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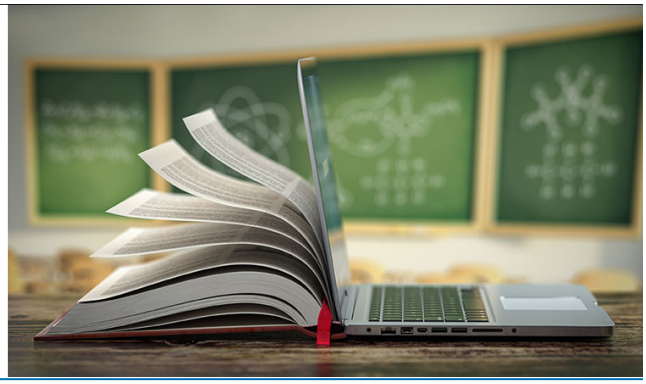

Current Practice in Rehabilitating Old Pipes for Water Distribution Network in Malaysia

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Abstract. The water distribution network (WDN) is critical in daily life because it provides treated water to consumers. However, WDN in Malaysia is facing a significant amount of water loss during the water distribution process (i.e., non-revenue water (NRW) with an average percentage of 35.6%. While one of the leading causes of NRW is old pipes, water operators are still facing barriers to rehabilitate old pipes to new pipes. Therefore, this study aims to identify the strategies to improve current practice in rehabilitating old pipes. To achieve that objective, open-ended individual interviews will be performed with sixteen individuals that have experience in managing WDN and NRW in Malaysia. This research contributes to identify the current practice/method, which has three main categories i.e. people, technology, and process in rehabilitating old pipes from industry practitioners' perspectives, which could assist researchers and industry practitioners in developing strategies to reduce NRW among water operators. The findings of this research can help to improve WDN in reducing NRW.

1. Introduction

A water distribution network (WDN) is critical in daily life because it provides adequate quality and quantity of water to all water consumers [1]. WDN consists of infrastructures that can collect, treat, store, and distribute water from water sources to consumers. Treated water is being distributed through a pipeline system, either open channel or buried pipes (underground pipes). WDN is a whole process of distributing treated water to consumers without any problems until losses of water during the distribution process is occurred due to some problems of pipe failure (ex. pipe leaks and pipe bursts). Losses of water during the distribution process will increase the level of non-revenue water (NRW). NRW is defined as the difference between the amount of water placed in the distribution system and the amount billed to consumers [2].

High levels of NRW reflect a huge volume of water being lost through leaks (real losses) and drinking water not being invoiced to customers (apparent losses) and unbilled authorized consumption. The level of NRW in developing countries, including Malaysia, ranges from 35 to 50 percent of the water produced [3]. Thus, the water distribution sector needs to improve the way it makes significant use of its water resources, particularly in NRW, to achieve sustainable water management. By reducing NRW in Malaysia, it will potentially lead to positive effects on the country's social (fairwater service bill), economic well-being (no more revenue losses of water), and will be able to save money [4].

Old pipes are one of the problems related to the pipeline system because of the existing pipes in Malaysia age more than 20 years. As pipe age, NRW from water reticulation mains will increase due to the associated water leakage [5]. Besides, old pipes will cause corrosion because of rust. The pipeline itself may indicate corrosion has eaten away the walls of the pipe to the point that the pipes are dangerously thin [6]. Old pipes are one of the causal factors of increasing NRW in Malaysia. Rehabilitation is one of the approaches to reduce NRW, which involves repairing or replacing old pipelines for WDN. The efficient and effective of the management process of existing current practice in rehabilitating old pipes for WDN in Malaysia faces challenges related to the aging of infrastructure, high cost of pipe replacement, population growth, extended urbanization, and climate change impacts [7].

This study aims to identify the current practice in rehabilitating old pipes for WDN in Malaysia. This paper analyzes a series of interviews with industry practitioners who have experience and knowledge in managing WDN and NRW to accomplish this objective. The analysis from interviews able to provide methods affecting the rehabilitating of the old pipes for WDN. From the data, the current practice in rehabilitating old pipes can be recognized. Researchers and practitioners from both the public and private sectors can use the findings to develop appropriate strategies to improve the current practice in rehabilitating old pipes for WDN in Malaysia.

2. Background

2.1. Techniques to improve WDN rehabilitation

One of the major challenges faced by the WDN company all around the world is the high losses of water during the water supply process [8]. While WDN includes works from the supply sources treatment plants, water supply systems, and storage facilities, the costliest part is the distribution system. This is caused by the aging of water distribution infrastructure networks, coupled with the continuous stress caused by operational and environmental conditions on these systems, which has led to deterioration and leakage. To put it into perspective, the first piped water system was built in 1652 in Boston, North America [9]. Since then, millions of miles of pipes have been laid, and it is not unusual (especially in older cities) that pipes are still in service for 100 years and older [9].

In addition, one of the best solutions to this challenge is to develop proper techniques to improve WDN rehabilitation. The techniques to improve WDN rehabilitation is to minimize the cost of the rehabilitation investment and all subsequent maintenance costs over a predetermined time horizon and subject to certain limitations. There are two main decision variables, (1) the type of rehabilitation alternative (e.g., replace with the same diameter pipe, replace with a larger diameter pipe, reline) and (2) the timing of its installation for every pipe in WDN. Every obstacle in the system must include at least one decision variable [9]. The criteria considered in the decision-making process included pipe diameter, pipe length, specific accomplishment duration, lifespan, pressure losses, cost, and installation conditions, while the methods that are considered during rehabilitation alternatives are compact pipe, slip line, subline, swage lining, and pilot pipe.

Besides, there is a study that makes optimal WDN design, and it aims to reduce the capital cost of investment in tanks, pipes, pumps, and other equipment [10]. Minimizing the cost of pipes is generally regarded as a prime objective, as its share of the capital cost of the water distribution project is very high. While in Egypt, WDN company must define methodologies and technologies for planning, designing, constructing, managing, assessing, and rehabilitating WDN that take into account local economic, environmental, and social factors to face the challenges of high losses of water. Therefore, it is essential to implement mitigation measures to extend the useful service life WDN promptly [11]. Sægrov et al. [12] explored current technological advances to detect leaks and assess pipe wall thinning while Xu et al. [13] applied potential solutions for the management of water leakage and explicitly

addresses the environmental benefits of each solution. Various researchers are trying to identify the best techniques to improve WDN rehabilitation that results in the reduction of NRW.

2.2. WDN rehabilitation in Malaysia

In Malaysia, water supply infrastructures that are built over the past 50 years and are facing aging problems due to deterioration that results in increased repair costs, failed water pipelines, and increased level of NRW [14]. Moreover, the quality and quantity of the treated water supply to the consumers have the potential to be decreased due to the aging pipes in the domestic WDN. On top of that, the areas of concern for water management in Malaysia is operational efficiency of the water industry is in good condition, ensure coverage and sustainability of quality water, high operation and maintenance cost and high NRW [15].

Bubtiena et al. [16] create pipe breakage prediction models that provide a platform for effective WDN rehabilitation strategies. The success of water pipes rehabilitation strategies are vital both in sustaining the efficiency of the WDN and in reducing costs [16]. Gupta et al. [17] examine the relevance of rehabilitation options in Malaysia using trenchless technology. Also, another study by Abdul Rahman et al. [18] developed a model calibration exercise methodology, taking into account two uncertainty parameters, Hazen-Williams roughness coefficient of the pipes and NRW in each nodal demand.

On the other hand, others suggest the usage of a compact pipe system as a solution of sustainability because it includes short installation times and minimal disruption of traffic flow and the public, while its commercial advantage is focused on the lower probability of potential leakages [19]. Ooi and Hui [14] develop a breakdown structure (WBS) for the life cycle cost model (LCC) model to be practiced in water infrastructure, considering that the LCC is vital for evaluating the efficiency of the water pipeline networks and for minimizing costs. Many studies from all over Malaysia are proposing solutions for WDN rehabilitation because improving WDN is crucial to reduce NRW.

2.3. Positioning of this study

Existing pipes in Malaysia are aging and become weak day by day. Weak pipes may cause pipe leakage, and such widespread pipeline leakage can itself indicate that corrosion has eaten away the pipe walls to the point where they are dangerously thin [8]. For example, the pipe leakage incident caused by old pipes at a water treatment plant in Semanggar, Kota Tinggi that affects 11,000 consumers [20]. Furthermore, 75% of NRW in Malaysia is caused by pipe burst and pipe leak [21]. Malaysia's NRW is at 35.5% in 2015, and one of the main factors contributed to the higher NRW was physical losses due to old network pipes [15]. In other words, improving the current practice in rehabilitating old pipes for WDN in Malaysia is essential to reduce the NRW in Malaysia. However, while researchers are identifying approaches for improvements, the existing body of knowledge is the lack of information on the current practice of WDN rehabilitation in Malaysia. Therefore, this research identifies the current practice of WDN rehabilitation in Malaysia.

3. Methodology

3.1. Data collection method

Figure 1 is summarize an interview session process flowchart to get data for the current methods in rehabilitating old pipes for WDN in Malaysia.

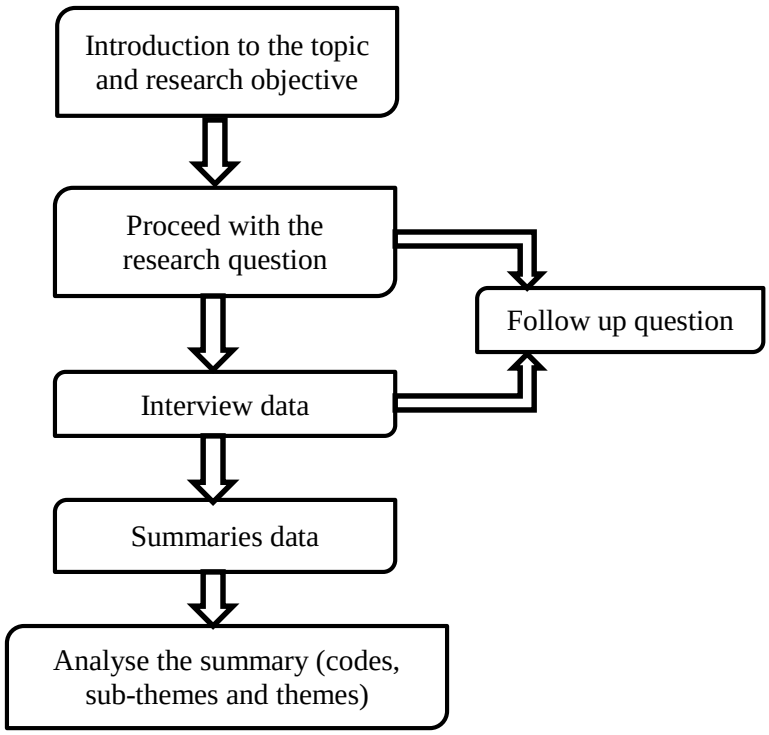

Figure 1. Interview session process flowchart.

Data on the current practice in rehabilitating old pipes for WDN in Malaysia are collected by interviewing practitioners that have experience and knowledge in managing WDN and in managing NRW to maintain a level of quality of the interviewees (i.e., purposeful sampling). Also, this approach has been used to identify success factors in other construction management topics, including design-build in public sector projects [22]. Individuals from different water distribution organizations throughout Malaysia are interviewed to ensure the data is comprehensive. Interviews allow industry practitioners to provide implicit knowledge of their situation. Also, open-ended questions encourage participants to contribute as much detailed information as desired while enabling investigators to ask probing questions as a means to follow-up. The open-ended questions include: (1) What are the methods used to know the locations for the old pipe leakage? Participants addressed the questions while the investigators took notes and provide follow-up questions. For verification purposes, the notes are summarized and sent to the interviewees. The interviews will be completed by following the principle of saturation.

3.2.*Data analysis*

The interview results are analyzed using thematic analysis to draw up lists of current practice in rehabilitating old pipes for WDN in Malaysia. This approach is chosen because it can help to make sense of the qualitative data [23]. Thematic analysis is a useful and flexible method for qualitative research in psychology and beyond [24]. Other areas in construction management that use this approach to analyze qualitative data include problem detection in construction projects [24], and change agent attributes at construction companies [25].

There are six steps in analyzing interview results using thematic analysis: (1) familiarize yourself with your data by transcribing the data, read and re-read the data, and jot down initial ideas; (2) creating initial codes, which mean the codes that define the feature of the data. The coded data is different from the analytical units, which are broader. The themes would rely on the data, but in the latter, the data is approached with specific questions; (3) searching for themes by collecting codes into potential topics,

collecting all relevant data for each possible theme; (4) reviewing themes and there are two levels in this step. The first level is checking whether the themes function concerning the coded extracts, and level two is checking whether the themes function concerning the whole data then, creating a thematic 'map' of the analysis; (5) defining and naming themes by continuous analyzing to refine the specifics of each theme, and the analysis tells the overall story, generating clear definitions and names for each theme; (6) producing the report. Developing the themes, subthemes, and codes define the current practice in rehabilitating old pipes for WDN in Malaysia.

4. Results and Discussion

Figure 2 summarizes the method used to identify the location for the old pipes that need to be replaced in Malaysia. This method was identified by analyzing interview data with sixteen individuals that have experience in managing WDN and NRW from Malaysia.

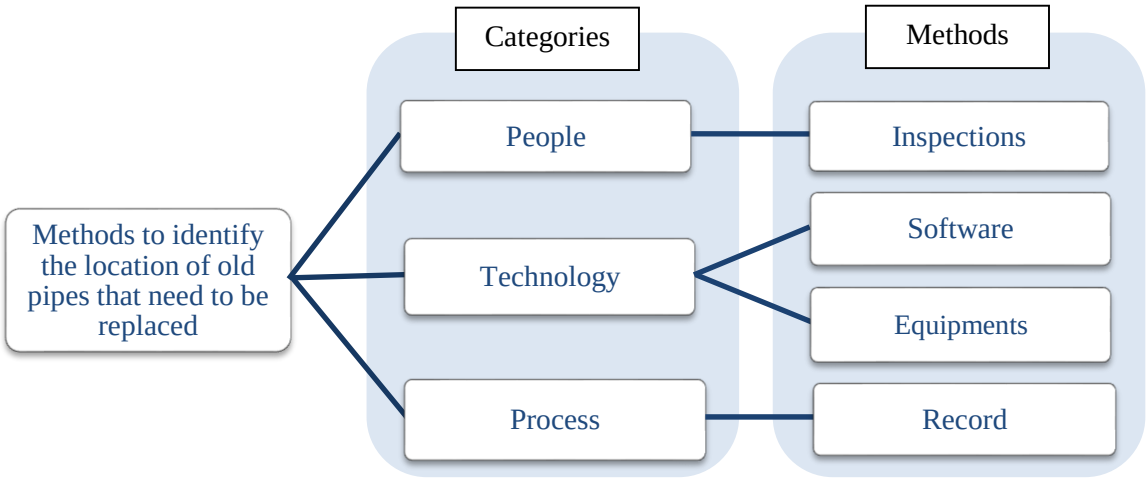

Figure 2. Method to identify the location of old pipes that need to be replaced.

The methods are themed into three main categories, people, technology, and process methods. The people method is related to the actionable done by the active leakage control (ALC) team or NRW team (ex. Doing a visual inspection by observing along the pipeline and check whether there is any leak or not). On the other hand, the technology method relates to techniques that they use in an easier way to locate pipe leaks or pipe bursts (ex. Using equipment like a smart ball to locate pipe leaks or pipe burst). While process method connected to the record in which water operators analyze the record of the frequency of pipe leaks (ex. Observing frequency of pipe leaks record at the same location to detect the location of the pipe that needs to be replaced). After that, they will be able to identify the causes of the leaks is from old pipes or other causes. The methods are discussed further in the following paragraphs.

4.1. Method to identify the location of old pipes that need to be replaced

4.1.1. People-related method to identify the location

People have two main categories, visual and sounding. Visual and sound inspections are reliable methods of detecting pipes in a state of advanced distress. Both methods are being used by the ALC team and NRW team to detect pipe leaks and pipe bursts. It can be used on external and internal surface inspection of pipelines. Visual inspection is a process that is only using a pair of naked eyes to look for flaws. It is far more cost-effective because it is not using any equipment. A well-trained ALC team or NRW team can recognize most signs of leaks. This is the basic way to locate pipe leak by observing along the pipeline and check any leaks on the surface of the pipe. If there is any sign of water coming

out from the surface of the pipeline, that indicates there is a pipe leakage or burst. Moreover, if there is a water loss on a big scale and we can see the location of the water loss so, the easy way is to close the valve for that pipe. Some of the answers from the interview summary highlighting this method include:

"By using visual inspection sounding (VIS) which is we find the leaks by eyes and sound which
means we will observe along the pipeline if there are any leaks or not"
"The cheapest method is to check the condition along the pipe. If there is a pressure drop, we
spot the nearest location from base to the tip. Peoples help to find it and report it. The pressure
drop is detected using pressure logger."
"Through daily check for the pipeline by physical or the data that we get."
"If the water loss on a big scale and we can see the location of the water loss so, the easy
way is to close the valve for that pipe."

On the other hand, sound inspection is to check the failure of the interior surface of the pipe wall with the specific sounding equipment. ALC and NRW teams use a sounding inspection to detect pipe failure when they cannot see the pipe failure with naked eyes. The classical method that had been used is sounding using a listening stick. The specific tool called acoustic localization will be used to do sound localization at a location that is suspected to be leaking. This tool is used on the valve, air valve, and meter to hear sound in the interior surface of the pipe wall. Then, after the leaks of the pipeline can be detected, the source of the leaks will find out whether it is because of the old pipe or other causes. Further action for pipe rehabilitation will be taken to improve WDN and reduce NRW at once. Sounding inspection needs to do often using high technology tool to improve the current practice for rehabilitating old pipes for WDN in Malaysia. Samples of the responses include:

"The staff from Non-Revenue Water will use a sort of sound proving tool to detect the pipe which
we cannot see with naked eyes."
"The classical method that had been used for sound inspection is using a listening stick."
"By using visual inspection sounding (VIS), which is we find the leaks by sound. The method is
we hear any sound of leaks in the area that we suspected to be leaked by using a hearing stick.
We use it on the valve, air valve, and hydrant/meter to hear sound in the pipeline."
"Internally (inside the pipe) is by doing sound localization, which we used a specific tool called
acoustic localization."

4.1.2. Technology-related method to identify the location

Software is one of the technologies that are very useful to detect pipe failure, which can be monitored by a computer. It can be used to detect pipe leaks or a pipe burst in a very convenient way compared to other methods. Geographical information system (GIS) is a software that can be integrated with supervisory control and data acquisition (SCADA). Data collected from the site using SCADA and analyzed it using GIS, allowing oversight of all operations related to the WDN and carrying out the necessary analysis to obtain the results needed to reduce NRW. GIS can also use the results of integration with hydraulic computer modeling and operational process simulation in the network for widespread surveillance in urban areas of WDN in a variety of GIS applications, from improving and controlling

the pump work to managing valves to detect the location and size of pipe leaks [26]. Responses that illustrate from the summary of interviews this method are:

> *"Based on map or GIS whether there is leaks or failure of the pipe, then we dig in the leaking area and see the condition of the pipe."*

Equipment is a technology that can be used to detect pipe leakage. The equipment that usually being used to detect pressure drops for a pipeline is a data logger. The data logger is an electronic device that works to obtain data (ex. Pressure, temperature, humidity, voltage, and current) from time to time with sensors. The data will be obtained through a data logger that is monitored daily. Specific tools like a smart ball, Leak Finder, Sound Sense, Sahara, Leak Noise Correlator, portable electronic listening stick, and hydrophone had been used to detect pipe leak and burst. All of the equipment is a high technology and highly cost-effective. Once the pipe leaks can be detected, pipe rehabilitation will be done based on the condition of the pipe. The pipe will be fixed or replaced with a new pipe based on the pipe's condition. Samples of responses from the summary interviews that illustrate this technology of equipment include:

> *"The way that they use to know the reading of the pressure is by installing logger data for a week for some high and low areas."*
> *"Through data logger that is monitored daily. A data logger is an electronic device that works to obtain data from time to time with sensors and equipment."*
> *"The method that we use to identify the pipes that need to be changed is by using sound sense, smart ball, leak finder…"*
> *"We are using smart ball and Sahara to identify the location of the pipe that needs to be changed."*

4.1.3. Process-related method to identify

Record is the process of getting data. The location of the pipe burst and pipe leaks can be detected by seeing the record of the cases that frequently happened. The location of the pipe that needs to be replaced can be identified by analyzing the most frequent pipe leaks in the record. The customers will make the record of pipe leaks. They will make reports of complaints about the problem of water quality in their areas. All the reports will be put in the record to be referred to as data. Through hydraulic analysis also can obtain current water consumption capacity then, water operators can determine the actual value of current needs in some areas and old pipes that need to be replaced with new pipes based on current needs. Other than hydraulic analysis, there is another method that is observed in the district meter area (DMA). DMAs are small groups of water users with a requirement to track the water supplied and consumed individually. The DMA leakage rate per connection will be observed by observing the reading entering the district meter area (DMA) higher than the meter reading per account. In this case, the water had been lost during the water supply process. Therefore, pipe replacement is vital when the leakage rate per connection is high in order to improve WDN and reducing NRW. Some of the answers from the interview review highlighting this method include:

> *"The number of accounts not so much, but water readings are entering the District Meter Area (DMA) higher than the meter reading per account. For example, water readings entering the DMA is 10,000 m³/month but the meter reading per account is 6000 m³/month. So this means 4000 m³/month of water had lost during the water supply process. Then, this case will be referred to the per account."*
> *"We identify the location of the pipe that needs to be changed is through the analysis of pipe leakage and pipe burst cases."*
> *"We are using the previous record. It is the easiest way to know the pipe that needs to be changed.*

Records like the type of pipes and size of pipes help to determine the life of the pipe."
"We will identify the frequency of the pipe leaks through data. Residents will make a report of leaks, and we will go and see the condition. If necessary, we will replace the pipe."
"We identify the location of the pipe that needs to be replaced through hydraulic analysis that can obtain current water consumption capacity then. Water operators can determine the actual value of current needs in some areas, and old pipes need to be replaced to new pipes based on current needs."

5. Conclusion

This study identifies the method/current practice in rehabilitating old pipes for WDN in Malaysia by analyzing individual interviews with sixteen professionals from water distribution operators and NRW operators using the thematic analysis. The key findings include:

- The current practice for rehabilitating WDN in Malaysia can be categorized into three categories: people, process, and technology.
- People relate to the inspection method; Technology can be associated with software and equipment; Process involves using recorded data.

Moreover, this study suggested and recommended the industry practitioners to improve the current methods and really do the current methods such as the inspections frequently to make sure the pipe leaks can be prevented, and the NRW can be reduced. Therefore, the lesson of this study would help the researchers and industry practitioners to use these findings for crosschecking their current practice and also develop strategies to enhance the success of rehabilitating old pipes for WDN and reducing NRW in Malaysia. The key theoretical contribution of this research is by providing a set of current practices for rehabilitation WDN in a developing country.

6. References

[1] Adeosun, O. O. (2014). *Water Distribution System Challenges And Solutions*. Wateronline.Com. https://www.wateronline.com/doc/water-distribution-system-challenges-and-solutions - 0001
[2] Frauendorfer, R., & Liemberger, R. (2010a). *e Issues and Challenges of Reducing Non- Revenue Water e Issues and Challenges of Reducing Non-Revenue Water*. https://www.adb.org/sites/ default/files/ publication/27473/reducing- nonrevenue-water .pdf
[3] See, K. F., & Ma, Z. (2018a). Does non-revenue water affect Malaysia's water services industry productivity? *Utilities Policy*, *54*(5), 125–131.
[4] Lai, C, Chan, N, & Roy, R 2017 *Understanding Public Perception of and Participation in Non-Revenue Water Management in Malaysia to Support Urban Water Policy Water*, 9(1), p 26
[5] Burn, S., DeSilva, D., Eiswirth, M., Hunaidi, O., & Speers, A. (1999). *(PDF) Pipe Leakage - Future Challenges and Solutions*. ResearchGate. https://www.researchgate.net/ publication/44055423_Pipe_Leakage_-_Future_Challenges_and_Solutions
[6] Asadi, Z S, & Melchers, R E 2017 ' *Extreme value statistics for pitting corrosion of old underground cast iron pipes Reliability Engineering System Safety'*, Vol 162, p 64 –71
[7] D'Ercole, M, Righetti, M, Raspati, G S, Bertola, P, & Maria Ugarelli, R 2018 *Rehabilitation Planning of Water Distribution Network through a Reliability* — Based Risk Assessment Water, 10(3), p 277
[8] Aşchilean, I, & Giurca, I 2018 *Choosing a Water Distribution Pipe Rehabilitation Solution Using the Analytical Network Process Method Water*, 10(4), p 484.
[9] Kleiner, Y. (1998). *Water distribution network rehabilitation: selection and scheduling of pipe rehabilitation alternatives* (Doctoral dissertation, National Library of Canada= Bibliothèque nationale du Canada).
[10] Suribabu, C R 2017 Resilience-based optimal design of water distribution network Applied Water Science, 7(7), p 4055–4066
[11] Marzouk, M, Hamid, S A, & El-Said, M 2015 A methodology for prioritizing water mains

rehabilitation in Egypt HBRC Journal, 11(1), p 114–128.
[12] Sægrov, S, Melo Baptista, J, Conroy, P, Herz, R, LeGauffre, P, Moss, G, Oddevald, J, Rajani, B, & Schiatti, M 1999 Rehabilitation of water networks Urban Water , 1(1), p 15 – 22
[13] Xu, Q, Liu, R, Chen, Q, & Li, R 2014 a Review on water leakage control in distribution networks and the associated environmental benefits Journal of Environmental Sciences, 26(5) p 955–961
[14] Ooi, C., & Hui. (2018a). *WORK BREAKDOWN STRUCTURE FOR WATER DISTRIBUTION PIPELINE NETWORKS*.http://eprints.utm.my/id/eprint/79174/1/OoiChuHuiPFGHT2018.pdf
[15] Abd Wahab, N. 'Aini. (2011). *OVERVIEW OF THE WATER SERVICES INDUSTRY IN MALAYSIA MDM. NOR 'AINI ABDUL WAHAB MDM. NOR 'AINI ABDUL WAHAB DEPUTY SECRETARY DEPUTY SECRETARY--GENERAL GENERAL (GREEN TECHNOLOGY AND WATER) (GREEN TECHNOLOGY AND WATER) MINISTRY OF ENERGY, GREEN TECHNOLOGY AND WATER, MINISTRY OF ENERGY, GREEN TECHNOLOGY AND WATER, MALAYSIA MALAYSIA OUTLINE OF PRESENTATION, 2(1), BACKGROUND*. https://www.mlit.go.jp/common/000135515.pdf
[16] Bubtiena, A M, El Shafei, A H, & Jafaar, O 2012 Review of rehabilitation strategies for water distribution pipes Journal of Water Supply: Research and Technology-Aqua, 61(1), 23–31
[17] Gupta, B S, Chandrasekaran, S, & Ibrahim, S 2001 A survey of sewer rehabilitation in Malaysia application of trenchless technologies Urban Water, 3(4), P 309-315.
[18] Abd Rahman, N, Muhammad, N S, Abdullah, J, Mohtar , W, & Melini, W H 2019 Model Performance Indicator of Aging Pipes in a Domestic Water Supply Distribution Network Water, 11(11), P 2378
[19] Abidin, Z. Z. (2019). *SMART SOLUTION TO SAVING WATER | The Star Online*. https://www.thestar.com.my/business/business-news/2019/02/18/smart-solution-to-saving-water
[20] Abdul Rahman, A. F. (2018). *Laporan rasmi paip bocor LRA Semanggar siap minggu ini | Astro Awani*. Astroawani.Com.malaysia/laporan-rasmi-paip-bocor-lra semanggar-siap-minggu-ini-177951
[21] Mohd Din, M. K. H . (2019, February 1). *Pelarasan tarif baharu air wajar dilaksanakan*. BH Online. https://www.bharian.com.my/berita/nasional/2019/02/526482/pelarasan-tarif-baharu-air-wajar-dilaksanakan
[22] Lee, Z P, Rahman, R A, & Doh, S I 2020, January Success *Factors of Design-Build Public Sector Projects in Malaysia* In IOP Conference Series: Materials Science and Engineering Vol. 712, No 1, p 012045 IOP Publishing
[23] Clarke, V, Braun, V, & Hayfield, N 2015 *Thematic analysis* Qualitative psychology: A practical guide to research methods, p 222-248.
[24] Rahman, R. A, Radzi, A R., Saad, M. S H, & Doh, S I 2020, January *Factors affecting the success of highway construction projects: the case of Malaysia* In IOP Conference Series: Materials Science and Engineering Vol 712, No 1, p 012030 IOP Publishing.
[25] Radzi, A R, Bokhari, H R, Rahman, R. A, & Ayer, S K 2 019 *Key Attributes of Change Agents for Successful Technolog y Adoptions in Construction Companies: A Thematic Analysis In Computing in Civil Engineering 2019: Data, Sensing, and Analytics* pp 430-437 Reston, VA: American Society of Civil Engineers.
[26] Aburawe, S M, & Mahmud, A R 2011 *Wate r Loss Control and Real-Time Leakage Detection Using GIS Technology* Geomatics Technologies in The City (GTC), p 10-13

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