Application of GIS and MCDM on Natural Environment Effect toward the Durability of Water pipe: A Conceptual Study

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Abstract. Utility is considered as one of the most important systems in all countries. A structured network is defined as a network comprising specific components and subsystems. Leakage of water pipes is a common problem around the world. The aim of this study is to estimate the durability of water pipe based on natural environment factor in Selangor, Malaysia. There are several proposed objectives listed such as to identify the parameters that affect the durability of the pipe, to develop GIS modelling to predict the durability of water pipelines and to generate durability of pipeline prediction maps to the study area. The criteria such as temperature, soil moisture, soil type, acidity, resistivity, landuse and slope were selected from the expert opinion and also from the previous study. The method used is Analytical Hierarchy Process (AHP) and GIS. AHP technique were used to calculate the weightage for each of the criteria. In this study, map of the mildsteel waterpipe durability estimation can be produced using ArcGIS.

1. Introduction
There are many types of utility including water, gas, electricity, and the internet. The utility system must be well maintained to avoid any unwanted event such as an explosion on a gas pipe, leakage on a water pipe, and town blackout that is related to the electric utility system. For water pipe utility, most of the pipes were buried underground and connected in a structured network in order to supply water to communities. A structured network is defined as a network comprising specific components and subsystems. In a water pipe network, multiple types of components complete each other in order to make the network work well such as station monitoring and control, start-up and shutdown system, power consumption monitor and also leak locations detection of the pipeline.

Leakage of water pipes is a common problem around the world. It is understood that water is a valuable resource to all living things. There is only three percent of freshwater around the world while over 97 percent are from the ocean, but only 1.2 percent of the freshwater is considered as surface water that supports all life. According to Economic Co-operation and Development (OECD) in 2012, Mexico City has the highest water loss (around 44 percent), followed by Naples (37 percent), and Montreal (33 percent). In Malaysia, the average water loss is around 35 percent which is higher than the government’s target of reducing non-revenue water (NRW) to up to 25 percent by 2020.
2. Literature Review
Leakage happens to water pipe network causing water to come outside of the pipe, also sometimes soil around the pipe seeps in causing the color of the water to change because of having mixed with the soil. The natural environment is one of the factors that cause harm to pipe networks such as corrosion. A factor causing corrosion is soil resistance, pH, temperature, moisture, and chemical composition [1].

Malaysia’s water supply management has experienced a huge change and remarkable improvement in the past few decades. Due to the increase in demand for urbanization, economic, and industrialization, the NRW has been getting higher from year to year (2005 – 2011). NRW is not a new issue among water service providers of the states in Malaysia. According to Malaysia Water Industry Guideline 2018, the rate of NRW in 2018 was 35.3 percent (5743 million liters per day) and some states have more than 50 percent rates such as Sabah (53.8 percent) and Perlis (63.1 percent).

Multiple types of water pipes were used to build a network underground a few decades ago and these leakage problem caused by poor maintenance and construction of the networks. The damages are also caused by extreme water pressure, poor materials, ground movement due to natural disaster, movement and also vibration from road traffic. Multiple factors that lead to NRW; poor management; lack of time replacement of devices; and inappropriate selection of pipes and devices [2]. It is important to know the characteristic of the pipes to determine their suitability to use in the application. Based on data from Malaysian Water Industry Guide 2018, there are several types of pipes used to build underground water networks include mild steel (29.1%), asbestos cement (27.1%), polyethylene pipes (19.0%), un-plasticized polyvinylchloride (14.3%), ductile iron pipes (8.0%), cast iron pipes (0.5%), and others (2.1%).

Multi-Criteria decision Making (MCDM) is a study about the model that is suitable for making decisions based on selected multiple criteria in order to give the best result of the study. The main objective of MCDM is to assist to provide a result that assists decision-makers in selecting the best alternative way to solve problems based on multiple criteria used in a study [3]. There are many Methods under MCDM branches but the most popular/preferred among researchers is Analytic Hierarchy Process(AHP) [4, 5].

3. Methodology
This section shows the proposed method of framework to achieve the aim and objectives of the research. There are six phases include problem determination, preliminary study, data collection, MCDM, result analysis and conclusion. Figure 1 shows the propose methodology of the research.

2.1 Site Study
Based on literature review and some valid sources, the best study area for this research is Selangor state (Figure 2). The main reason for choosing this area is because of data acquisition and availability that can be easily obtained and collected by government and NGO agencies.

Selangor state is one of the thirteen states of Malaysia and is located in West Malaysia at the estimated coordinate 3.0738° N, 101.5183° E. The total area is about 8000 square kilometers and according to Uddin (2021), the total population is 6,555,400 [6]. The mean annual temperature is around 26 degrees with average daily range between 21 to 32 degree and receives annual rainfall of 1200 mm [7]. Figure 2 shows the location of the study area.
Figure 1. Flow of General Methodology

Figure 2. Study area
2.2 Criteria Used
The proposed criteria used in this research are temperature, soil moisture, soil type, acidity, resistivity, landuse and slope. Land Surface Temperature (LST) is a radiative skin temperature of a land surface. It is measured by infrared remote sensor of satellites. This data will be provided by meteorologist department of Selangor. The lower land temperature is presented in softer color while high temperature is presented in darker/high contrast color. Soil resistivity refer to the how much the soil conducts an electric current. According to Dreym Engineering PLLC (Electrical engineering experts) website, they have ever mentioned about soil can severely impact pipeline health.

Soil resistivity is depend on soil moisture as a the higher the moisture the lower the resistivity and this mean the lower the resistivity will lead to a higher corrosive in soil. Soil map represent the classification and group of soil in geographic form. In this study, soil map will present soil type around Selangor state and will be used as one of the criteria/parameter in this study. Acidity of the soil is one of the factors that can harm water pipes. The level of acid is presented in pH unit. The most important data in this map’s attribute data is the value of pH in every location in the Selangor map. The level of pH value can be categorized as low and high following standard guideline of Malaysia.

Landuse reflects the land purpose and type of land used in certain states and regions. In this study, some researchers found that landuse is also one of the factor of pipe burst/broken. For example, the land that is used for transportation may cause pipe surrounding to burst because of pressure put by vehicle itself and has been agreed by expert during the past interview. Land slope is rate of elevation’s high within a given linear distance. Leakage from buried pipe in a soil slope can lead to failure of the slope and safe distance from the slope is the key to avoid these failure [8]. The pipe that proposed to be install in future must be out of range from the critical slope to avoid failure.

These criteria are referred to the previous study and from expert opinion. Two types of sources will be used as a guideline in evaluating criteria. The first source is based on literature reviews and from expertise recommendation where a formal interview will be made to discuss reliability and relevancy of criteria obtained from a literature review that soon will be used and tested on the study area. The recommendation from an expert will be used especially in evaluating the weight of main and sub criteria

2.3 Technique Used
Analytical hierarchy process (AHP) is used for calculated the weightage of the criteria. At first the intensity or scale preference are being assigned to each criteria in order to control the consistency of the result obtain. The scale preference are refer to the parameters by Saaty [9]. This scale are being given by the respondents and for this study, it based on the previous research.

AHP is only used for calculate the weightage for criteria and basically refer to the previous study in ecotourism. The process of the evaluation will be done by calculating the weight of each proposed criteria using three different methods which is rank sum, rating and AHP. Each main criteria is presented in the form of map layer in ArcGIS. The subcriteria must be the attribute data (which is related to the objective) in the map layer. The data of subcriteria will be categorized based on literature review/standard guide/and experts’ views before calculating them using a specific formula. All the main and sub-criteria which have their own weight will be combined together to form a model. The purpose of the model is specifically focused on estimating risk area that affects lifespan of pipes.

3. RESULT AND ANALYSIS

3.1 Proposed Map
The data will be process using the calculation using AHP and other techniques. The map contains information will be separated into five categories namely very low, low, medium, high, and very high risk on pipes.

The risks interpreted by ‘year’ unit which mean the lower the year of durability, the higher the risk on the location. The risk interpretation may be different depending on different methods used but should not have much differences when comparing side by side comparison. The final output from each method
will be compared to history of pipe replacement to validate the accuracy of each method using RMSE. The highest accuracy output will be selected to use for model testing outside of the study area to see the effectiveness of the model.

References

[1] Benmoussat, A., & Hadjel, M. (2017). Corrosion Behavior of Low Carbon Line Pipe Steel in Soil Environment. Eurasian Chemico-Technological Journal. https://doi.org/10.18321/ectj626

[2] Tabesh, M., Roozbahani, A., Roghani, B., Faghihi, N. R., & Heydarzadeh, R. (2018). Risk Assessment of Factors Influencing Non-Revenue Water Using Bayesian Networks and Fuzzy Logic. Water Resources Management. https://doi.org/10.1007/s11269-018-2011-8

[3] A.N., Othman., Naim., W. M., M., W., & S., N. (2012). GIS Based Multi-Criteria Decision Making for Landslide Hazard Zonation. Procedia - Social and Behavioral Sciences. https://doi.org/10.1016/j.sbspro.2012.02.126

[4] Aziz, N. F., Sorooshian, S., & Mahmud, F. (2016). MCDM-AHP method in decision makings. ARPN Journal of Engineering and Applied Sciences. https://doi.org/10.1109/TIE.2013.2297315

[5] Odu, G. O. (2019). Weighting methods for multi-criteria decision making technique. Journal of Applied Sciences and Environmental Management. https://doi.org/10.4314/jasem.v23i8.7

[6] Uddin, S., Lu, Q., & Nguyen, H. (2021). Truck impact on buried water pipes in interdependent water and road infrastructures. Sustainability (Switzerland). https://doi.org/10.3390/su132011288

[7] Parthiban, K., Vanitah, R., Jusoff, K., Nordiana, A. A., Anuar, A. R., Wahid, O., & Hamdan, A. B. (2016). GIS mapping of basal stem rot disease in relation to soil series among oil palm smallholders. American Journal of Agricultural and Biological Science. https://doi.org/10.3844/ajabssp.2016.2.12

[8] Zhu, H., Zhang, L., Chan, K., & Chen, C. (2018). Design safe distance between a buried pipe and a soil slope. Proceedings of the Institution of Civil Engineers: Geotechnical Engineering. https://doi.org/10.1680/jgeen.17.0015

[9] Saaty, T.L. (1972). An Eigenvalue Allocation Model for Prioritization and Planning. Working Paper, Energy Management and Policy Centre: University of Pennsylvania