International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume-2, Special Issue 3 (July-Aug 2014), PP. 54-58

IDENTIFICATION OF CRITICAL LEVEL OF ASSETS BY USING ANALYTIC HIERARCHY PROCESS FOR WATER ASSETS MANAGEMENT

Mohd Hazley Halim[1], Abdul Hakim Mohammed[2]
[1]Pengurusan Aset Air Berhad (PAAB)
[2]Universiti Teknologi Malaysia

Abstract - **The management of a water asset is becoming more complicated and demanding, not only to keep the water asset in good condition but also in an optimal manner. To overcome these challenges water asset should be managed according to the critical level of each asset that is determined base on the identified critical criteria for each asset hierarchy. The main purpose of this study is to identify the critical level of each asset by using analytic hierarchy process (AHP). The research methodology consists of a series of focus group workshops and the utilization of analytic hierarchy process. A series of focus group workshops with subject matter experts in the water industry will be conducted to produce a hierarchical framework for water assets through a sequence of pair-wise comparison judgments. Analytic hierarchy process will be utilized to derive the multi criteria decision making (MCDM) preferences from stakeholders and to compute the corresponding relative weights of their decision preferences towards the asset criticalities. By using this method, the water industry will be able to analyze the quantitative information and develop a single framework for the water assets. It will be beneficial in water asset management and serve it purposed for transparency, effective and efficiency in managing water assets for future.**

Index Terms - **Utility, asset management, water, MCDM**

I. INTRODUCTION

Water supply infrastructure in Malaysia has been built progressively over the last 50 years. With the increased in demand of supply and customers' expectations of achieving the Key Performance Index (KPI) set by National Water Services Commission (SPAN) as the regulator, a new management practice has to be introduced for the construction and maintenance of new and existing assets to meet these demands. This is important to Pengurusan Aset Air Berhad (PAAB) as the facility licensee and water operators as the service licensee, which are committed to deliver satisfactory performance based on an agreed target of Key Performance Indicators (KPI) set by National Water Services Commission as the service regulator. With the introduction of Water Services Industry Act 2006 - Act 655 (WSIA) and migration to the new licensing regime, PAAB has become the only custodian of national water assets. Upon migration to the new regime, many of the water infrastructure assets handed over by service licenses to PAAB is old and near towards the end of its life.

Historically water assets were managed based on personal knowledge of the assets and processes. As more experienced engineers and experts approach towards their retirements, decades of undocumented and irreplaceable experienced and knowhow of the assets and systems will be lost. As tomorrow's expert can always be built on expertise available today, it is critical to maintain the knowledge, condition and critical level of the water assets for future planning purposes.

In today's environment where customers continuously demand increased levels of quality service, it is imperative that organizations constantly enhance their performance and exceed their customers' expectations. For Pengurusan Asset Air Berhad ("PAAB") or Water Asset Management Company (WAMCO), which is entrusted by the Federal Government under the Water Services Act 2006 (Act 655) to develop the nation's water infrastructure in Peninsular Malaysia and the Federal Territories of Putrajaya and Labuan, the emphasis on the delivery of treated water supply is increasing, water operators are being made more directly accountable for the management of the resources involved in the delivery of public services.

Under the new water supply regime, water supply assets presently owned by Service Licensees will be handed over to PAAB. As the new asset owner of water supply assets, PAAB needs to know what assets they own, where the assets are, the condition of the assets, the remaining useful life and the value of these assets. These asset data and information are highly important for effective implementation of Asset Management program. Therefore, it is really crucial for PAAB to understand the current condition of the assets for the purpose of CAPEX and OPEX planning

II. SCOPE OF RESEARCH

Water was a State matter; as such treated water supply was the purview of respective States. Up to the initiation of the Water Supply Industry Act, State Governments own the water infrastructures, managed, operate and maintained all water related infrastructure to provide the service.

The Federal Government stepped up efforts to reform the industry in 2003 for the benefit of all stakeholders including the Federal Government, consumers and the State Government. It is an extensive process that includes amendments to the Constitution and passing of new legislations to enable the Government to materialize the reformation.

Parliament approved the amendments to the Ninth and Tenth Schedules of the Federal Constitution in January 2005. The amendment to the Ninth Schedule involves the transfer of water supplies and services from the State List to the Concurrent List. In other words, the water supplies and services is now a shared responsibility between the State and the Federal Government. It is a pertinent move that gives the Federal Government authority over the water services in all States except Sabah and Sarawak. The Tenth Schedule was also amended and as a result, the revenue from water supplies and services (previously assigned to the States) is now assigned to the Federal Government.

In July 2006, further to the amendments to the Constitution, Parliament passed two new legislations namely the Suruhanjaya Perkhidmatan Air Negara Act 2006 and Water Services Industry Act 2006 (WSIA). The former provides for the establishment of Suruhanjaya Perkhidmatan Air Negara (SPAN) or National Water Services Commission as the technical and economic regulator and set out the function and powers of SPAN. WSIA, on the other hand, provides the legal framework required for the regulation of the water and sewerage service.

Pengurusan Asset Air Berhad (PAAB) was established on 5th May 2006 as a wholly owned company under the Ministry of Finance Incorporated. PAAB is intended to be a Facility Licensee under the Water Services Industry Act 2006 - Act 655 (WSIA). The WSIA defines "Facilities Licensee" as a person who is licensed under this Act to own a water supply system or sewerage system or any part of the water supply system or sewerage system.

A new model was developed, targeting to resolve the financial woes of the water services industry, promote financial sustainability in the State water operators, and alleviate the Federal Government/taxpayers' financial burden. In the long run, the Federal Government wants the state water operators to achieve full cost recovery and attain financial independence. These efforts will ultimately lead to improvement in the quality of water supply and the efficiency of the industry's services.

Under the new model, a separation of responsibilities between water asset owners and operators were made. State water operators will no longer be responsible for developing water infrastructure and it's funding so as they are solely responsible in providing water services to consumer and improving their operational efficiency. The responsibilities of developing water infrastructure and sourcing for its funding will be transferred to PAAB.

Under this new arrangement, PAAB will take over the existing water assets in the States so as to transform the state water operators to asset-light entities. PAAB will then become water assets owner after buying over the water assets from the states. In exchange for the assets, PAAB will assume the States' outstanding Federal water supply loans of an equivalent sum. (However, for some states where the value of the water assets is more than the outstanding loan, the surplus value will be taken into consideration and the settlement terms will be negotiated.)

By transferring the loans to PAAB, the State Governments will be immediately relieved of the heavy burden of settling the Federal water supply loans. The Federal Government, on the other hand, will own the States' water infrastructures via PAAB, enabling it to have better control over the water industry.

After transferring the assets, the State Governments will still be responsible for providing water supply services in the states. However, instead of owning the water assets, the State water operators (Service Licensees) will lease these assets back from PAAB (Facilities Licensee) for operation and maintenance with a fee. With the lease income, PAAB will repay the Federal Government loan over time. The relationship of the various stakeholders can be shown in Figure 1 below.

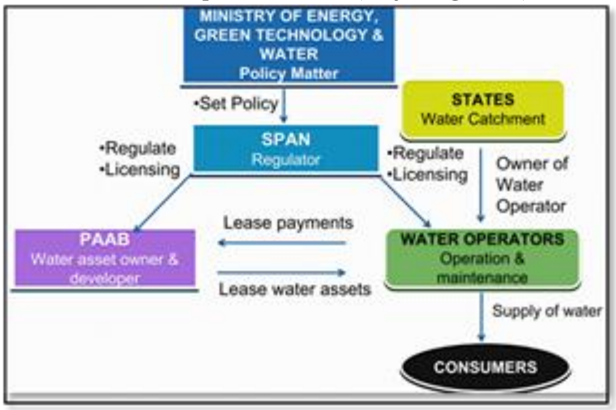


Fig. 1. Relationship of the various stakeholders

Under section 31 of WSIA, the Water Services Commission (SPAN) may direct the Facilities Licensee to construct or extend public water supply systems or public sewerage systems. Section 35 of WSIA requires the Facilities Licensee to construct, refurbish, improve, upgrade, maintain and repair its water supply system and sewerage system. PAAB is also responsible of funding all its water asset capital expenditure.

The largest factor for Service Licensees to cost water rates is the lease rental to be paid to PAAB and the operational and maintenance cost to operate and maintain its water supply system. Billions of Ringgit Malaysia had been invested for the

Water infrastructures managed by Service Licensees today and billions more to be planned, designed or under construction for present and future demand. Many new facilities and pipelines will be much more complex and costly to operate and maintain than of the past. As these new assets come on line, PAAB as the asset owner requires more sophisticated approaches to better manage all the water assets it owns.

No	States	Asset System	GIS
1	Johor	TOMMS	Smallworld 4.0
2	Melaka	Not Available	Strumap 5
3	Negeri Sembilan	Not Available	ESRI
4	Selangor	Not Available	ESRI
5	Perak	Not Available	Strumap 5
6	Pulau Pinang	TOMMS	Strumap 5
7	Perlis	Not Available	Mapinfo
8	Kedah	Not Available	Mapinfo
9	Kelantan	Not Available	ESRI
10	Terengganu	Not Available	ESRI
No	States	Asset System	GIS
11	Pahang	Not Available	ESRI
12	Labuan	Not Available	ESRI

Table 1. Existing systems in water operators for asset management purposes.

Earlier in 2009, PAAB has conducted a desktop study on the availability of GIS and Asset Management implementation for water operators in Malaysia excluding Sabah and Sarawak. Based on the findings as shown in Table 1, almost 10 out of 12 water operators are managing their assets manually without proper record keeping and systematic approach. Without proper system to identify the critical assets there will be no clear knowledge of the condition of assets and how they are performing. These asset lives are not optimized and this leads to replacing the asset prematurely, which is generally expensive in the long run.

III. RESEARCH OBJECTIVE

The objective of this research is to identify and developed the list of criteria and elements that will be used to identify the critical levels of assets. Not every asset presents the same failure risk, therefore it is important to know which assets are required to sustain in the water system's performance to ensure continuously water connection supplied are delivered to consumers.

In earlier days, most of the assets have been managed and monitored using gut feel and local knowledge. Expenditure patterns were based on knowledge of the age of the assets and some assessment of historical failure pattern and wild guess of the asset life expectancy. Without proper Asset Management practice there will be no clear knowledge of the condition of assets and how they are performing, this knowledge lacking will leads to replacing the asset that is generally the most expensive option whenever a premature asset failure occurs.

The criteria of the critical assets must be kept up to date to ensure that the utility is spending its time and resources on the appropriate assets. The criteria developed must incorporate with the replacement of assets. If an asset that was critical primarily due to its likelihood of failure fails and is replaced with a new asset, the critical asset number will go down since the likelihood of failure is much less. Therefore, Multi-criteria Decision Making (MCDM) method through Analytical Hierarchical Process (AHP) technique will be used in this study.

IV. RESEARCH METHODOLOGY

Multi Criteria Decision Making (MCDM) method has been widely applied to various techniques and disciplines. A literature review on the MCDM methods which has been used in research from 1999 to 2009 with a total of 628 papers were identified to be reviewed (Abbas and Mahdi, 2011). The papers were extracted from 20 different journals the tabulation of MCDM methods has been classified based on the techniques and disciplines.

On the other hand, a search by using Science Direct has turn out a total of 1128 papers in 200 journals on the applications of MCDM. Out of 628 papers from the 20 journals earlier, 386 papers (61.5%) have been used as an application while the remaining 242 papers (38.5%) were non application. In the context of MCDM in application, out of 386 papers reviewed a total of 72 papers (18.7%) were used in Water, Business and Financial Management. Based from the 10 years review on MDCM methods, AHP was the most widely technique used as compared to other such as ANP, SAW, TOPSIS, DSS and MOP

MCDM is a methodology use to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective. Although a variety of techniques exist for the development of weights for the criteria, one of the most promising would appear to be that of pairwise comparisons developed by Saaty in the context of a decision making process known as the Analytical Hierarchy Process (AHP) (Saaty, 1980). The most common practice use at this moment was practitioner experience to assess the condition of water mains due to the lack of standard on the condition assessment scale for water mains, which they can depend upon to measure the condition of their water system (Al-Barqawi and Zayed, 2006).

Asset management is the collection, processing, analysis and maintenance of extensive information about various types of assets such as equipment, facilities and other resources to plan work to be executed to maintain these assets at an operational level in the most cost-effective fashion possible (Lemer, 1998). In terms of public-works infrastructure like water supply network, the priority of asset management is making decisions about the effective and efficient development, use, maintenance, repair and replacement.

In order to manage all these assets in the most cost effective manner, an assessment especially on the critical level of assets need to be clearly defined. Typically, this process will relate to the assessment on existing condition of the assets. This will provide a good indication on which items of plant are most critical to the process and able to act quickly through diagnoses an impending failure. As a part and parcels of the rating of an asset, the weightage of critical level will be obtained by using an AHP

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method that helps the decision-maker facing a complex problem with multiple conflicting and subjective criteria. AHP provides a proven, effective means to deal with analyzing the data collected for the decision criteria and expediting the decision-making process. This method claimed to be one of the best methods with comprehensive, logical and structured framework. As shown in Figure 2, it enables people to make decisions involving many kinds of concerns including planning, setting priorities, selecting the best among a number of alternatives, and allocating resources. In summary, the AHP provides decision-makers with logical decisions based on analytical methods, which eliminate the chances of challenge in decision making (Saaty, 1982).

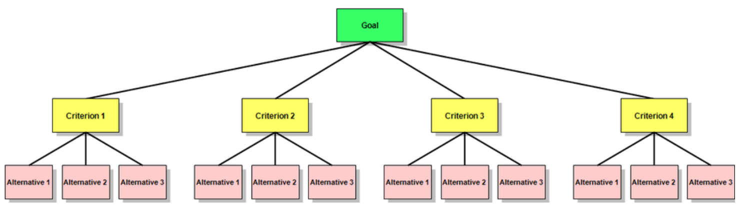


Fig. 2. Abstract diagram of pairwise comparison by hierarchy

In order to ensure the results that will be obtained are beneficial to the water operators. A focus group approach will be used to identify the critical level of assets. The focus group is a tool to gather information with very high quality output for decision making purposes.

A focus group can be utilized for many purposes such as development, evaluation, planning and need assessment (Krueger and Casey, 2000). In this research, a carefully planned series of discussions have been designed to obtain the results for the determination of critical level related to water assets.

The focus group for the determination of assets critical level shares the same features of other discussion methods. However, it must be designed to follow the steps

- A controlled process and environment whereby the participants will interact among themselves;
- The process of data collection and interpretation are well structured;
- Participants are selected according to the specific requirements which have the same area of interest.

The participants for the focus group discussion are attended by the following agencies

- National Water Services Commission
- Kementerian Tenaga, Teknologi Hijau & Air (KeTTHA)
- Pengurusan Aset Air Berhad (PAAB)
- Syarikat Air Melaka Berhad (SAMB)
- Syarikat Air Johor Holding Sdn Bhd (SAJH)
- Syarikat Air Negeri Sembilan Sdn Bhd (SAINS)
- Lembaga Air Perak (LAP)
- Bahagian Bekalan Air, JKR Perlis
- Malaysia Water Association (MWA)

As for main criticality analysis criteria, there are two evaluation condition have been determine to chart the assets failure which are probability and consequences of failure. This formed Level 1 of the evaluation. The probability evaluation comprised of physical condition, site, failure history, assets life, maintenance practice and historical knowledge that are included in the model are identified. On the other hand, the consequences of failure will evaluate other area such as social, financial and environment aspect

The two level of evaluation are later been sub divided into Level 3, 4, 5, 6, and 7 which subject to each asset detail for each component. Figure 3 is an example of a result of Pump House which is structured by hierarchy obtained during the discussion.

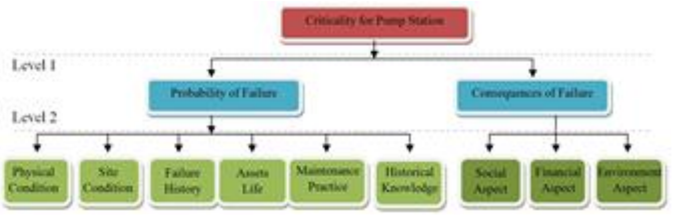


Fig. 3. Hierarchy of assets critical level developed for Pump House

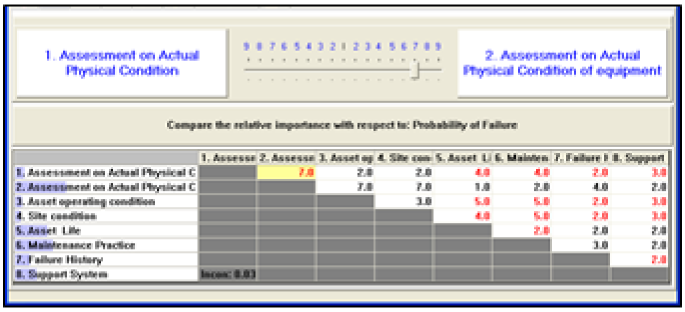
The level of assets obtained was screened and discuss further with the participants to identify and deliberate the criteria and weightage given by each respective participants groups. A commercial software by the name of Expert Choice which has been incorporated with AHP requirement was used as a tool to identify and prioritize the asset critical level. Once the hierarchy has been constructed, the participants will be able to analyze it through a series of pairwise comparisons in matrix table that derive the numerical scales of measurement for the nodes. Each factor weight represents the relative critical of this factor among the other factors.

To assist, a scale numbers were developed to guide and provide a framework to participant for the purpose of the judgment simplification process in Expert Choice. Below is the scale and definition used in this research.

Scale of Criticality	Definition	Explanation
1	Equal Important	Two elements are equally important with regard to the element in higher level
3	Moderate more Important	A is slightly favored than B
5	Strongly More Important	Experience and judgment strongly favor one over the other. A is strongly favored than B
7	Very Strongly More Important	Experience and judgment very strongly favor one over the other. A is very strongly favored than B
9	Extremely More Important	The evidence favoring one over the other is the highest possible validity. A is extremely more favored than B
2, 4, 6, 8	Intermediate values	Compromise is needed.

Table 1. Numeric scale for condition assessment

The basis of judgements in giving the weight for each criteria or factor is by the focus group decision. Through a set of pairwise comparison at each level of the hierarchy, a matrix is developed whereby each entities indicate the strength of an element over another element with respect to a given criteria at the above level. Figure 4 shows the weightage of pair-wise comparison matrices for pump station given by participant for Level 3



	1. Assess	2. Assess	3. Asset op	4. Site con	5. Asset L	6. Mainten	7. Failure I	8. Support
1. Assessment on Actual Physical C		7.0	2.0	2.0	4.0	4.0	2.0	3.0
2. Assessment on Actual Physical C			7.0	7.0	1.0	2.0	4.0	2.0
3. Asset operating condition				3.0	5.0	5.0	2.0	3.0
4. Site condition					4.0	5.0	2.0	3.0
5. Asset Life						2.0	2.0	2.0
6. Maintenance Practice							3.0	2.0
7. Failure History								2.0
8. Support System	Incon: 0.03							

Fig 4. Pairwise matrix table and the weightage

In the Figure 4 above, the probabilities of failure for pump house were assessed. The weightage given to the assessment of actual physical condition of equipment is very strongly more important with weightage of 7 as compared to the assessment on actual physical condition. This process continues to other comparison with each factor evaluated respectively.

Once all level for the respective of assets have been discussed and agreed. The comparison in terms of critical level of assets are assessed and the results obtained as show in Figure 5 that the assessment on actual physical condition of equipment is the most important criteria for critical analysis as compared to others.

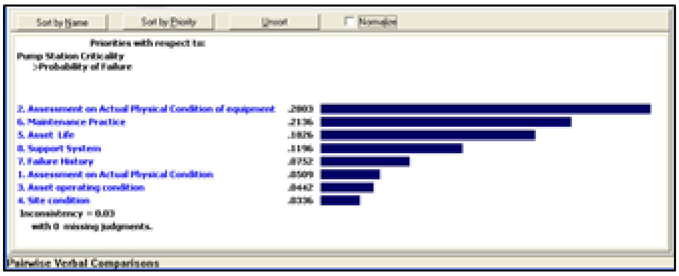


Fig 5. Chart to view the priorities derived in Expert Choice

The next step is to calculate the Consistency Ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments. If the matrix is consistent, then, the weights can be accepted. The threshold on the consistency ratio has been set not more than 0.1. If exceed, the process has to be repeated until the minimum ratio results has been achieved. This is to make sure an evaluation based on the assumption is rational, i.e., if A is preferred to B and B is preferred to C, and then A is preferred to C.

Conceptually, it is applied mathematical formula to evaluate the consistency. Saaty (1977) has proposed a consistency index (CI), which is related to the Eigenvalue method:

CI = , (3) where λ max = maximal Eigenvalue

The consistency ratio , the ratio of CI and RI, is given by:

CR = CI/RI, (4)

where RI is the random index (the average CI of 500 randomly filled matrices).

If CR is less than 10%, then the matrix can be considered as having an acceptable consistency.

V. RESEARCH OUTCOME

The urban water supply is a large and complex infrastructure that has been expanded from time to time continuously. While getting older, water supply assets, are exposed to the deterioration process and eventually reach the end of their useful life. Some assets will reach this point sooner than other assets. In addition, depending on the type of asset, it will either reach that point through amount of use or length of service. Also as assets deteriorate, the performances of the assets are affected. There are many factors that will affect how much life a given asset has. Factors such as poor installation, defective materials, poor maintenance, and corrosive environment will shorten an asset's life, while factors such as good installation practices, high quality materials, proper routine and preventative maintenance, and non corrosive environment will tend to lengthen an asset's life.

When an asset fails or under performs, it can be expected that the consumers will be affected. Since there are enormous amount of asset, it become a great task to manage the asset systematically. Some assets need to be replaced immediately while others need better maintenance. This task has greatly helps by introducing element of criticality. Not all assets are equally important to the system's operation, some assets are highly critical to operations and others are not critical at all. Furthermore, critical assets are completely system specific. Certain assets or types of assets may be critical in one location but not critical in another.

The idea of asset critical level is fundamental to asset management. Assigning criticality enables the organization to begin implementing the practice of asset management by providing a formal and systematic means to:

- Determine which assets deserve attention and money to prevent failure and risks.
- Determine appropriate maintenance level.
- Determine priority works for renewal or replacement.
- Carry out more accurate financial planning.
- Carry out technical analysis and review strategies for planning, acquisition and operation.

This research has been conducted to determine the critical level assets through Analytical Hierarchy Process (AHP), which is generally used as the Multi-criteria Decision Making (MCDM). The AHP provides a convenient approach for solving complex problems in asset management especially in asset critical level. By using this method, PAAB will able to analyze both quantitative and qualitative information into a single framework for the assets. This will definitely assist PAAB especially in asset management and serve it purposed for transparency, effective and efficiency for the better management of water assets.

REFERENCES

[1] Al-Barqawi, H. and Zayed, T. (2006). Condition Rating Model for Underground Infrastructure Sustainable Water Mains, J. of Performance of Constructed Facilities, ASCE, May, 20(2)

[2] Crespo, A., (2007). The Maintenance management Framework: Models and Methods for Complex System Maintenance Springer Series: 108

[3] Lemer, A.C. (1998), Progress toward integrated infrastructure-assets-management systems: GIS and beyond, Proceedings of the APWA International Public Works Congress. NRCC/CPWA Seminar Series in Innovations in Urban Infrastructure, pp.7-24

[4] Ishizaka Alessio, Labib Ashraf (2009), Analytic Hierarchy Process and Expert Choice: Benefits and Limitations, ORInsight, 22(4), p. 201–220

[5] Saaty, T. (1977). A scaling method for priorities in hierarchical structures. Journal of mathematical psychology 15(3): 234-281.

[6] Saaty, T. (1982). Decision Making for Leaders: The Analytic Hierarchy Process for Decision in a Complex World. Lifetime Learning Publications, Belmont, California.

[7] Saaty T L (1980) The Analytic Hierarchy Process, McGraw Hill International.

[8] Saaty, T. (2006). Rank from Comparisons and from Ratings in the Analytic Hierarchy/Network Processes. European Journal of Operational Research 168(2): 557-570.

[9] Krueger, R.A., & Casey, M.A. (2009). Focus groups: A practical guide for applied research, 4th edition. Thousand Oaks, CA: Sage.