WORK BREAKDOWN STRUCTURE FOR WATER DISTRIBUTION PIPELINE NETWORKS

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WORK BREAKDOWN STRUCTURE FOR WATER DISTRIBUTION PIPELINE NETWORKS

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"To my beloved father and mother, and siblings, thank you for all your support in terms of spiritual and encouragement."

"To all my fellow friends, thank you for all your support."

To people who guided and helped me,

Prof. Dr. Miswan @ Abdul Hakim Bin Mohammed (Main Supervisor)

and

Dr. Mat Naim Bin Abdullah (Co-Supervisor)

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ABSTRACT

Pipe is one of the basic infrastructures in water treatment and distribution systems. In Malaysia, water supply infrastructure which has been built progressively over the last 50 years, now is facing the ageing asset problems due to the use and deterioration over the years. The deterioration of water pipeline networks has increased the cost of repairing, for replacing failed water pipelines and the cost of non-revenue water. In order to solve this problem, a huge amount of budget is needed to maintain, rehabilitate, replace and dispose the water pipeline networks. Considering that the Life Cycle Cost (LCC) is essential in determining the water pipeline networks performance and to minimize the amount of cost, development of Work Breakdown Structure (WBS) for LCC Model to be practiced in water infrastructure is important. The first objective of this research is to develop a WBS for water distribution pipeline networks. Second, to determine the weightage of element for each category of the WBS and third, to investigate the readiness of the water industry for the implementation of LCC and the WBS for water distribution pipeline networks. The methodology used include Delphi Method and Analytic Hierarchy Process in the process of developing WBS and determining the weightage of each category of elements where ten respondents (practitioners from water operators in Malaysia) are interviewed. The readiness of implementing LCC and WBS for water distribution pipeline networks was determined through a Likert-scale questionnaire and the feedbacks of 35 respondents from the water industry practitioners selected randomly were analysed using descriptive method. This research has built the WBS for water distribution pipeline networks and the weightage suggests that capital consume the largest portion (74.3 percent), followed by operation and maintenance (17.8 percent), meanwhile the disposal consume the smallest portion (7.9 percent). The findings also revealed that the practitioners were ready to implement the WBS constructed by this research. The WBS developed has now filled up the gap in academic and also gives contribution to the water industry.

ABSTRAK

Paip adalah salah satu infrastruktur asas yang amat penting dalam sistem rawatan dan pengagihan air. Di Malaysia, infrastruktur bekalan air yang telah dibina secara progresif sejak 50 tahun yang lalu, kini menghadapi masalah penuaan aset. Kemerosotan rangkaian paip air telah meningkatkan kos membaik pulih, penggantian saluran paip air dan kos air tidak terhasil. Dalam usaha untuk menyelesaikan masalah ini, sejumlah wang yang besar diperlukan. Pertimbangan kos kitaran hayat (LCC) adalah penting untuk menentukan prestasi rangkaian saluran paip air dan untuk mengurangkan jumlah kos yang diperlukan, pembangunan struktur pecahan kerja (WBS) untuk Model LCC adalah penting untuk diamalkan dalam infrastrucktur air. Objektif pertama kajian ini adalah membangunkan satu WBS untuk rangkaian saluran pengagihan paip air. Objektif kedua adalah bagi menentukan wajaran bagi setiap kategori elemen dalam WBS manakala objektif ketiga adalah untuk menentukan kesediaan industri air bagi pelaksanaan LCC dan WBS untuk rangkaian saluran pangagihan paip air. Kajian ini menggunakan kaedah Delphi dan Proses Hierarki Analitik untuk membangunan WBS dan menentukan wajaran bagi setiap kategori elemen dimana sepuluh orang responden yang terdiri dari pengamal dari agensi-agensi perkhidmatan air di Malaysia ditemuramah. Kesediaan pelaksanaan LCC dan WBS untuk rangkaian saluran pengagihan paip air ditentukan melalui borang soal selidik skala Likert dan analisis deskriptif digunakan untuk menganalisis data yang dikumpul daripada 35 orang responden dari industri air yang dipilih secara rawak. Kajian ini telah membangunkan WBS untuk rangkaian saluran paip pengagihan air. Wajaran bagi setiap kategori elemen menunjukkan bahawa modal merupakan kategori elemen terbesar (74.3 peratus) diikuti oleh operasi dan penyelenggaraan (17.8 peratus), manakala pelupusan merupakan kategori yang paling kecil (7.9 peratus) diantara semua kategori. Hasil kajian ini juga menunjukkan bahawa industri air bersedia untuk melaksanakan WBS yang dibina dalam kajian ini. WBS yang dibina telah mengisi ruang dalam bidang akademik dan juga memberi sumbangan dalam industri air.

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
CBS	-	Cost Breakdown Structure
LCC	-	Life cycle cost
WGMM	-	Weighted geometric mean method

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Assets are things that will create products and services, which in turn allow citizens to have a safe and sound quality of life, happiness and general well-being. Such assets include water and wastewater infrastructures, road, vehicles, plant and machinery and software. An asset is any object which can be used to produce a product or service to meet the needs of a client or customer. Essentially, asset can be divided into three categories which are discrete, linear and intangible. Discrete assets are assets that have a clear and unique boundary where it is usually fixed or mobile. Examples, pumps, reservoir and buildings are considered as fixed assets while vehicles are mobile assets. Linear assets are assets which are continuous with one or more undefined boundaries and it is typically fixed such as underground water pipelines, sewer pipelines, rails, road and drains. Lastly, the intangible assets refer to the assets which do not have boundaries and the examples for intangible assets are software programs and electronic data (Lutchman, 2006).

Water supply systems or water pipelines which categories under linear assets is one of the indispensible infrastructure which help in carrying out our daily water supply. Over the years, people had used different type of materials to create their own type of water pipeline networks to supply water. The earliest known evidence of water pipeline networks was found around 3000 century ago and the earliest use of cast iron water pipe for water supply was built around the year 1560. The water piping system not only helps to deliver daily water supply but it can also be used to distribute waste water away to the sewer systems. In the water treatment and distribution system, pipelines are used in various stages to connect from one equipment to the others. For example, pipelines are needed to draw raw water extracted from the dam to the water treatment plant. In addition, pipelines are also used to connect most of the water equipment or water assets to deliver and distribute water. Water treatment plant can be divided into several levels where each level has its own function in treating raw water. In order to transport water from one level to the others, pipelines are required.

In pace with the trend of increasing water demand due to population and economic growth, it has led to a water crisis in many parts of the world especially in developing countries. To overcome this situation, efficient water infrastructures and advance technology are required (Hasnul Mohamad Salleh, 2012) and water pipelines are one of the essential water infrastructures in improving the situation. Unfortunately, the water crisis problems which occurred are mainly due to poor water pipelines which are not being maintain properly. All these water pipeline networks which have last for decades have deteriorated and lost value due to certain condition such as age, material type, soil condition, topography and weather and all these would affect its quality and performance (Mann and Frey, 2011; Tran, 2011; Ugarelli *et al*, 2010; Hollands, 2010; Venkatesh,*et al*, 2008). Furthermore, the burden of old water pipeline networks are not only limited to the cost of repairing and replacing failed water pipelines but it also includes the cost of non-revenue water. In other words, old and poor water pipeline networks not only required a massive amount of money to rehabilitate but it also caused the loss of water which does not reach to the end-users due to pipe leakages or pipe damages.

Water distribution pipelines which are now facing serious deterioration has led to ineffective water supply and caused inconvenient to the end-users. According to Varnier and Rahman (2004), due to the lack of available funds and decision support system, most of the rehabilitation and replacement works have been neglected and these works are only carried out when failure occur. In Black and Veatch report (2012), the major issues currently facing by the industry are firstly, aging water and sewer infrastructure, followed by managing capital costs and funding or availability of capital. Agreed by Selvakumar and Tafuri (2012), currently one of the hot topics in water utilities are the aging issues of the water assets. Figure 1.1 below shows the result for importance of industry issues obtained from a survey respond by water utility leaders.

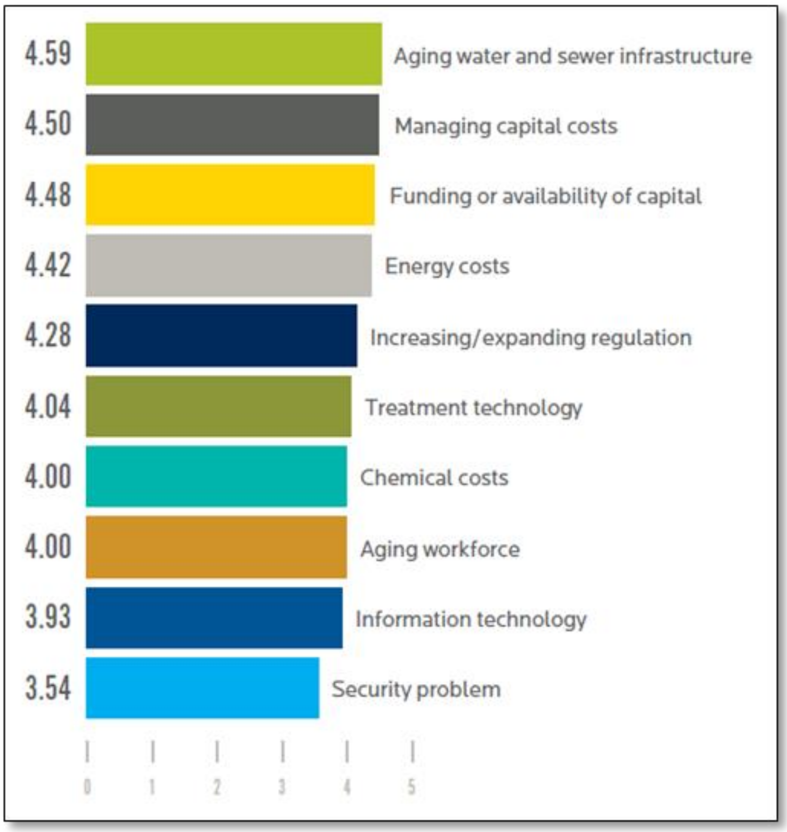

Figure 1.1 Importance of industry issues

Sources: Black and Veatch (2012)

Today, aging water distribution pipelines have been a major challenging task faced by most of the municipal council in many developing countries. As stated in the convening report of Financing Sustainable Water Infrastructure 2011, the nation's water pipeline ages and populations have grown beyond the capacity of existing systems. The water pipelines built years ago are now unable to support the ever increasing amount of supply. The report also stated that, water infrastructure which was built decades ago is now at a critical juncture, especially those pipelines which were located at the industrialized population growth centers established after World War II.

Underground water distribution pipelines constructed and installed during 1800s, 1900s and post-1945 will start to fail after a couple of decades due to aging. Based on a study carried out in North America, there are over 300,000 of water main breaks which occur annually due to the aging pipeline system. Those decaying pipeline systems are believed to pose environmental or public health hazards or both (Cohen, 2012). On the other hand, Holland's (2010) aging water distribution system has caused 35 billion gallons of water leak and each year the people pay $25 million dollar for water which never reached them. However, this aging water infrastructure problem does not only happened in develop country such as United States but is also now a major problem happening in Malaysia.

Malaysia water distribution pipeline system has been built progressively over the last 50 years. Due to usage and deterioration over the years, the water pipeline networks in Malaysia are now facing with the aging assets problems (Mohd Hazley and Abdul Hakim, 2012). Chief Operating Officer of Salcon Berhad, Ir. Ooi Cheng Swee also stated that 40% of the water pipeline networks in Malaysia are now very old (Underground Infrastructure Magazine, 2012). The pipelines which are facing with aging problem are now losing its capital value and deteriorating in its performance. Water pipeline networks which are not properly managed might also cause a higher rate of failure (Hoover 2002). For example, leakages which are not repair on time might cause non-revenue water just as reported that the aging pipelines have produced more than a third of non-revenue water from the total water pumped out of the reservoir and the amount of non-revenue water produced are enough to supply every family all over Malaysia for 189 days or fill up 797,600 Olympic sized swimming pool. Besides, due to the pipelines being buried underground, it is difficult to detect any leakages and damages as it aged until failure occurs. Consequently, the minor leakages and damages might accumulate over the years and it may lead to bursting of the damaged pipelines and caused local floods and structural damage.

As a result, massive amounts of fund are needed to carry out periodical maintenance, rehabilitation and replacement of the pipelines and its components in order to prevent from further deterioration. Several literature reviews, mentioned that countries which are facing aging water distribution system, are also facing limited budget in maintaining and replacing water distribution pipelines. This also happen in Malaysia. Based on the survey carried out by Black and Veatch (2012), it shows that the aging water infrastructure also bring high impact to the financial health of the system. As the infrastructure aged, rehabilitation and replacement need to be carried out in order to maintain its service level. Thus, sufficient funds are needed to ensure that the maintenance works could be carried out. Figure 1.2 below shows the result obtained from the survey where most of the water utility leaders agreed that rehabilitation and replacement of infrastructure has a high impact on its financial health.

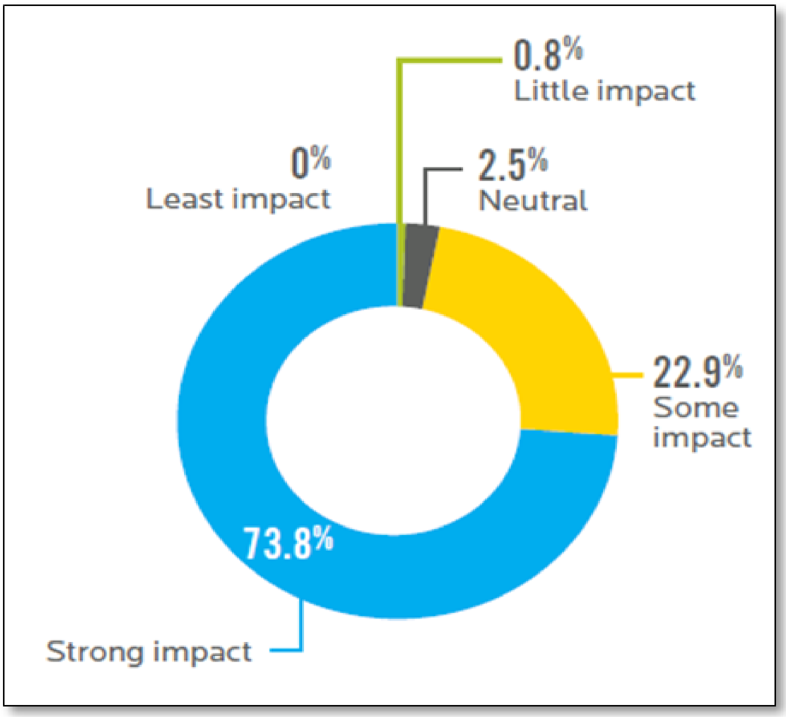

Figure 1.2 Impact of rehabilitation and replacement on financial health

Sources: Black and Veatch (2012)

Apart from aging factors, the ever increasing population's growth and developed cities has fastened the deterioration of water infrastructure. Besides, other combinations of factors such as sewer overflows, unsatisfactory infrastructure performance, and high rates of water lost have also caused high capital outlay in rehabilitation and replacement of the utilities. The U.S. Environment Protection Agency (EPA) mentioned that in the next 20 years, billions of dollars might be needed to be invested in water infrastructures which have deteriorated. In order to continue supplying drinking water to the nations, installation of new infrastructure as well as rehabilitation of existing infrastructures which have aged and expansions of undersized infrastructure required huge amount of money. In the convening report of Financing Sustainable Water Infrastructure 2011, it was reported that hundreds of billions of dollars are needed to repair and expand the existing water pipelines. This is required in order to maintain the pipelines performance and to ensure that it provide sufficient water supply to end-users. In addition, a number of previous studies also stated that it is expected to cost the municipal council over several billion to trillion of dollars to construct, upgrade and replaced the water distribution pipelines over the next 20 years (Cohen, 2012; Hollands, 2010). This is because the maintenance and replacement of old water pipelines are bound to get costlier over time as the works need to carry out are bound to get heavier (Mohd Hazley and Abdul Hakim, 2012; Baird, 2010; Ugarelli *et al*., 2010).

As the pipelines in a system account for the lion's share in a lifetime cost, the local governments thus face the challenging task on balancing between both spending on maintenance and repairing the water pipelines. According to the American Society of Civil Engineers (ASCE), the need to maintain and rehabilitate the nation's aging water pipelines will exceed the local governments' ability to make the necessary capital investments, resulting in a projected $84 billion capital funding gap by 2020 (Cohen, 2012). This has been proven by the survey done by Black and Veatch (2004) where the second and third issues concerning the water utilities leaders are managing costs and available of funds. The survey also shows that rehabilitation and replacement work have a high negative impact on finance. Besides, during economic downturn, the gap between the needs to rehabilitate and replacement of pipelines and financial requirement had widened (Black and Veatch, 2004). Most of the investors refuse to invest as they do not see any improvement in the water infrastructure systems efficiency and the reduction of water loss rates. The decrease in investment had resulted in the maintenance works which needed to be carried out has been ignored.

Apart from this, Malaysia is currently also facing the same issues. Most of the old pipelines are not well maintained and replacement inadequate due to limited budgets (Underground Infrastructure Magazine, 2012). From an interview carry out previously during the preliminary study in this research, it can be concluded that one of the most critical water assets in Malaysia currently are water distribution pipelines. These water assets incurred an excessive amount of money due to continuous maintenance. It was also agreed by the contractor from water industry interviewed in the preliminary study that water distribution pipelines are now facing several critical problems such as aging, corrosion and leakage. In years to come, if these old pipelines are still not being maintained or replaced, while the other pipelines continue to age over time, the money needed to maintain the whole networks will be much costly (Mohd Hazley, 2012; Baird, 2010; Ugarelli *et al*., 2010). In order to solve this problem, an enormous amount of money is needed to maintain, rehabilitate, and replace the water pipeline networks. Moreover, if the old pipelines are left too long to maintain and replace, there will be an economic loss when additional money is spent for emergency repair that could have been avoided. Furthermore, from a proactive standpoint, a good well taken decision made on pipe rehabilitation need to be done in order to avoid inconvenience to the end users due to service interruptions (Amarjit, 2011).

Unfortunately, for most of the time, the limited amount of money allocated are not spent wisely on resources and treatment works which require high initial capital outlay. As a consequence, the ever increasing demand was not served, the maintenance of the aging water pipelines had been neglected and the water supply network could not be upgraded or expended fully (Hasnul Mohamad Salleh, 2012). However, it is also unrealistic to replace all deteriorated and failed water pipeline networks simultaneously (Shahata and Zayed, 2008) because it would cost much more amount of money and caused some inconvenience to the end-users. As the available fund is limited, the investment on project such as replacing aging water pipelines and upgrading water pipelines must be in least capital but comparatively high in benefit and effect (Baird, 2010). Nevertheless, the limited budget issue is mainly due to the lack of LCC implementation.

The reason why there is a lack of implementation of LCC in water distribution pipeline networks is because there is no urgent need of LCC to calculate the total cost needed to maintain and rehabilitate the newly built pipelines. As the life span of a water distribution pipeline could exceed more than 100 years, then, generally after a water distribution pipeline is completely built and buried underground, it would not be maintained or rehabilitated for a long time. Moreover, even when there is any leakage or minor damage to the pipelines, it can still perform well and does not cause major problems. As time passed, the buried underground pipelines which have been used for decades would have started to deteriorate, aged and the leakages and damages accumulated would get worse. Currently, aging water distribution pipelines and limited budget have become a challenging task faced by most of the municipal council and due to this a decision support tool for pipeline renewal has become essential. As a result, LCC is now required to be implemented to calculate the amount of budget required and to select the most cost effective alternative in maintaining, rehabilitating and replacing the poor water distribution pipeline networks.

1.2 Issues

Based on literature, LCC actually has been widely practiced in most of the industries such as military, construction, oil and chemical, manufacturing, transport infrastructure and water infrastructure. In construction industry, LCC has been widely practiced in countries such as Australia, New Zealand, United State of America and United Kingdom. Its long term benefits were also widely acknowledged (Hoffart and Hirsch, 2011; Lindholm and Suomala, 2004; Woodward, 1997). Yet, most of the previous research stated that the implementation of LCC by the practitioners and decision makers are still relatively slow. The slow implementation of LCC especially can obviously be seen in the water industry as most of the water infrastructures still do not implement LCC although LCC has been developed and implemented since year 1965. In water industry, until recently only several water infrastructures such as drainage system, sewerage system and pump house have implemented LCC (Waghmode *et al*., 2010; Mohammad A. Ammar *et al*., 2012; Shahata and Zayed, 2013).

In water distribution pipeline networks, the implementation of LCC has just started a few years ago. Due to the aging water infrastructure issues, several previous study had been carried out in United States to develop decision support tools, and LCC is one of the decision support tools which have been adopted by Shahata and Zayed (2013) and Ammar *et al*. (2012). However, both the researchers only adopted

LCC as a decision making tools in choosing the best rehabilitation method for water distribution pipelines and not focusing on the cost incurred within the life cycle of the pipelines. In Ammar *et al* (2012), the researchers focus more in selecting the most suitable rehabilitation method, while Shahata and Zayed (2013) is more concerned on testing the uncertainties in rehabilitation of water distribution pipelines. Moreover, Ammar *et al*. (2012) do not consider the pipe specification parameters as the researchers conclude that those parameters do not give any effect on the rehabilitation method ranking. Thus, it can be concluded that no LCC model has been developed for the life cycle of water distribution pipeline networks.

1.3 Problem Statement

In Malaysia as well, LCC is also not widely implemented especially in water industry. A preliminary study has been carried out previously and seven respondents have been interviewed, two respondents from Department of Water Resources (Jabatan Bekalan Air) and the other five respondents consist of contractor and consultant. Based on the results obtained from the interview, it can be concluded that Malaysia water industry does not practice LCC in decision making and the current practice by the practitioner in decision making is Value Engineering (VE). One of the interviewee from Department of Water Resources claimed that practically LCC should be implemented and practiced by the industry in decision making as stated in the 10th Malaysia Plan (Rancangan Malaysia ke-10).In a convention held under National Asset and Facilities Management themed “Enhancing Values through Total Asset Management in the 10th Malaysia Plan”, one of the objectives is to formulate sustainable integration of asset planning, life-cycle costing, monetisation, performance monitoring, good governance and best-practices in managing the Malaysian built-environment. This reveals that the government urges LCC to be implemented for effective management of the asset. However, practitioners in the industry still do not implement LCC and even some of the contractors claimed that they do not know about LCC. They usually make their decision based on the quotation given by the supplier or based on VE. This phenomenon has been agreed by Matthews (2012) as most of the decisions are usually made based on the in-house and consultant expertise. As a result, from the interview, it can be concluded that the water industry in Malaysia still do not practiced LCC and thus no LCC model has been developed in Malaysia.

Based on the review of LCC guidelines and tutorial from different countries which practiced LCC widely, the most basic step to develop a LCC model is firstly to develop a cost breakdown structure (CBS). Cost Breakdown Structure is a breakdown structure which classifies the costs within a project into cost units and cost elements. Agreed by El-Haram *et al*. (2002), CBS is a structure that helps to facilitate the identification of elements in each life cycle phase of a project. It is necessary to be created in order to conduct a LCC analysis. Hence, this means that CBS is a structure which is necessary to be developed before a LCC model can be formed. Therefore, this shows that the lack of CBS development is one of the reasons why LCC is not being implemented. According to Langdon (2010), a CBS illustrate all the costs which emerged in each single phase of the asset's LCC and its purpose is to identify, define and organize all elements to be taken into account in a LCC. Figure 1.3 below shows an example of LCC breakdown structure where all the cost categories can be further breakdown into smaller elements such as acquisition cost, purchasing price, administrative/engineering cost, installation cost, training cost, conversion cost and transportation cost. Hence, it could be a checklist for the practitioners to locate the cost data and to itemize into the correct category of cost.

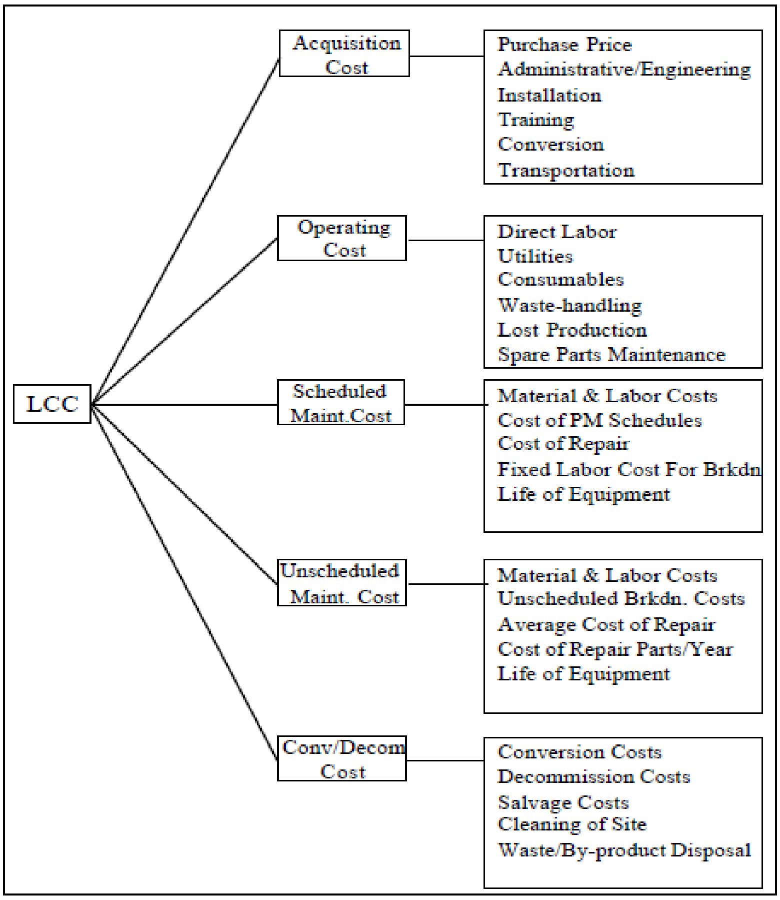

Figure 1.3 Life cycle cost breakdown from society of automotive engineers (SAE) model

Source: Barringer and Weber (1996)

Although there are several CBS which have been developed by previous researchers, however, all are from different industries such as construction industry, automotive industry, oil and chemical industry, and so on. Obviously it can be found that all the elements included in the CBS varies from one to another. However, even if the CBS developed are from the same industry such as construction industry, it may also vary (Langdon, 2010). Agreed by Langdon (2010) and Barringer and Weber (1996), elements in CBS vary in scope and details from one CBS to the other. Therefore, the existing CBS from different industries might not be suitable to be applied directly for the water distribution pipelines CBS. Apart from that, due to the lack of historical data and previous research, the elements that need to be included in the water distribution pipelines CBS are mostly unknown. So, a new CBS is required to be developed in order to suit the water industry specifically for water distribution pipeline networks.

Apart from the lack of CBS development, the other reasons for the slow implementation of LCC are due to the lack of proper guidelines and historical data (Jenne van der Velde *et al*., 2013; Wijnia and Herder, 2009; Eric Korpi and Timo Ala-Risku, 2008; U.S Department of Transportation, 2002; Abd. Ghani and Abdullah, 1997). Most of the time, data collected by the practitioners are from multiple sources or organizations and the data is often kept separately and in different form based on the usual practice of the practitioners individually. This situation led to incomplete documentation of historical data and sometimes it may cause missing data as well. For example, data which have been collected years ago might be kept in a more traditional way which is the filling method, while the present day data are currently kept technologically, such as in a Microsoft Excel form. So, when the data are kept in different forms, those old data which are kept in the file could get lost easily or forgotten. On the other hand, the use of technological way may also cause error, when some of the data are wrongly entered by the practitioners. This is also agreed by Fabrycky and Blanchard (1991) where the costs data identified are often placed in the wrong cost category and improperly applied. Besides that, due to lack of proper guideline, some important data might also not be collected and vice versa. As a consequence, the LCC calculated might be inaccurate as there are too many missing data or data which are not entered in the correct cost category.

Apart from that, according to Hoffart and Hirsch (2011), the reasons for the lack of LCC usage are due to the complexity of implementation, calculation and identification of the elements. Due to the data been often kept separately and in different forms, it is a challenge for the practitioners to identify and gather the appropriate elements which are used in the calculation. In the analysis of LCC, the costs that were taken into consideration are the initial purchase cost and also the other costs which incurred during the whole life span. As defined in ISO 15686-1 (2000), LCC is a technique which enables comparative cost assessment to be made over a specific period of time, taking into account all relevant economic factors, both in terms of initial capital investment and future operational costs (Ugarelli, 2010). For a water distribution pipeline networks, the life cycle costs consist of acquisition cost which includes consultancy from the expert, design and construction costs, equipment, and also the operational and maintenance costs for the whole life span. All activity cost incurred after acquisition needs to be taken into consideration as without the periodic maintenance and rehabilitation, the water distribution pipelines will not provide continuous service to the end-users. This shows that there are quite a number of elements which will be included in the LCC model for water distribution pipelines. Therefore, it might be a challenging task in identifying and collecting all the elements, as it involves too many items.

In addition, in a CBS there will be several different cost categories such as research and development costs, acquisition costs, operation costs, maintenance costs and disposal costs (Fabrycky and Blanchard, 1991; Barringer and Weber, 1996; Kawauchi and Rausand, 1999). In most cases, when there is a constraint in budget allocation or there is a need to reduce the total cost of a project, decision makers tend to reduce the acquisition costs by purchasing cheaper equipment. There was previously a research done, which states that the acquisition costs only consume 20% to 40% of the total project cost because acquisition costs are only paid once when the project started (Woodward, 1997; Lindholm and Suomala, 2005). The major costs which consumed the lion’s portion of the total project cost are the operational costs and maintenance costs as both these costs required periodically payment throughout the whole life span of the equipment. However, different equipment might have its own life span and characteristics. Some equipment might have a very high acquisition cost but relatively low operational and maintenance costs while others might have comparatively high acquisition cost and also high operational and maintenance costs, like water distribution pipelines. Apart from acquisition, operational and maintenance costs, sometimes disposal costs for certain equipment might also be expensive. As an example, water distribution pipelines which are buried underground may cost a massive amount of money during its disposal. Thus, in water distribution pipeline networks, which cost categories consume the largest portion and which consume the smaller portion of the total cost are unknown. Therefore, there is a need to determine the weightage of each of the cost category in order to ease the decision makers in adjusting the budget allocated.

In conclusion, in order to overcome the aging water distribution pipeline networks and limited budget problems, a LCC is required for the project. The LCC is needed to calculate the total budget cost which is required for allocation for the maintenance, rehabilitation and replacement of the poor pipelines. To develop a LCC model for water distribution pipeline networks, a CBS for water distribution pipeline networks need to be developed first. Furthermore, to obtain a more accurate budget, the weightage for each cost category needs to be determined so that the consumption of each cost category over the total project cost can be made known. In addition, as discuss previously, the concept of LCC is still very new in the water industry and most of the practitioners still do not implement it in their daily practice, thus, the readiness of the water industry for the implementation of the LCC and CBS need to be investigated as well. Unfortunately, as the actual cost for each identified element is hard to obtain in from the industry, thus, the elements identified are just merely the name of the elemetns and it does not contain any cost figure in it. Therefore, the breakdown structure developed later on in this research will be known as Work Breakdown Structure (WBS) and although there is a word “costs” in the name of the element’s category, but it does not relate to any cost figure as well.

1.4 Research Question

Based on the problem statement stated above, the research questions are as below:-

1) What is the work breakdown structure for water distribution pipeline networks?

2) What are the element's weightage for each category in the work breakdown structure for water distribution pipeline networks?

3) Does the water industry ready to implement the life cycle cost and work breakdown structure for water distribution pipeline networks develop in this research.

1.5 Research Objective

Based on the problem statement stated above, the objectives of this research are as below:-

1) To develop work breakdown structure for water distribution pipeline networks.

2) To determine the element's weightage for each category in the work breakdown structure for water distribution pipeline networks.

3) To investigate the readiness of water industry for the implementation of life cycle cost and the work breakdown structure for water distribution pipeline networks.

1.6 Research Scope

The scope of this study is focusing only in the water distribution pipeline networks which are used to deliver treated water from reservoir or pump house to the end-users in Malaysia. The scope for respondents will be the practitioners, engineers and quantity surveyors who will carry out decision making on maintaining and rehabilitating water distribution pipeline networks.

1.7 Research Methodology

The methodology in this research consists of three stages as shown in Figure 1.4 below in order to achieve the three objectives:-

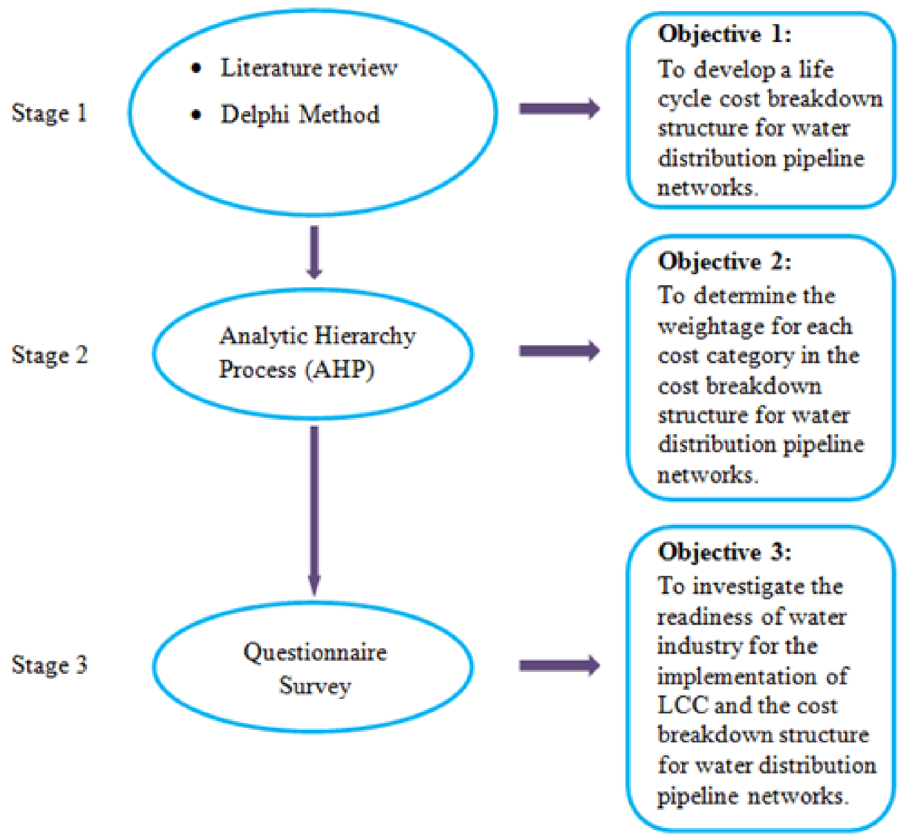

Figure 1.4 Research methodology flow

In order to achieve the objectives, several methodologies have been applied. The first objective which is to develop a life cycle cost breakdown structure for water distribution pipeline networks will be achieved through literature review and Delphi method. Firstly, the elements will be identified through literature review. The elements are the cost breakdown which is found in LCC equation. From the review, elements for any assets from any industries in LCC model will be collected. After collecting and identifying all the elements, Delphi method will be applied. The elements will be justified by the respondents through the first round of interview in order to obtain the suitable elements for water distribution pipeline in life cycle cost model. The respondents who consist of practitioners, engineers and quantity surveyors from the water industry will be selected by using purposive judgment sampling method.

Next, from the results obtained, a CBS will be drafted and the second round of interview could be conducted. The drafted CBS will be reviewed by the respondents during the interview. After collecting all the comments and opinions from the experts, the second draft of CBS will be developed. The same process will be repeated until a consensus is obtained from all the respondents interviewed. Thus the first objective of this research is achieved.

For the second objective, Analytic Hierarchy Process (AHP) will be applied in order to obtain the weightage of each cost categories. A pairwise questionnaire survey will be developed and the experts will be interviewed again. The data collected will be analyzed and from the results obtained, the weightage of each cost category will be determined.

Then, a questionnaire will be designed using Likert scaling questions. The CBS developed will be attached in the questionnaire and the questionnaire will be distributed to a group of respondents selected randomly. The data collected will then be analyzed and from the data obtained, the readiness of the industry in implementing LCC and CBS will be determined. Finally, a conclusion will be drawn out and some recommendations for further study will be suggested.

1.8 Significance of the Research

This study is important because through this study, the elements in WBS for water distribution pipeline networks would be identified and a WBS could be developed. The developed WBS could then help in estimating the expenses required in a more economical manner and lessening the relative cost for time. Besides, by having a WBS, all the elements which are required in the calculation of LCC analysis such as acquisition costs, operating costs, maintenance costs and disposal costs will be known and this will ease the practitioners in collecting the cost data. In addition, it can also be a checklist for the practitioners in categorizing all the cost data collected into the correct categories. This will help the practitioners in the industry such as Pengurusan Aset Air Berhad (PAAB) and other water operators who need to carry out LCC analysis. Moreover, WBS may also help the practitioners to demonstrate a good stewardship of the water distribution pipelines as it might provide a clear record for all the data collected and minimize the percentage of lost data. This can prevent from future controversy and the documentation may possibly help to preserve important knowledge and information for future practitioners and decision makers. Besides, by knowing the elements involved, the cost of maintenance, rehabilitation and replacement may possibly be calculated.

In addition, the weightage obtained through this research could also help the practitioners from water industry in identifying which category has the highest weightage and which category has less weightage. Thus, the water operators could then spend the budget allocated more wisely. As the concept of LCC helps practitioners to understand all the costs incurred, this may encourage practitioners to find a correct balance between investment costs and operating expenses. Thus, extra cost for maintenance, rehabilitation and replacement may possibly be saved. Furthermore, the construction of water pipeline networks is an important part of the water supply system as it is a huge one-time investment and it has a long period of operation cycle. Therefore, by having this research, the budget obtained could probably be allocated more wisely according to the weightage obtained and it might help in estimating the one-time investment cost and the budget cost needed during the operation period of the water pipeline networks. As a result, there will be sufficient budget in maintaining the water distribution pipeline networks over its predictive useful time. This will help in decreasing the loss of non-revenue water and increases the effectiveness of the water supply. Then the people in Malaysia could enjoy a better water quality in their daily life.

This study could also be used as an academic resource for others that have interest in doing some research in developing life cycle cost model for water distribution pipeline networks.

1.9 Structure of the Research

Chapter 1
A brief description about the research will be discuss in this chapter where it includes background of study, problem statement, research objective, research scope, importance of research, research methodology and structure of the research.

Chapter 2
Definition and the model of LCC will be discussed in this chapter. All the elements included in each and every phase of LCC model will be discussed in detail and identified. Steps in developing LCC model will be discuss as well.

Chapter 3
This chapter will focus on the description of research method used on data collection and data analysis. Interview and questionnaire survey will be selected as the research method used for collecting data.

Chapter 4

In this chapter, researcher will analyze all the data collected and the results of the analysis will be discussed. The conclusion in this chapter will achieve the objectives of this research.

Chapter 5

This is the last chapter of the research and it concludes the overall research that has been carried out as well as the findings of the research. Further studies will also be recommended at the end of this chapter.

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