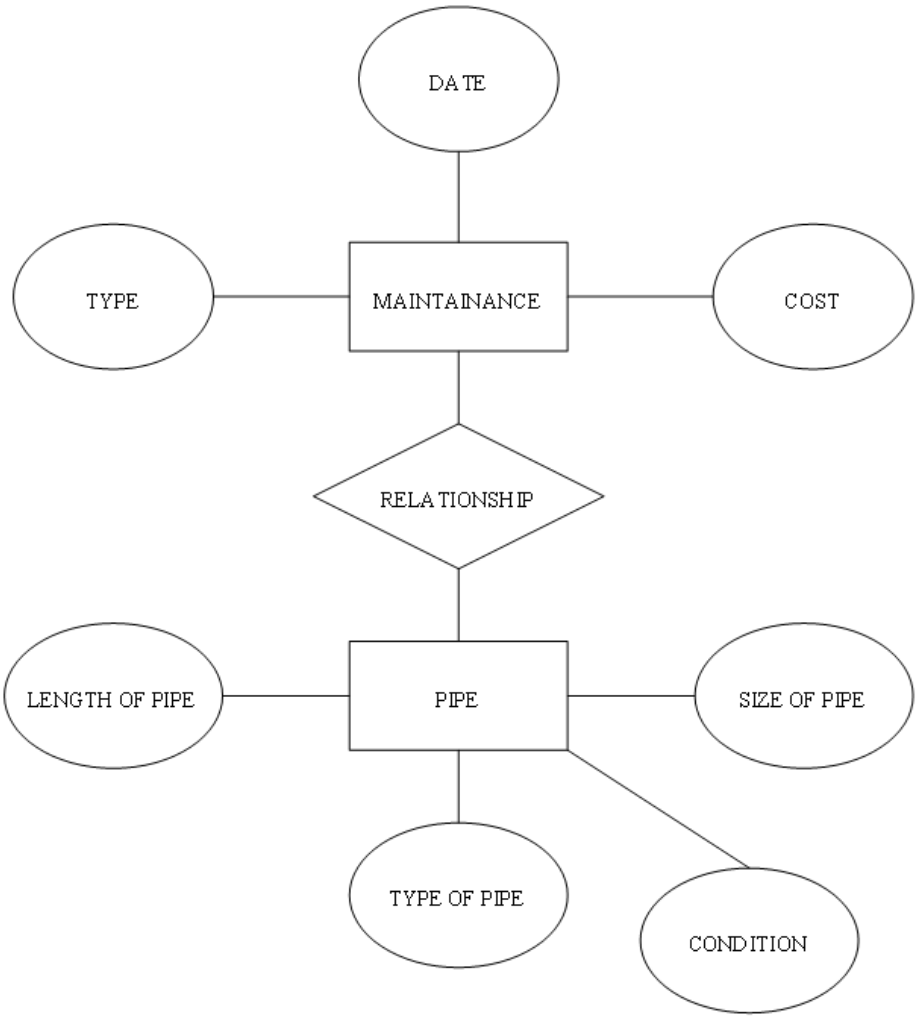

Fig. 3 *Database Development ER Diagram for Water Pipe Distribution*

3. Result and Discussion

The database was developed, and the waterpipe distribution system was digitized using the software QGIS, as shown in Fig. 4 and Fig. 5 shows the digitize layer on basemap without the OpenStreetMap (OSM) layer.

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Fig. 4 *The Developed Database in QGIS*

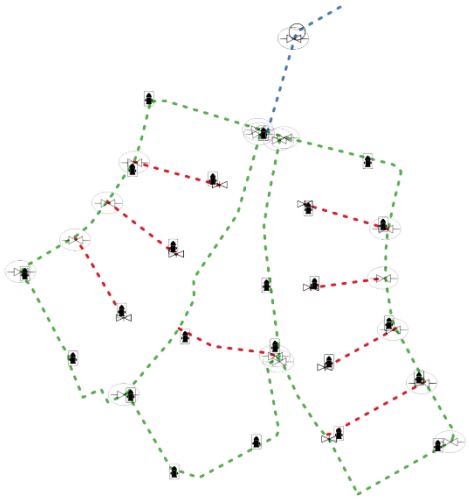

Fig. 5 *The Digitize Layer without the Basemap*

3.1 Discussion

The GIS database offers a clear and easy-to-use visual representation of the pipe network. The map shows various details like the type of material, diameter, and age of the pipes, allowing users to see and understand their characteristics quickly. Each pipe is labeled with an ID, and different symbols are used to represent different materials and sizes, making it simple to tell them apart. The attribute tables hold the information about each pipe, including its material. Users can easily access this information by clicking on a pipe segment on the map. Moreover, the Identify Features tool lets users click on any pipe to get detailed information, making it straightforward to find and examine specific pipes and their maintenance history.

From (R. Rajadurai & Aneetha Vilventhan, 2021), the findings indicate that using the RIM-GIS models allowed for a 3D representation of underground utilities, which helped identify potential conflicts before construction [6].

From the developed database, it can enhances decision-making and strategic planning such as by integrate the various data types into a single system, it can enable planners to evaluate various maintenance strategies and infrastructure improvements [7]. Additionally, the GIS database also can facilitates long-term infrastructure planning by providing insights of visualization into the current state of the network and predicting future maintenance needs [8].

For maintenance planning, the GIS database can help by using buffer analysis to create maintenance zones around important pipes, like older ones or those frequently needing repairs. Buffer can help in identifying neglected regions for guiding future infrastructure expansion to ensure thorough service coverage. For instance, when planning for the future, if maintenance records are kept, it's like having a guide, as shown in Fig. 6. This

approach helps in identifying which maintenance tasks should be prioritized, ensuring resources are allocated in the most efficient way. Imagine a system that allows the filtering and querying of pipes based on characteristics such as age or material, assuming this information has been input into the system. Optimized scheduling reduces the likelihood of unexpected failures and ensures that maintenance efforts are focused on the most critical parts of the network. By examining historical maintenance records, patterns of frequent repairs can be identified, aiding in allocating resources where they are most needed, thus enhancing overall efficiency.

From the analysis of the questionnaire and the effectiveness of the software, it is easy to manage the data and information and visualize it by following the procedure. The analysis also shows that the respondents agree with digitizing the utility map in QGIS.

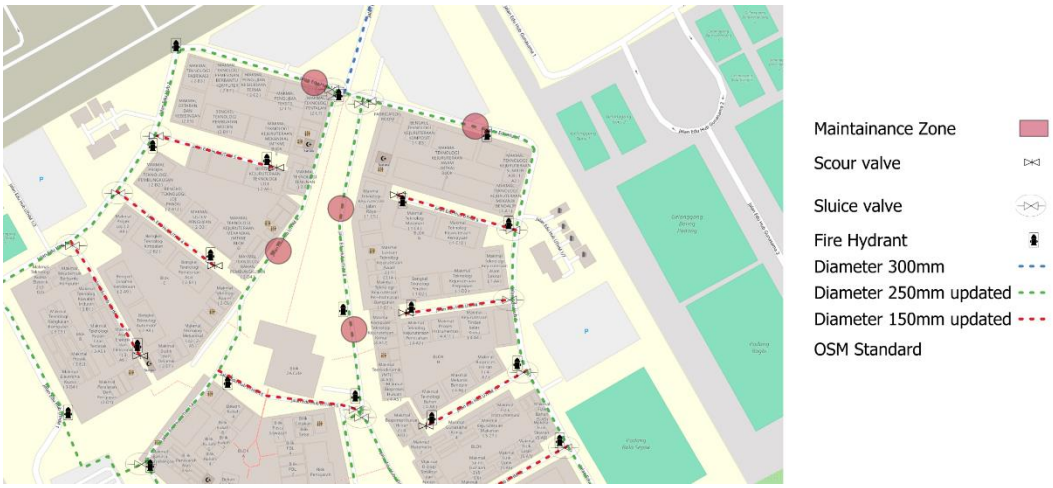

Fig. 6 *Example of the Maintainance Zones that Required More Attention*

4. Conclusion

In conclusion, this study has achieved goals based on the results and analysis carried out. The main objectives of this study are to develop the database, digitize the utility map, and verify the database with the staff of the Facility Management Department of UTHM Pagoh.

For this study, it can achieve Goal 6 SDG which is it ensure the water and sanitation for all as it well-maintained distribution systems are more efficient in delivering water, minimizing wastage through leaks and improving overall water management for the main water pipe distribution. Besides that, proper maintenance also ensures that water pipes remain functional, reducing leaks and contamination risks, thus improving access to safe drinking water.

The end result of this study is a GIS-based water pipe distribution database. The result is a combination of spatial data and attribute data obtained from the UTHM Facility Management. The spatial data refers to the utility pipe network, while the attribute data refers to the features of the pipe. This makes it easy to access data visually or from attributes. The search is also faster and more systematic as it can refer directly to the visual display with a single click. This ability to simultaneously access information can help management more efficiently.

The GIS database provides a comprehensive, user-friendly illustration of pipe networks that shows the detailed attributes like material, diameter, and age for each pipe. Users can interact with the map to access specific information about the pipes, enhancing understanding and facilitating maintenance decisions. By integrating varied data, the system supports strategic infrastructure planning and maintenance, using techniques such as buffer analysis to highlight areas needing attention. This approach can optimum the resource allocation, minimizes unexpected failures, and improves service coverage through informed planning. Feedback from respondent indicates a strong approval for digitizing utility maps using QGIS, highlighting the ease of data management and visualization this method offers.

4.1 Recommendation

For the recommendation, we can develop and digitize the database for the infrastructure of the entire Edu Hub Pagoh for seamless maintenance planning and can achieve Goal 9 SDG which is build resilient infrastructure and industrialization.

Other than that, this QGIS software can be introduced to other management teams, such as using road networks and asset tracking at College University Tun Hussein in Malaysia. This will make it easier for them to see and manage each of these assets in QGIS and for future planning. For the road network, creating buffers around road segments or intersections allows to understand the areas that influenced by roads. This is crucial for planning

where to build infrastructure, how emergency services can respond effectively, and assessing environmental impacts. For instance, buffers help to see which areas might be affected by noise or need special environmental consideration.

Although this software can store many data, it cannot store a large amount of data and is limited horizontally if it has only one point in the visual layer to fill in the data attribute. So, for this recommendation, the data storage section in the attribute table can be updated and improved by adding new features to add a wide range of data in one layer point to make it easier to store data on a regular basis. In addition, the interface for QGIS can be updated to make it easier to operate during the new data storage process.

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