A COMPARATIVE STUDY OF ISSUES AND CHALLENGES IN REDUCING NON REVENUE WATER RATES IN PULAU PINANG AND PERLIS, MALAYSIA

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by

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LIST OF ABBREVIATIONS

AC	Asbestos Cement
ALC	Active Leakage Control
ALR	Awareness, Location, and Repair
AWER	Association of Water and Energy Research Malaysia
CAPEX	Capital Expenditure
DMA	District Metering Area
GIS	Geographic Information System
IWA	International Water Association
IWRM	Integrated Water Resource Management
JKR	Jabatan Kerja Raya
KETTHA	Kementerian Tenaga, Teknologi Hijau dan Air
KPI	Key Performance Indicator
MLD	Million Litre per Day
MWA	Malaysian Water Association
MWIG	Malaysia Water Industry Guide
NGO	Non-Governmental Organisation
NRW	Non-Revenue Water
OPEX	Operation Expenditure
PAAB	Pengurusan Aset Air Berhad
PBAPP	Perbadanan Bekalan Air Pulau Pinang
PLC	Passive Leakage Control
PPWSA	Phnom Penh Water Supply Authority
PRV	Pressure Reducing Valve
SPAN	Suruhanjaya Perkhidmatan Air Negara
SPSS	Statistical Package for the Social Sciences

SYABAS	Syarikat Bekalan Air Selangor Sdn Bhd
WSIA	Water Service Industry Act
WSP	Water Service Provider

KAJIAN PERBANDINGAN ISU DAN CABARAN DALAM PENGURANGAN KADAR AIR TIDAK BERHASIL DI PULAU PINANG DAN PERLIS, MALAYSIA

ABSTRAK

Di Malaysia, ketidakupayaan negeri-negeri dalam pengurangan kadar Air Tidak Berhasil (NRW) telah memberi kesan negatif terhadap negara dalam pengurusan air. Tujuan kajian adalah untuk mengenal pasti isu-isu dan cabaran yang dihadapi oleh pembekal perkhidmatan air (PPA) di Malaysia dalam pengurangan kadar NRW di negeri masing-masing. Satu penyelesaian yang mempertimbangkan pelbagai faktor-faktor dalam pengurangan NRW telah dicipata dalam kajian ini. Kaedah campuran yang mengabungkan kaedah kualitatif dan kaedah kuantitatif telah digunakan dalam kajian ini. Kedua-dua faktor dalaman dan luaran yang mempengaruhi prestasi PPA dalam proses pengurangan NRW telah dikaji dengan membandingkan pengurusan NRW di Pulau Pinang (kadar NRW yang terendah) dan Perlis (kadar NRW yang tertinggi) melalui temubual kualitatif dan pemerhatian. Persepsi orang awam dan penglibatan mereka dalam pengurangan NRW juga dikaji melalui soal selidik. Keputusan menunjukkan bahawa kehilangan fizikal (real loss) dan kehilangan komersil (apparent loss) merupakan dua elemen utama yang menyebabkan kadar NRW tinggi di banyak negeri di Malaysia. Minat unit pengurusan, sumber manusia, kemampuan kewangan, dan kapasiti teknikal sesuatu PPA dalam pengurangan NRW telah dikenali sebagai faktor-faktor dalaman yang mempengaruhi sesuatu PPA dalam mengurangkan NRW. Bagi faktor luaran, penglibatan pihak berkepentingan, penglibatan orang awam, dan dasar pengurangan NRW yang komprehensif dikenalpasti sebagai faktor penting. Dalam perbandingan pengurangan NRW di Pulau Pinang dan Perlis, strategi pengurangan NRW di Pulau Pinang telah meliputi kedua-dua strategi pencegahan (preventive) dan asas (basic) yang boleh mengelakkan kerugian NRW. Sebaliknya, strategi pengurangan NRW yang digunakan oleh Perlis hanya strategi asas yang boleh menyelesaikan isu-isu NRW apabila ia dijumpai dan dilaporkan. Di samping itu, kajian ini

juga mendapati bahawa penglibatan orang awam dalam pengurangan NRW di Pulau Pinang dan Perlis masih rendah dan perlu ditingkatkan. Ini adalah sebab kebanyakan responden dari kedua-dua negeri itu tidak mempunyai pengetahuan, kesedaran, dan persepsi yang baik mengenai isu NRW. Kedua-dua Pulau Pinang dan Perlis masih perlu melakukan banyak kerja supaya orang awam boleh dilibatkan dalam mengurangkan NRW. Berdasarkan keputusan kajian, cadangan untuk memperbaiki pengurusan NRW di kedua-dua negeri Pulau Pinang dan Perlis telah dibuat. Akhir sekali, kajian ini menyimpulkan bahawa pengurangan NRW memerlukan sumbangan daripada semua pihak yang berkaitan. Satu rangka kerja pengurusan NRW yang menyeluruh akhirnya telah dicadangkan sebagai penyelesaian bagi PPA dalam mengurangkan NRW. Rangka kerja ini membekalkan suatu strategi pengurusan komprehensif yang lebih baik mengenai bagaimana prestasi PPA dalam mengurangkan NRW boleh ditingkatkan melalui pengurusan faktor dalaman dan faktor luaran.

A COMPARATIVE STUDY OF ISSUES AND CHALLENGES IN REDUCING NON REVENUE WATER RATES IN PULAU PINANG AND PERLIS, MALAYSIA

ABSTRACT

In Malaysia, the states' inability to curb Non-Revenue Water (NRW) losses has negatively impacted the country's progress in reducing NRW rates. This research attempts to identify the issues and challenges faced by Malaysia's water service providers (WSPs) in reducing NRW rates in different states in order to contribute towards developing a comprehensive solution for NRW reduction. A mixed methodology combining both qualitative and quantitative methodologies is adopted to provide a comprehensive analysis. In this study, both internal and external factors influencing a WSP's performance in NRW management were studied by comparing NRW reduction in Pulau Pinang (lowest NRW rate) and Perlis (highest NRW rate) via qualitative interview and field observation. Public perception of and involvement in NRW reduction was also studied via quantitative questionnaire survey. Results show that real and apparent losses were the two major elements contributing high NRW rates in many states. The level of interest of the management unit, human resources, financial capacity, and technical capacity of a WSP were found to be the internal factors influencing a WSP's progress in reducing NRW. For the external factors, stakeholder involvement, public engagement, and a comprehensive NRW reduction policy were identified as important factors. In the comparison of NRW reduction in Pulau Pinang and Perlis, NRW reduction strategies adopted by Pulau Pinang's WSP covered both preventive and basic strategies which can prevent the occurrence of NRW losses. In contrast, NRW reduction strategies adopted by Perlis's WSP were only the basic strategy that can solve the NRW issues when seen and reported. In addition, the study also found that public involvement in NRW reduction in both Pulau Pinang and Perlis is low and still has plenty of room for improvement. This is because most respondents from both states did not have good knowledge, awareness, and perception on NRW issue. Both Pulau Pinang and Perlis's WSPs still have much to do to effectively engage their public in reducing NRW. Based on the research findings, suggestions to improve NRW management of both states were made at the end of the study. Finally, this study concludes that reducing NRW requires contributions from all relevant water stakeholders. A comprehensive NRW management framework was finally developed as a solution for WSP in reducing NRW. This framework provides a comprehensive management strategy on how a WSP's performance in reducing NRW can be improved via internal factors and external factors.

CHAPTER ONE

INTRODUCTION

1.1 Research background

Water has become one of the most important global issues in the twenty-first century, both in terms of development and environmental conservation (Chan, 2002a). However, only a few understand how water is actually managed. Managing water well requires appropriate water governance that covers water resources, water service and water trade-off management (Connor et. al., 2012). Today, one of the major challenges faced by the water management sector in many Asian cities is the high rates of non-revenue water (NRW). Maintaining water sustainability can become very difficult if large volumes of treated water are lost from a water supply system. Furthermore, heavy losses in the water distribution system will hinder the water utilities when trying to keep water tariffs at an affordable rates (Frauendorfer & Liemberger, 2010).

NRW represents the difference between the volume of supplied water and the volume of billed water in a water supply system. NRW can be caused by water loss through theft, pipe leakage, pipe burst, meter inaccuracy, and other uncountable losses once treated water leaves the water treatment plant (Lambert & Hirner, 2000). For a water utility, NRW is a good performance indicator, as high NRW rate indicates poor water management. A study conducted by the Asian Development Bank in 2010 indicated that, NRW rates of the countries in South East Asia were recorded at an average rate of 35 percent, ranging from 4 percent to 65 percent amongst the countries. Consequently, huge challenges are faced by most water utilities in Asia in managing NRW rates (Frauendorfer & Liemberger, 2010).

Malaysia is considered a water-rich country. With more than 3,000 mm of average annual rainfall, it has more than 556 billion cubic metre (m^3) of annual renewable surface water (Abdullah & Mohamed, 1998). However, this huge amount of water resources does not make the country free from water problems, as Malaysia is still facing serious water problems that have threaten current and future water security (Chan, 2002b; Ithnin & Baharom, 2014). And much of these Malaysia's water problems are largely caused by human (Chan, 2009a). Chan (2004) has documented the major water issues in Malaysia, highlighting water wastage as one of the most important. One of the contentious water issues is NRW. In 2013, Malaysia's national NRW average rate was recorded at 36.6 percent. According to the statistic provided by the *Suruhanjaya Perkhidmatan Air Negara*(SPAN), in 2013, Pulau Pinang recorded the lowest NRW rate at 18.2 percent, whereas Perlis state recorded the country's highest NRW rate of 62.4 percent.

Pulau Pinang is one of 13 states in Malaysia. It is located near the north-western coast of Peninsular Malaysia with a population of 1.5 million in 2010, and it is also one of the most developed states in Malaysia (Pulau Pinang State Government, 2010). *Perbadanan Bekalan Air Pulau Pinang Sdn Bhd* (PBAPP) is a privatised water company that served as the licensed water operator in Pulau Pinang since 1999, and is currently owned by Pulau Pinang State Government to protect public interest (Maidinsa, 2011). In Malaysia, PBAPP is considered as one of the most successful privatised water companies in the region (Chan, 2007b). As a holistic and integrated water service provider, PBAPP's responsibilities include extraction of raw water, treatment of raw water, distribution and supply of treated water, and billing for water supply service in Pulau Pinang. However, Pulau Pinang is a water-stress state with 80 percent of its water supply sourced from the Muda River which has its origins in Kedah State (Chan, 2005). Water consumption of 809 million litres per day necessitates Pulau Pinang to look for alternative water resources (SPAN, 2014). It triggered PBAPP to introduce NRW reduction programme which focuses to reduce water loss (Maidinsa, 2011). As the result of the implementation of the NRW reduction programme, PBAPP has managed to keep Pulau Pinang's NRW rates below 20 percent in the last few years (Lai et. al., 2013) .

On the other hand, Perlis's NRW rates have always been the country's highest in recent years. From 2011 to 2013, Perlis's NRW rates were 59.8 percent in 2011, 66.4 percent in 2012, and 62.4 percent in 2013 (SPAN, 2014). With the state's surface area of 812 km^2, Perlis is the smallest state in Malaysia. It is also located at the northern part of Peninsular Malaysia and shares its borders with Thailand. In comparison to Pulau Pinang's privatised water service, Perlis's water service is provided by a state government department, which is the Water Supply Department under the *Jabatan Kerja Raya* (JKR) Perlis. JKR Perlis is a state government department officially formed in 1970, and water supply department is one of the departments of JKR Perlis (JKR Negeri Perlis, 2014). Before the privatization of public utilities emerged in Malaysia, JKR used to be the water service providers of many states in the country, but nowadays, Perlis is the only state in Peninsular Malaysia with water services provided by JKR.

1.2 Problem Statement

According to a study conducted by Chan in 2004, NRW is one of the major water issues which has been threatening Malaysia's water sustainability for more than a decade. In the country's history, there were 57 water treatment plants with a total capacity of 3.8 million cubic metre per day in the year 1996 (McIntosh, 2003). However, this huge amount of water produced did not benefit the people at all due to high rate of NRW losses. In 1997, Malaysia experienced a serious water crisis caused by the El Nino weather phenomenon. This crisis then triggered the Malaysian government to start dealing with the issue of NRW which had been threatening the country's water supply for many years (Kingdom et. al., 2006).

Referring to the Eighth (2001), Ninth (2006) and Tenth Malaysia Plan (2010), the Malaysian government had spent RM 2.5 billion from 1996 to 2010 for reducing the country's NRW rate. Nevertheless, the country's NRW rates still remain very high amongst the states, ranging from 20 to 60 % with the national average of 36.8 % from year 2000 to year 2010. A study was conducted by Malaysian Association of Water and Energy Research (AWER) and it was found out that, from 2008 to 2013, NRW losses cost about RM 10 billion of revenue loss in the country's water sector (AWER, 2014). By referring to the data provided by *Suruhanjaya Perkhidmatan Air Negara*(SPAN), the latest water statistics in 2013 showed that five of the 13 states in the country recorded NRW rates greater than 50 percent. This is not a good sign as it showed that the government's investment on the NRW reduction programme did not bear fruit. Such high rates of NRW have severely jeopardized the country's water security. Coupled with population growth, agricultural intensification and industrial expansion, amongst others, it has exacerbated Malaysia's water problems.

No business is sustainable if it loses a significant portion of its marketable product, but that is exactly what is happening in Malaysia now with NRW. The states' inability to curb NRW losses has negatively impacted upon water resources. Water consumers are now demanding that the states and water service providers must reduce their NRW rates to save water before they can start revising water tariff. It appears futile if water consumers were to save water and such a large amount of water is lost through NRW by the water service providers. Based on such high rates of NRW, water management is not sustainable, and the expenses for the NRW reduction program are not cost-efficient. This will jeopardize Malaysia's water security leading to negative effects on population and economic growth. Without water sustainability, the New Economic Model will collapse and Malaysia will also not achieve its 2020 vision (Chan, 2011).

1.3 Research Question

a) What is the current NRW water loss situation in Malaysia and what are the reasons leading to this situation?

b) What are the existing strategies for tackling NRW in Pulau Pinang (Lowest NRW rate) and Perlis (Highest NRW rate)?

c) How does the public perceive NRW and its reduction, and how can the public get involved in NRW management?

d) What is/are the current framework/s of NRW management used by water service providers in Malaysia, and how effective are they?

1.4 Research Aim

The aim of this research is to develop a holistic NRW management framework and identify the strategies that can be carried out to reduce the NRW loss situation of Malaysia's water supply system, and to address the challenges and barriers of implementing these strategies in the Malaysia water sector, especially for states with high rates of NRW.

1.5 Research Objectives

a) To identify current NRW situation in Malaysia and the reasons leading to this situation.
b) To study and examine the existing strategies for tackling NRW issue in Pulau Pinang (Lowest NRW rate) and Perlis (Highest NRW rate).
c) To investigate public perception of NRW issue and its reduction, especially in Pulau Pinang and Perlis states.
d) To develop a sustainable framework of NRW management that can improve water service provider's performance in reducing NRW rate.

1.6 Significance of the Study

When NRW issue is not well managed, it means water conservation and water demand management are not implemented effectively (McIntosh, 2003). Besides, high rates of NRW may lead to unnecessarily high water tariff in the long run (Frauendorfer & Liemberger, 2010). As NRW rates in Malaysia still remain high at rates well over 30 percent, it can be concluded that existing NRW reduction programme is ineffective in reducing NRW rate in many states. As such, the main challenge for Malaysia's water sector is to reduce the NRW rates, especially for states with high rates of NRW.

Furthermore, according to Chan (2010), to solve the water loss issue in Malaysia is to understand and address the human aspects of NRW, especially in engaging and mobilizing water consumers and the community in helping to manage NRW losses in Malaysia. As part of this research, investigation of human aspects of NRW in Malaysia is important to understand the perception and the knowledge of NRW among the communities. It is helpful for the government and water service providers to develop a plan to increase the knowledge and awareness as well as provide education of NRW reduction for the community in order to help Malaysia's water sector to reduce NRW water loss.

This research attempts to identify the obstructions and problems faced by Malaysia's water service providers for reducing NRW rates in different states in order to contribute towards developing a better solution for NRW reduction. In addition, this research investigates the factors contributing to the high NRW rates that had threatened Malaysia's water security for many years. This research aims to develop a NRW management framework at the end of the research via involvement of all stakeholders to increase the efficiency of water service providers in managing NRW in Malaysia.

1.7 Scope of the Study

To study the water loss situation in Malaysia, the research focuses on studying the components that contribute towards high rate of NRW in Malaysia. The components include real loss, apparent loss, and unbilled authorized water consumption discussed in chapter two. In addition, the research identifies the states that contribute to high rate of NRW based on the latest water statistics.

An in-depth comparative study on NRW reduction strategies was conducted in Pulau Pinang and Perlis State. Hence, this research is a comparative study aimed at developing a better NRW management framework by comparing Pulau Pinang (the lowest rate of NRW) with Perlis State (the highest rate of NRW). Water service providers which are responsible for reducing NRW rate in both states were selected as the key respondents of study. In order to evaluate the efficiency of NRW management in the states, this research focused on evaluating the performance of selected water service providers in solving NRW-related issues. Besides, this research targeted more in examining the real loss and apparent loss management in Pulau Pinang and Perlis State, as real and apparent losses are commonly known as the major components of NRW in many countries (Frauendorfer & Liemberger, 2010).

The study on public perception of NRW reduction was only conducted in the capital city of Pulau Pinang (George Town) and Perlis State (Kangar). The data provided by water service providers and SPAN regarding the pilferages of water, reported and unreported pipe burst/ leaking were also studied to investigate the perception of NRW reduction in the community.

1.8 Organisation of Thesis Chapters

This research is divided into five chapters. The structure of the thesis is as follow:

Chapter 1 presents the introduction to the thesis. It provides a brief background of the study, problem statement, research questions, objective of the study, scope of study, as well as the organisation of the study.

Chapter 2 presents a comprehensive literature review of the NRW management and other related water issues via examination of journal articles, book chapters, reports and other published materials related to this research. In addition, the elaboration of the conceptual framework is presented in this chapter.

Chapter 3 addresses the study area and also presents the methodology of the research, description of the research design, measurements, methods of data collection and statistic tests used in the study.

Chapter 4 discusses the analysis and the results. The results are then summarised.

Chapter 5 summarises the findings of the research, and presents the research outcome, as well as some recommendations for future research. A NRW management framework is developed in this chapter as the final outcome of the research. The conclusion of this study is presented at the end of the chapter.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews the literature of this thesis. It presents the theories, concepts, and variables of this study related to NRW management as well as related water resources issues. A conceptual framework is discussed and formulated in this chapter.

2.1 Non- Revenue Water and its Components

In the early 1990s, the term "unaccounted- for water" (UFW) was widely used by many water utilities to evaluate their performance in managing water loss. During that time, there was no standardized definition of UFW, and the performance of water utilities could not be compared. In the early 2000s, a Water Loss Task Force was created by the International Water Association (IWA) to develop appropriate performance indicators related to water loss management (Frauendorfer & Liemberger, 2010). An article by Lambart and Hirner (2000) introduced a standard terminology and appropriate performance indicators for managing water loss. The term "Non- Revenue Water" (NRW) was first introduced as a performance indicator to measure the annual volume and percentage of unbilled water (unbilled authorised consumption and water loss) to the annual system input volume of a water supply network. A recommendation was then made to use the term of "non- revenue water" as a primary indicator of water loss management instead of using "unaccounted-for water", the term UFW was discontinue due to its unstandardized definition (Alegre et. al., 2000; Lambert, 2003).

Non- Revenue Water (NRW), as shown in Figure 2.1, is defined as the difference in the volume of water in the water supply network and the volume of water billed to the customers. NRW in the water distribution system is caused by water loss through water theft, pipe leakage, pipe burst, meter inaccuracy or data handling error, and other uncountable losses once the water leaves the water treatment plant. Generally, NRW consists of three components: real loss, apparent loss and unbilled authorised consumption (Lambert & Hirner, 2000).

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption
m^3/ year</td><td rowspan="2">Billed Authorized Consumption
m^3/ year</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water
m^3/ year</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumtion
m^3/ year</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water
m^3/ year</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
m^3/ year</td><td rowspan="2">Apparent Losses
m^3/ year</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metered Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses
m^3/ year</td><td>Leakage on Transmission and/ or Distribution Mains</td></tr>
<tr><td>Leakage and Overflow at Utility’s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to the point of Customer Metering</td></tr>
</table>

Figure 2.1: International Water Association (IWA) Standard International Water Balance and Terminology (Lambert & Hirner, 2000).

System input volume is defined as the annual input volume of water into a defined part of the water supply network. Real loss is defined as the annual volume of physical water loss from the water supply network, including all types of leaks, bursts, and overflows in service reservoirs, mains, and service connection pipes up to the point of customer metering (Fanner, 2004). Apparent loss consists of unauthorized consumption and meter inaccuracy, for example illegal water connection and water theft, and all types of meter inaccuracy reading at the customer meter and production meter, for example meter under registration and data handling errors. Whereas unbilled authorised consumption includes the water used by the water utilities for operation purpose (e.g.: flushing and cleaning), water used for firefighting, and water provided free to certain consumer groups (Frauendorfer & Liemberger, 2010; Lambert & Hirner, 2000).

2.2 Benefits of Low Non- Revenue Water

In developing countries, NRW is one of the most severe issues threatening water security of the country (Kingdom et .al., 2006). Indeed, water management would not be sustainable if a country has high NRW. High rates of NRW cause significant volume to be lost before reaching the consumer. Consequently, additional investments to produce more treated water is needed to cover the loss, plus the problem of revenue loss caused by apparent losses, the operation of the water utility would collapse in the long run if the NRW problems are left unresolved (Frauendorfer & Liemberger, 2010). Conversely, a low NRW rate indicates a sustainable management of water supply in a country.

By reducing NRW to lower rates, more treated water could be available to reach water consumers, and more revenue would be gained and the water production cost (e.g.: energy, chemical, and operating cost) would be lower (Giustolisi et.al., 2013). At the same time, the investment for upgrading the capacity of water supply networks can be postponed as more water is available in the system, and water consumers can enjoy reasonable tariff and efficient water services. In addition, establishing NRW reduction strategies create another business opportunity and this indirectly lead to positive economic growth. Besides, the water utility can have a better understanding of the water consumption as the water consumption pattern with minimized NRW rate can be more reliably to be analysed and projected (Frauendorfer & Liemberger, 2010; Kingdom et al., 2006; Mclntosh, 2003). Today, many countries are still facing the problem of high NRW. Despite the benefits of NRW reduction are well-known, many water service providers still suffer from high NRW rates because reducing NRW is a complicated and long process. NRW management not only covers technical solution which requires huge financial input, but also includes non-technical solutions which require participation from other stakeholders.

2.3 Factors Influencing Non- Revenue Water

In general, NRW reduction strategies are recognized as the direct factor to determine the NRW rate in a city, as these strategies serve as the solutions to reduce each NRW's components: real loss, apparent loss and unbilled authorized consumption (Lambert, 2002). These strategies, technically, are the most influential factors in determining the NRW rate, and majority of these strategies advocate technology and engineering solutions to reduce NRW. Many perceive that solving water problems depends highly on engineering solutions, but in fact, apart from the technical factors which is discussed in detail in a later section, other factors from the aspect of human behaviour, management and governance could play a significant role in NRW reduction. In addition, other than the water utility, stakeholders such as the public, the government, private company, contractor, consultant, and politician each has its impacts to the outcomes of NRW reduction activities.

Furthermore, the type and number of NRW reduction activities in a city depend on the financial capacity of the water utility. This is linked to the water tariff, the types of water utility (public, private, or public-private), the governance of the water utility, and the funding that provided by the government for NRW reduction (González et.al., 2012). Higher water tariffs make the water utility financially more capable in investing in NRW programmes. Financial capability of a private water company is claimed to be better than a public water utility. Interest of the water utility's management unit in NRW reduction could make the water managers invest more time and resources in reducing NRW. Politicians and policy makers are the key persons to determine the water tariff and governments' funding for NRW, and they are also the responsible parties to raise public concern and awareness on NRW which could indirectly affect the number and outcome of NRW reduction activities (González et.al., 2011; Gumbo & van der Zaag, 2002).

Moreover, Gonzalez et. al., (2012) found out that population growth could influence NRW rate of a city. This is because the increased number of water consumer will increase the complexity of water infrastructures. For example, extra piping is required to be laid to meet increased water demand, as well as more meters are required to be installed. These would increase the complexity of NRW management because the WSP would have to handle more accounts as well as manage a large network of pipe mains. Besides, there are other factors that can affect the outcomes of the NRW reduction strategies. Public involvement in

NRW reduction activities such as reporting pipe leakage and illegal water use could improve a water utility's efficiency in reducing NRW (Farley et al., 2008). Staff's discipline, competency, capacity, and motivation in reducing NRW are definitely the direct factors that drive the outcomes in NRW reduction. A knowledgeable, responsible, and honest water manager definitely executes good implementation of the NRW reduction activities (González et al., 2011). Moreover, collaboration is needed in between the water utility, contractor, private company and governments to draw up a comprehensive and appropriate planning for reducing NRW in a city (González et al., 2012; Kanakoudis & Tsitsifli, 2012).

2.3.1 The Phnom Penh Experience, Cambodia

In Phnom Penh, the NRW was about 70 percent in the early 1990s. Poor governance of Phnom Penh Water Supply Authority (PPWSA) was attributed to be the cause of high NRW. Issues such as lack of capacity, corruption, and poor working culture of the staff of PPWSA made the city suffer from high NRW. Most of the staff were underpaid, with average monthly salary of only 20 US Dollar. Hence, the staff had low discipline, poor morale, lack of motivation, and were inefficient. The top management of PPWSA only worked for self-interest, and nepotism was common within the company. Illegal water use was common because connections of formal water supply through PPWSA were difficult. Ironically, the person who provided the service of illegal pipe connection actually had a good relationship with the top management of PPWSA. Due to the poor billing system, PPWSA did not have enough financial capacity to carry out pipe replacement programme as well as to repair leaking pipes which caused high real loss in Phnom Penh (E. S. Chan, 2009).

However, Phnom Penh's NRW has now been lowered to an acceptable rate after the above issues had been solved through a water service reform which was initiated by the Cambodian Government with the help from several developed countries and international development organizations (Biswas & Tortajada, 2010). Since the PPWSA reformed in 1993 and it practices a new work culture as an 'Educating, Motivating and Disciplining' water authority. Top management of PPWSA was restructured by including more young people with higher educational and professional qualifications. By giving more responsibility to these young managers, they would also be paid with higher salary and bonus if they give good performance. Whereas staff with poor performance or found guilty of malpractices would be penalized. All the staff including top management and the technical staff were given a serious warning on not to abuse their power, especially not to get involved in illegal pipe connections. The local communities are advised use proper pipe connections through PPWSA, and incentives would be given if one reports on illegal connections. In addition, the public is also advised to report pipe leakage (Biswas & Tortajada, 2009; E. S. Chan, 2009).

Several NRW reduction strategies has been introduced after the restructuring of PPWSA, with a team was introduced to inspect and disconnect the illegal connections. A 24-hour repair team was also formed and is responsible for inspecting and repairing pipe leakages in the city. A pipe replacement programme was started with funds given by several donors. Today, as a result of all these reforms, NRW in Phnom Penh is lower than 10 percent. Furthermore, water supply in Phnom Penh city is now covering about 90 percent of the total population (Biswas & Tortajada, 2010).

2.3.2 The Manila Experience, Philippines

In Manila, the west and east parts of this metropolitan city are served by two different private water companies because of political influence (Wu & Malaluan, 2008). Some time ago, privatization was recognised as the solution to address high NRW, but today NRW rate in East Manila has been reduced to a very low rate (below than 10 %), whereas West Manila still experiences high NRW rate (more than 50 percent) (Asian Development Bank, 2010). This has proven that privatisation is not the best solution to address high NRW; at least it is not enough to reduce NRW to a lower rate by just privatising NRW reduction activities.

The failure of West Manila's water company in reducing NRW was alleged to be due to the mismanagement of its staff in carrying out NRW reduction activities, as its management unit did not have a clear direction in reducing NRW (Dimaano, 2012). Another major reason was its ineffective strategies in engaging the public in reducing NRW. It is a different scenario in East Manila, each of its staff was motivated and had a clear responsibility in NRW reduction activities, and its community water management programme succeeded in engaging the public who reported pipe leakage and illegal water use (Wu & Malaluan, 2008).

2.3.3 Summary of the Factors Influencing NRW Reduction

Figure 2.2 summarizes the factors influencing NRW reduction. Factors such as staff performance, human resources, technology capacity, interest of management unit, and financial capacity affect the performance of a WSP in conducting NRW reduction activities, which directly affect the outcomes of the NRW reduction strategies. Financial capacity of a WSP in reducing NRW is largely dependent on two factors, which are the revenue from water sales and funding provided by the government. Stakeholders also play a crucial role in setting water tariffs for sustainable cost recovery of WSP in reducing NRW, and they can make contribution to the outcomes of NRW reduction strategies by cooperating with WSP, such as reporting pipe leakage and illegal pipe connection. In addition, there are also the other factors such as water demand, geographic factors, water infrastructure, and availability of water resources which could indirectly affect NRW situation in a city. For example, limited water resources and high water demand in a city leave the WSP in the city with no choice but to reduce NRW rate in order to sustain water supply in the city. Above all, NRW is a complex issue involving many factors. It has to involve all the stakeholders along the process of reducing NRW. The NRW rate cannot be reduced effectively through the implementation of NRW reduction activities alone. Hence, managing all factors that contribute to the NRW reduction activities is necessary.

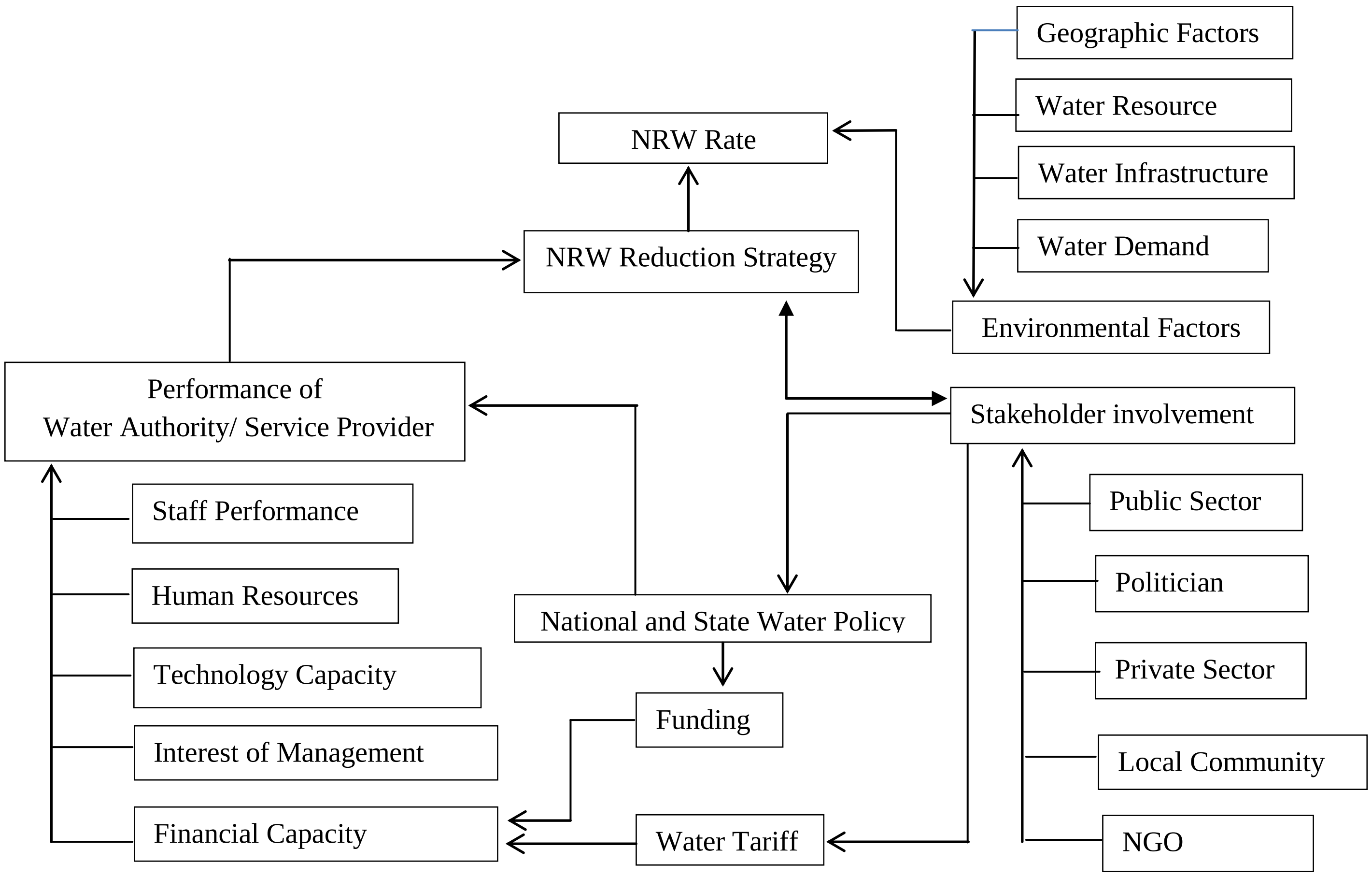

Figure 2.2. Factors influencing NRW reduction

2.4 Non- Revenue Reduction Strategy

To reduce NRW rate, its components: real loss, apparent loss, and unbilled authorised consumption have to be reduced. As reducing NRW is a complicated and long process which require different strategies and different performance indicators to deal with different NRW's components, this section highlights the NRW reduction strategies and performance indicators for reducing NRW's components.

2.4.1 Real Loss Reduction Strategy

Real loss is always the major component that builds up the NRW rate in many cities. There are four methods to reduce real loss: speed and quality of repair, leakage control (active and passive), pressure management, and pipeline and assets management (Fanner, 2004). Speed and quality of repair and leakage control are the methods to reduce the volume of real loss by reducing the time needed for detection and repair of pipe leakage. Leakage control is divided into passive and active leakage control (Puust et al., 2010). Passive leakage control (PLC) is the most basic method of leakage control. By adopting this method, the water utility will take action to repair pipe only if the leak or burst is seen and reported by the public or its own staff. This method is widely used by the water utilities in developing countries (Frauendorfer & Liemberger, 2010). Whereas active leakage control (ALC) is an advanced method for detecting and locating the pipe leakage before it is reported. The water utility plays an active role in detecting and locating leaks by using some tools and equipment (Pilcher, 2003). The details of how active leakage control is implemented will be discussed later. Leakage control strategy can be very influential to the outcome of speed and quality of repair. The concept of Awareness, Location, and Repair (ALR) has been introduced to measure the performance of speed and quality of repair. Speed and quality of repair determines the volume of leak- or burst- caused real loss, and ALR refers to the time taken to be aware, locate and repair the leaked pipe (Liemberger & Farley, 2004). This means that the quicker the leak is detected, located, and repaired with good quality material and work, the more water will be saved. Basically, speed and quality of repair and leakage control are the short-term strategies which aim to reduce the volume of real loss after the leak occurs. There are strategies aimed at avoiding pipe leakage.

Pressure management is a useful method to reduce the frequency of leaks in a water supply network. As high pressure in the water supply networks will cause pipes to crack leading to leakage opening, it is important to manage the water supply pressure to protect the water supply networks, especially the piping system (Cassa et. al., 2010). Pressure reduction is a method of pressure management and it is commonly used by water utilities to prevent leakage (Thornon, 2003). A pressure reducing valve (PRV) has to be installed to control the water flow pressure. This PRV control the water flow pressure within certain zones to ensure it is not too high to cause pipe cracking and not too low to cause low water supply pressure at the consumer point. For example, if the incoming water flow pressure is too high and tend to cause pipe cracking, the PRV serve as a watchman as it reduces the water flow pressure before the water passes through it (Farley et al., 2008). This method usually comes with the District Metering Area (DMA) which is discussed in section 2.4.2. Generally, PRV is known as a cost-effective method to reduce the frequency of leak compared to pipeline and asset management which usually require high investment (Mutikanga et al., 2012).

Pipeline and asset management is the most effective method in reducing the frequency of pipe leaks. But this method is also the most expensive method to be implemented. In most countries, water utilities' pipe replacement programme is carried out to rehabilitate or replace the pipes that are prone to leak, viz. usually the aging pipes. There are factors to determine which pipeline should be replaced or rehabilitated first; such factors are frequency of burst or leak (leak and burst record), pipe age, health concern, etc (Hu et. al., 2009). Different countries have different consideration when deciding which pipe should be replaced first, as the factors that cause pipe failure in each country are different. In Malaysia, the pipeline rehabilitation and replacement programme is focused on replacing asbestos cement (AC) pipes, mainly because AC has been proven as a material that could cause negative impacts to human health (Lambert, 2002). Moreover, AC pipe indicates an old water infrastructure in Malaysia, as AC pipes were the main piping material used to build water infrastructures between the 1950s and 1980s, and this aging piping could be the reason for high frequency of pipe leakage (Hu et al., 2009; Rampal & Lim, 2002).

2.4.2 Active Leakage Control

As mentioned above, active leakage control (ALC) is an advanced method in controlling leak. By implementing ALC, water utility will play an active role in controlling leak. To establish ALC in a water utility, DMA must be introduced for leak awareness purpose. DMA is a discrete zone in which the water supply network is isolated. The creation of DMA is to enable flow monitoring in the discrete zone. With DMA, water consumption, and water flow in and out from this zone will be measured in detail. With this crucial data, the water utility will be able to detect unreported or underground leak by calculating the volume of water loss in this particular area (Farley & Liemberger, 2005; Morrison, 2004). When a DMA has high volume of water loss, leak detection activities will be prioritised to be focused in this area, and these activities can minimise the time taken to detect and locate the leaks.

Once a DMA is targeted, leak detection and leak localisation activities will be carried out in that area. The leak localisation activity often begins with leak localising, whereby an activity is carried out to narrow down the suspected leak location before the exact leak location can be found by another activity. Leak localising can be done by step test, correlator survey, acoustic logger survey, ground motion sensors and ground penetrating radars (Puust et al., 2010). Once a suspected area is localised, the water piping will be pinpointed to locate the leak precisely by using leak detection equipment. The leak detection equipment commonly used are ground microphones, leak noise correlators, noise loggers, and sounding sticks (Farley et al., 2008; Pilcher, 2003). After the leak location is found, the water utility will proceed to repair the leaked pipe.

2.4.3 Apparent Loss Reduction Strategy

Apparent loss can be reduced by managing meter inaccuracy, data transfer error (meter reading error), data analysis error and unauthorized consumption (Rizzio et al., 2004). Meter inaccuracy is among the most common element that caused apparent loss in many cities. The reason for meter inaccuracy causing apparent loss is inaccurate meter reading as this could cause under-registration of water consumption, leading to revenue loss of water utility due to certain amount of the consumed water not registered and billed (Farley et al., 2008). Factors that cause meter inaccuracy are complex, as meter accuracy is determined by the interaction of several factors, and a lot of assessment have to be done to identify the factors contributing to meter inaccuracy (Mutikanga et al., 2011). Such factors are meter type, unfavourable water consumption pattern, bad water quality, environmental conditions, meter position, water tempering, water supply pressure, and installation of storage tank (Arregui et al., 2006; Fontanazza et al., 2014). This could explain why aging meter tends to be inaccurate, as time slowly deteriorates the mechanism of meter in recording water consumption. To reduce the problem of meter inaccuracy, old meters need to be changed from time to time while other factors have to be managed. Suspended solids in the supplied water also have to be reduced. Besides, meter has to be installed with proper position and proper meter type. In addition, intermittent water supply has to be avoided, water supply pressure has to be optimised, and water consumption pattern of the consumer has to be monitored. Furthermore, meter has to be maintained and replaced regularly by water utility, and meter policy has to be introduced.

The other problem that could cause apparent loss is meter reading and data analysis errors. Meter reading error usually refers to the error that happens when the meter reader wrongly records the reading (Frauendorfer & Liemberger, 2010). For example, meter reader could simply place the decimal in a wrong place due to negligence. Meter reader could also record a wrong meter reading because of accepting a bribe from owner. Meter reading error could lead to data analysis error. Data analysis error happens in the process of data handling and billing. In a water utility, data handling and billing involve different processes and different persons are in charge and this usually involves the meter reading department and billing department. Error could happen in the process of meter reader in taking meter reading up until the meter reader hands the recorded reading to the billing department. The other error that could happen is when the staff in billing department is calculating the water bill. To deal with these problems, staff of the meter reading department and billing department have to be specifically trained and motivated. Highly accurate tools and equipment have to be used in recording meters and calculating water bill. For example, the use of electronic recording machine should replace traditional hand written method, and the latest billing software has to be introduced to the billing department. Routine reading verification activity is suggested to be carried out to check the reading submitted by meter readers (Farley et al., 2008).

Unauthorised consumption is largely caused by societal problem rather than technical problem. Unauthorized consumption is not common in developed country, but in many developing countries, apparent loss is built up by high rate of unauthorised consumption (Mclntosh, 2003). Unauthorized consumption refers to illegal use of treated water, for example connecting pipe illegally, modifying water pipe to bypass meter, and illegal use of water from hydrant. Society problems such as low income, corruption and dishonest water consumers are among the causes of unauthorized consumption. To deal with the problem of unauthorized consumption, the public must be involved as part of the solution, and water awareness campaigns have to be conducted to educate the public regarding the issues related to NRW. Staff that work for water authority must be trained and educated, as they are the direct persons who inspect the illegal water use. For example, the East Manila's water utility introduced community NRW management programme to engage the local community to be the street leaders who help water utility in investigating unauthorised consumption and reporting suspected leak. Today, East Manila enjoys low NRW rate and this programme has been proven to be effective in solving unauthorized consumption (Frauendorfer & Liemberger, 2010). Figure 2.3 summarizes the indicators of NRW reduction strategies that discussed above.

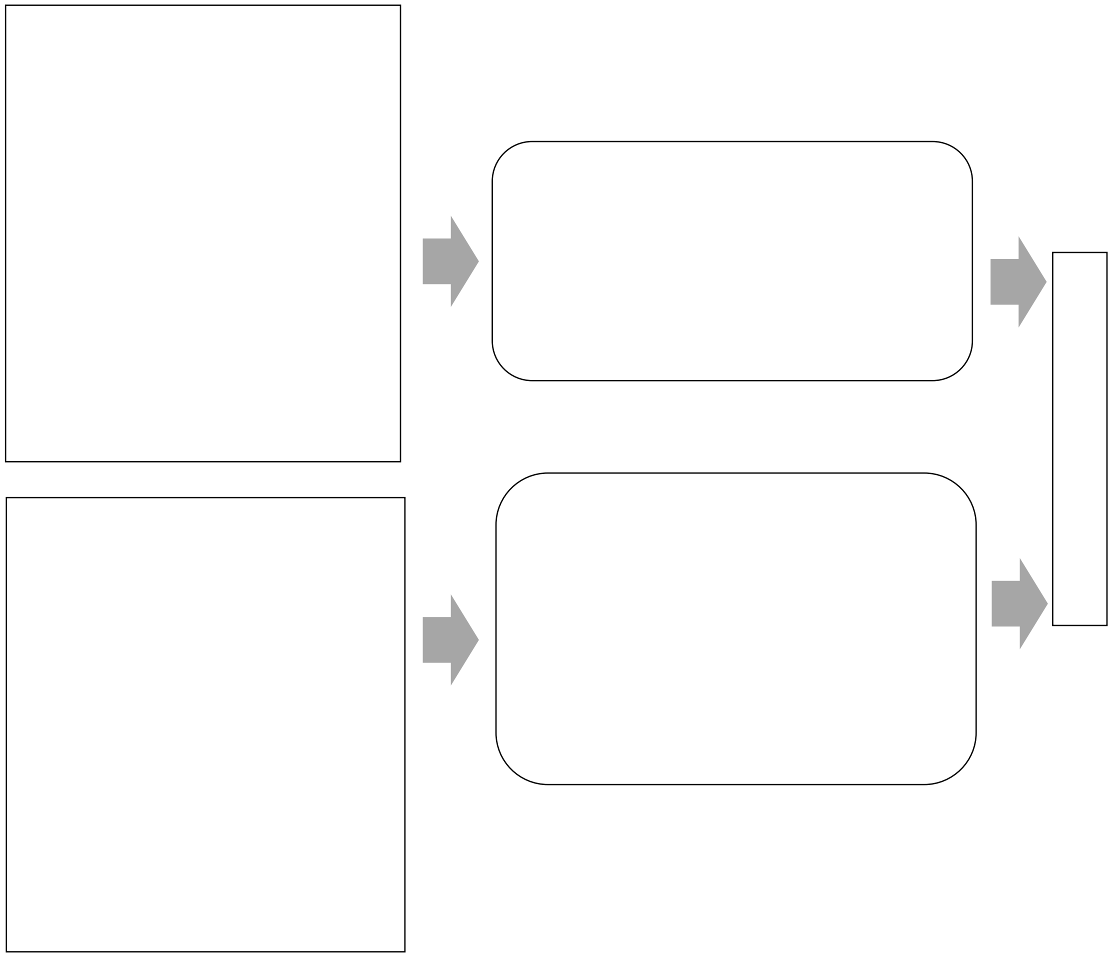

Figure 2.3. NRW reduction strategies and its' indicators

2.5 Malaysia's Non-Revenue Water Management

2.5.1 History of Malaysia's Non-Revenue Water Management

NRW is a water issue that has been threatening Malaysia's water security for years (Chan, 2009a). In 2013, Malaysia's NRW was hovering at an average rate of 36.6 percent, with the states' NRW rates ranging from 18.2 percent to as high as 62.4 percent (SPAN, 2014). If the NRW rate cannot be reduced, then water management in Malaysia will not be sustainable, as more than 95 percent of the nation use pipe water (Chan, 2004). In Malaysia, water service was decentralised since independence in 1957. During the early years after independence, the water service in every state was operated by state government water supply departments, as well as the responsibility in reducing NRW. However, privatisation of water services began at the end of 1980s aimed by state governments to meet the increased water demand and to improve water service efficiency (Chan, 2009a). Nevertheless, some of the states' water utilities chose to be partly privatised (corporatised) and are still under state government ownership (Tan, 2012). Consequently, most of the country's states water utilities have been either fully privatised or partly privatised (corporatised), and this placed the responsibility of NRW reduction on the state's water service providers (WSPs).

2.5.2 Water Reforms Restructuring in Malaysia

Recently, the Malaysian federal government has initiated the reformation of its water sector with a new water policy put in place in 2006. State water legislations that were previously implemented were replaced by two acts, viz. Water Service Industry Act (WSIA) 2006 and National Water Services Industry Act (SPAN Act) 2006. With these two new acts, water services will be renationalised, whereby the responsibility of the regulation of water services will be moved to the federal government. However, water resource, catchment and river basin will remain under state government control. To govern the water service sector, the federal government has formed the *Suruhanjaya Perkhidmatan Air Negara*(SPAN) in 2007 to enforce the WSIA. Today, SPAN plays an important role in advising the federal government on the national water policy. The water supply service which was previously regulated by the state government will be moved to SPAN after the water reforming agreement is signed between the federal and the state governments (Teo, 2014). Table 2.1 shows states that have signed the agreement with federal government.

State	**Signed Year**
Melaka	2008
Negeri Sembilan	2009
Johor	2009
Perlis	2010
Pulau Pinang	2011
Perak	2012
Selangor	2014

Table 2.1. States that signed water restructuring agreement with signed year (Source: Malaysian Ministry of Energy, Green Technology and Water, 2014).

Other than the water services, by signing the water restructuring agreement, water assets previously owned by the state or the private sector will then be transferred to *Pengurusan Asset Air Berhad* (PAAB), which is a water asset management company fully owned by the Ministry of Finance Incorporated. After the state's water asset is transferred, PAAB will then lease these assets back to the licensed WSP at affordable rates. This is an "asset-light model" advocated by Malaysian Government to reduce the burden of WSPs in terms of expenditure of developing and maintaining water infrastructures. Under this model, PAAB will be responsible for funding and developing water infrastructures of the states. However, the WSP will still be responsible for maintaining and operating the water supply system (Teo, 2014). For example, development of new water treatment plants will be done by PAAB, the operation and maintenance of the treatment plants will be done by the licensed WSP.

2.5.3 Malaysia's Non-Revenue Water Management after Water Restructuring

As shown in Table 2.1, seven out of 11 state governments in Peninsula Malaysia have already signed the water restructuring agreement with the federal government. Nevertheless, only five of these have migrated their water assets and loans, while Perlis and Selangor are still in the process of migration. The WSPs which previously operated the water service in these five states have been given a three-year license as an authorized WSP of the states (Teo, 2014). More importantly, after the water restructuring, there are positive changes in Malaysia's NRW management.

Today, SPAN plays a role in monitoring the Key Performance Indicators (KPIs) of all the licensed WSPs. The NRW rate is considered by SPAN as one of the most important KPIs, and all licensed WSPs are required to achieve the targeted NRW rate in order to get their license renewed by SPAN. PAAB serves as the facilities licensee that owns the water supply infrastructures of the states that have completed the migration of water assets. WSIA clearly states that the facilities licensee is responsible to construct, refurbish, improve, upgrade, maintain and repair its water supply infrastructures. Major water projects related to real loss reduction such as pipe replacement programme, pipe rehabilitation programme, development and installation of new water supply infrastructures which was previously conducted by state's WSP has now been shifted to PAAB.

On the other hand, minor works such as pipe repairing and meter replacement programme will be initiated by WSPs. WSPs can either conduct these works by their staff or by the contractor. The expenses of these minor works are allowed to be claimed from PAAB. Besides, the planning of pipe replacement programme, meter replacement programme, expansion of water supply infrastructure, etc. is still the WSP's responsibility. Hence, planning should be included in the WSP's three-year business plan which needs to be submitted to SPAN for renewing licence every three years. In addition, the licensed WSP has the right to bill the water consumer, install a meter and sub- meter, connect or disconnect water supply, and carry out testing and commissioning of water meter. This effectively means that the licensed WSP is also responsible for conducting meter maintenance programme, revenue collection, and also disconnect unauthorized pipeline connections when necessary. These are the main activities related to apparent NRW loss reduction (Lai et al., 2014).

Above all, after the water restructuring, the federal government now plays an active role in monitoring the performance of WSPs in managing NRW through SPAN and PAAB. SPAN serves as the regulatory body that manages the performance of WSPs in water services including NRW management. PAAB serves as the water asset provider that reduces the NRW through water asset management such as sourcing funds for meter and pipe replacement programmes. In comparison, the WSP is responsible for conducting technical works related to NRW reduction.

2.6 Stakeholders Involvement in Non-Revenue Water Management

A management model cannot be claimed to be holistic and comprehensive if stakeholders are not actively involved. Research has proven that stakeholders involvement in environmental management can improve the quality of decision making by providing