Non-Revenue Water and Efficiency of States' Water Supply Management in Malaysia

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***Abstract*— Non-Revenue Water (NRW) is currently being one of the issues heatedly discussed in Malaysia and reflects the performance of the states' water supply management. In 2008, the Federal Government restructures the water industry and centralized the water management of the state government by establishing SPAN (National Water Services Commission) and PAAB (Water Asset Management Company). The objective of SPAN and PAAB is to improve the efficiency of states' water operators in Peninsular Malaysia including Labuan. The Government has urged the state water supply to manage NRW problems more effectively because it gives an impact on the efficiency as a whole, thus the revenue collection specifically. Therefore, this study is to measure the effect of NRW on the efficiency of the state water supply agencies following the restructuring of the water industry in Malaysia. DEA approach (Data Envelopment Analysis) has been used to measure the technical efficiency and second stage regression (Tobit) is used to determined factors that effect efficiency. The findings showed that immediate strategies need to be taken to improve efficiency and NRW of the states' water supply management.**

***Keywords*—** *Non Revenue Water, DEA, SPAN, PAAB, Malaysia*

1. Introduction

Non-Revenue Water (NRW) is defined as the difference between supplied water from water treatment plant and metered quantity to the consumers [1]. NRW components consist of physical and commercial losses (water consumed but gives no revenue).. Higher the rate of NRW reflect higher the revenue loss to the state. Since restructuring, NRW has been used as a KPI benchmarking among other items by SPAN.

NRW are one of the major issues affecting water utilities in the developing world because it will seriously affects the financial viability of water utilities through lost revenues and increased operational costs. A high NRW level is normally a surrogate for a poorly run water utility that lacks the governance, the autonomy, the accountability, and the technical and managerial skills necessary to provide reliable service to their population [2].

In 2006 the Water Services Industry Act (WSIA) was introduced by the Federal Government and the setting up National Water Services Commission (SPAN) and Water Asset Management Company (PAAB) in 2007. The objectives of the restructuring in the water services industry in Malaysia is to provide a holistic regulation, supervision and monitoring of water services industry which covers both water supply and sewerage services. Table 1 shows state's water supply agencies flowing the establishment of SPAN and PAAB.

Table 1: State's water agency

State	Operator
Johor	Syarikat Air Johor Holdings Sdn Bhd (SAJH)
Kedah	Syarikat Air Darul Aman (SADA)
Kelantan	Air Kelantan Sdn Bhd (AKSB)
Melaka	Syarikat Air Malacca Berhad (SAMB)
Negeri Sembilan	Syarikat Air Negeri Sembilan (SAINS)
Pulau Pinang	Perbadanan Bekalan Air Pulau Pinang (PBAPP)
Pahang	Pengurusan Air Pahang Berhad (PAIP)
Perak	Lembaga Air Perak (LAP)

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Perlis	Syarikat Air Perlis (SAP)
Selangor	Syarikat Bekalan Air Selangor (SYABAS)
Terengganu	Syarikat Air Terengganu (SATU)
Labuan (Federal territory)	Jabatan Bekalan Air Labuan
Sabah	Jabatan Air Sabah
Sarawak	Lembaga Air Kucing

Source: Malaysia Water Association (2010)

States' water supply management have experienced a dramatic changes with a remarkable improvement in water services over the past few decades [3]. Due to increasing in population growth, industrial and agriculture development, demand for water also has change. These factors and coupled with inefficient water management have led to a water shortage. Therefore, water resources and their use should be governed efficiently by stakeholder to ensure sustainable water supply because of the limited water resources. Furthermore, with deterioration in the quality of the water and in turn creating socio-economic problems to consumers (households and industries) [4]. Figure 1 shows percentage of State's NRW for 2016.

The highest NRW level recorded nationwide in 2016 is Perlis and Sabah with 61% and 52% respectively and the expected level to be achieved in 2025 is 25% for all state. Melaka and Pulau Pinang are the only state that has already achieved to the target level, while other states still far behind the target.

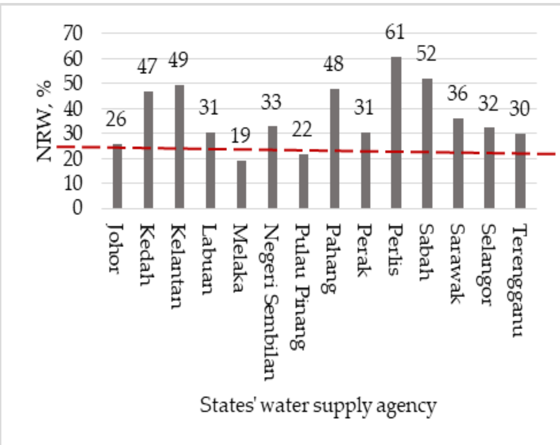

Figure 1: Percentage of NRW by State's water supply, 2016

The main factors that contribute to NRW are from physical and commercial losses. Physical loss is due to a pipe burst or leakage (particularly the old asbestos cement pipe). While commercial loss are inaccurate meter reading (quantity showed by the old meters is less than the actual), water theft by illegal tapping, maintenance of the water supply system through pipe flushing after leakage repair works, reservoirs cleaning and fire brigade use [5]. High NRW rate shows that the water operator has a problem of instability of water supply infrastructure and its link to the efficiency. Efficiency of water service reflected through the water supply interruption to the consumers and the quality of treated water supplied.

2.0 METHODOLOGY

Efficiency of a firm consists of two components : technical efficiency, which reflects the ability of firm to obtain maximal output from a given set of inputs and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology [6], [7]. To measure technical efficiency DEA is used while second stage Tobit analysis is used to identified factors that effect efficiency.

Data Envelopment Analysis (DEA)

DEA is a piece-wise linear combination that connects the best practice observations and forms a convex production possibility set. It was developed by Charnes, Cooper and Rhodes [8] and was applied to non-profit organizations where the objectives of profit maximization and cost minimization may not be considered as the vital factor.

DEA also has been used to measure efficiency in water services for developed countries and less developed countries, including Malaysia. Studies by Crain and Zardkoohi [9] Lambert, Norman and Stoker [10], Dischev and Raffiee [11], Bhattacharyya et al. [12] and Aubert and Reynaud [13] used DEA to measure efficiency of water services in United States. While studies on efficiency of water servies in United Kingdom were undertaken by OFWAT[14], Cubbin and Tzanidakis [15], Thanassoulis [16], Thanassoulis [17], Saal et al. [18], Erbetta and Cave [19], Saal, Parker and Weymar Jones [20].

In Malaysia, studies on water service efficiency are limited. Studies by Lee and Lee [21], Muniasamy [22] and Lee, Tan and Lee [23] emphasized on comparison between water services under private and public sector. While study by Saad and Harun [24] focused on impact of SPAN and PAAB on water supply efficiency in Peninsular Malaysia folowing the restructuring of water industry in Malaysia.

Data for this study have been obtained from the Malaysian Water Industry Guide published by Malaysian Water Association (MWA) from year 2000 to 2016. The data set used in this study includes operating expenditure (RM Malaysia), length of mains (km), total consumption (m^3) and number of connection. Decision making unit (DMU) in this study consists of 14 states which including Labuan, Sabah and Sarawak even though they are not included under SPAN and PAAB regulation.

For estimation purposes, the operating expenditure is used as an input based on study by Thanassoulis [16]. While output used such as the number of supply connections, the length of the main (reflecting the dispersion to clients) and the amount of water delivered as outputs in the modeling of water distribution are adapted from study be Lee and Lee [21]. A constant returns to scale assumption was applied since the states' water supply services is under the public sector and regulated by the the Federal Government.

Theoretically, constant return to scale (under input orientation) can be defined as [7];

min_θλ θ.

subject to ;

$$-y_i + Y\lambda > 0$$

$$\theta x_i - X\lambda > 0 \qquad (1)$$

$$\lambda > 0$$

where, θ is the input technical efficiency score having a value 0 ≤ 1. λ is a Nxl vector of constants while λX and λY are the input and output vectors respectively. The value of θ will be the efficiency score for the i-th water service operator. It will satisfy θ less than or equal to 1. Value of 1 indicates a point on the frontier and hence a technically efficient DMU. The linear programming problem needs to be solved N times (i.e. for each decision making unit) and a value of θ is provided for each firm in the sample. To account for variable returns to scale, the same equation can be modified with the convexity constraint ensures that an "inefficient unit" is only benchmarked against similar sized of peers (DMUs). The variable returns to scale (VRS) of DEA model is defined by adding the constraint [25]:

$$\sum \lambda_i = 1$$

Technical efficiency score can be affected by pure efficiency or scale efficiency. Pure efficiency is refer to relative ability of operators to convert input into output while scale efficiency measures to what extent the operators can take advantage of return to scale by altering its size towards optimal scale [6]. Scale efficiency (SE) of the i-th firm can be calculated by the ratio of score technical efficiency under constant to scale with score technical efficiency under variable to scale.

$$SE_i = \frac{TEiCRS}{TEiVRS}$$

where SE=1 implies scale efficiency and SE<1 indicates scale inefficiency. However, scale inefficiency can be due to the existence of either increasing or decreasing returns to scale. The efficiency scores in this study are estimated using the computer program, DEAP and Efficiency Measurement System, EMS Ver. 1.3 by Professor Holger Scheel, University Dortmund [26].

Second Stage regression(Tobit)

To test the determinants of efficiency in Malaysian water industry, three models of efficiency (TE, PTE and SE) will be tested against the determinants of water service efficiency. Since the DEA technique produces efficiency scores which are bounded by 0 and 1, hence, it is appropriate to use a limited dependent variable approach, such as Tobit model to perform the multivariate analysis. The possible determinants of the efficiency of water service industry are investigated using a random effects. The Tobit model is used to investigate the determinants of efficiency. The standard Tobit model can be defined as follows:

$$Yi = \begin{cases} \beta^T X_i + \varepsilon_i, \beta^T X_i + \varepsilon_i > 0 \\ 0, \beta^T X_i + \varepsilon_i \le 0 \end{cases} \qquad (2)$$

where ε ~N (0,σ2), β is the coefficient parameter for independent variable X_i. When DEA scores are transformed, the coefficient of the Tobit model can be interpreted as if it is a coefficient of an ordinary least squares regression. That is, it indicates the expected proportionate change of dependent variable with respect to one unit change in independent variable X_i , holding other factors constant.

Based on the analysis framework discussed above the following equations have been estimated;

$$TE_{it} = \beta_0 + \beta_1 T_{1it} + \beta_2 T_{2it} + \beta_3 NRW_{it} + \beta_4 Cap_{it} + \beta_5 GDP + \beta_6 Den_{it} + \mu_{it}$$

$$PTE_{it} = \beta_0 + \beta_1 T_{1it} + \beta_2 T_{2it} + \beta_3 NRW_{it} + \beta_4 Cap_{it} + \beta_5 GDP_{it} + \beta_6 Den_{it} + \mu_{it}$$

$$SE_{it} = \beta_0 + \beta_1 T_{1it} + \beta_2 T_{2it} + \beta_3 NRW_{it} + \beta_4 Cap + \beta_5 GDP_{it} + \beta_6 Den_{it} + \mu_{it}$$

where:

TE : Technical efficiency
PTE : Pure technical efficiency
SE : Scale efficiency
T_1 : Domestic tariff rate
T_2 : Industry tariff rate
NRW : Non- revenue water
Cap : Capacity of water
GDP : Gross domestic product
Den : Density (Population per km)

3.0 FINDINGS AND DISCUSSION

Based on DEA's results, the mean technical efficiency scores for Malaysian water services as a whole was 65% over the period of this study. The score of technical efficiency is determined by pure efficiency and scale efficiency. Pure efficiency defines the ability of the industry to buy and manage input. Scale efficiency refers to water operator proposing the best operating results in the production or optimal scale production.

Technical Efficiency Score (CSR)

Overall technical efficiency score measures the ability of water supply operators to maximize output with existing inputs. The mean score for technical efficiency during the period of study is 65%. The overall technical efficiency score will be influence through pure and scale efficiency. Among the state's water operator, Perlis is the most efficient with an average score of 100% in pure efficiency and scale efficiency. Thus, allowing Perlis to achieve technical efficiency with score one over the period 2007-2015. Among other state that achieve a good performance are Pulau Pinang 89%, Perak 88% and Sarawak 83%. Previous study by Saad and Harun [24], Lee and Lee [21] and Lee, Tan and Lee [23] showed that Pulau Pinang are the only state that can sustained good performance over period of the study with good performance in efficiency score, total revenue, low tariff rate and low non-revenue water

With regard to pure efficiency the average score, water operator in Johor, Perak, Perlis and Selangor achieve 100% score through the period of study. While Pahang, Melaka, Kedah, Negeri Sembilan, Kelantan are inefficient over the period of this study (refer Table 2). Melaka and Sabah water operator registered the lowest pure efficiency with 63% and 65%. These water operators should focus more on their internal management, by focusing on service management to more effectively involve recruitment of staff with high skills and experience, good in asset management and reduce political interference in the management [27].

For scale efficiency, Perlis, Pulau Pinang, Melaka, Perak and Sarawak are the most efficient among other state. Selangor and Johor are the lowest average score scale efficiency with 31.2% and 42.6%. While Perak, Selangor and Johor each registered 100% of pure efficiency over the study period but their scale efficiency is less than 100% (Perak=88%, Johor=43% and Selangor=31%). Thereby, water operator in these states focus more on optimizing their scale production in order to achieve 100% of overall scale efficiency score.

Table 2: Average CRS, VRS, SE score and Trend from 2007-2015

Water supplier	Overall TE score (Average)	Overall VRS score (Average)	Overall SE score (Average)	Trend of Return to Scale
Perlis	1.000	1.000	1.000	Con.
Melaka	0.570	0.639	0.892	Dec.
Perak	0.879	1.000	0.879	Dec.
Johor	0.426	1.000	0.426	Dec.
Kedah	0.699	0.894	0.782	Dec
Kelantan	0.777	0.880	0.791	Dec.
N. Sembilan	0.661	0.821	0.807	Dec.

Pulau Pinang	0.886	0.962	0.922	Dec.
Pahang	0.541	0.788	0.686	Dec.
Sabah	0.401	0.652	0.642	Dec.
Sarawak	0.833	0.959	0.868	Dec.
Selangor	0.312	1.000	0.312	Dec.
Trengganu	0.753	0.897	0.827	Dec.
Labuan	0.407	0.778	0.521	Inc.

Regression (Tobit) findings

Studies conducted by Lee and Lee [21] only use the income of each state (GDP) and NRW in its analysis to see factors affecting the efficiency of water supply management. For this study we used dependent variable as the efficiency score in the DEA analysis while independent variables are domestic tariff rates, industry tariff rates, density, GDP, NRW and water capacity to identify factors affecting the efficiency of water supply. The variables that has been choosen are based on previous study by da Silva e Souza et.all [28], Kirkpatrick, Parker and Zhang [29], Guder, Kittlaus, Moll,Walter dan Zschille [30], Estache and Rossi [31], Anwandter and Ozuna [32] and Byrnes, Crase, Dollery and Villano [27]

Table 3 shows the relationship between technical efficiency, pure efficiency and scale efficiency and relationships with independent variables which is domestic tariff (tariff 1), industry tariff (tariff 2), NRW, density, GDP and water capacity. Higher GDP leading to lower efficiency scores may be rationalized along the argument that greater amount of economic activity demands greater need for water thus putting greater pressure on the operational and distributional process. Higher likelihood of incidences of water theft and pilferages that can easily lead to higher non-revenue water levels. In any event, non-revenue water was also a negative factor, another expected result as greater occurrence of such problems are likely to hamper the firm's performance in terms of total output and total expenditure incurred thus causing much technical inefficiencies.

The findings show that there are four factors influencing the efficiency of water supply management namely domestic tariff (tariff 1), industry tariff (tariff 2), NRW and density. Tariffs 1 and Density showed an efficiency at 5% significance , while tariff 2 and NRW at 1% significance. Tariffs 1 and NRW show negative relationships with efficiency, meaning that if domestic tariff rates are high and NRW is high then the water industry is inefficient. This happens in Kelantan where high water tariff rates do not encourage households to use tap water but prefer to use existing wells. Hence, existing piping facilities are not fully utilized to induce inefficiency.

Table 3 : The relationship between Technical Efficiency, Pure Efficiency And Scale Efficiency with Independent Variables

Variables	TE	
	Coefficient	P>| z |
Constant	1.1058	0.000***
Tariff 1 (domestic)	-0.9107	0.001**
Tariff 2 (Industry)	0.1646	0.094*
NRW	-0.0032	0.083*
capacity	9.38e-06	0.888
GDP	-1.49e-06	0.331
Density	0.0007	0.042**

Variables	PTE	
	Coefficient	P>| z |
Constant	0.8899	0.009***
Tariff 1 (domestic)	-0.7044	0.120
Tariff 2 (Industry)	0.2159	0.220
NRW	-0.0038	0.331
capacity	0.0001	0.379
GDP	-6.59e-06	0.310
Density	0.0012	0.021**

Variables	SE	
	Coefficient	P>| z |
Constant	1.1204	0.000***
Tariff 1 (domestic)	-0.0890	0.769
Tariff 2 (Industry)	-0.0352	0.673
NRW	-0.0046	0.000***
capacity	0.00007	0.169
GDP	-1.67e-06	0.059*
Density	0.0001	0.444

Similarly, high NRW rates due to leakage of pipes and water theft and related causes result in reduced state governments. This leads to inefficiency in water supply management. These two variables have a strong relationship. Percentage of entitlement to domestic tariff is 5%, while NRW is at 1%.

Industrial tariff rates and density have a positive relationship with efficiency. That means higher industrial tariff rate and density increasingly efficient state water supply industry. This is because the industrial tariff rate is much larger than domestic tariffs and the yield to water operators from the industrial tariffs is also increasing. This high industrial water tariff is also subsidized to domestic tariffs [23].

For density, it refers to the increasing number of populations per km increasingly efficient because the per unit costs are low and this benefits the water supply operator. But if a low population cost per unit is high and it is detrimental to water operators as all sources are not fully utilized and all existing water pipe facilities are not used by the public as happened in Kelantan.

Under the PTE or the efficiency of efficiency involving the internal management of water supply operators (OPEX), only density alone is the determinant factor of efficiency. This is because internal governance regarding input use contributes to efficiency in water operators. This is because the higher the density becomes the operator of water supply because the cost per unit is low and the operator can maximize profit. This is also due to the good supervision of the internal management of water supply operators [33], [13],[34]. Although Density is only at a 5% level of significance, it is the only factor that contributes to management efficiency compared to other irrelevant variables. As seen from the point of view of the efficiency of the contributing factors, the NRW and the state GDP are both negatively associated with efficiency

Strategies to Improve NRW

Inefficiencies in the scale is due to an increase in NRW. NRW that has been targeted by SPAN in 2020 is 26% for each state (Figure 1). However NRW rate for 2015 is still a long way to achieve the targeted level. Thus the most effective ways in handling the NRW problems nationwide is through holistic approaches which involve the following scope of areas [5]:

- Comprehensive leakage repair works and maintenance.
- Replacement of old production meter.
- Establishment of District Metering Zones (DMZ).
- Proper Water Pressure Control and Replacement of dilapidated pipes.
- Proactive to customers complains (Customer Service Centre).
- Special Task For to Manage NRW programme.

While NRW has been used as an indicators for performance of operators in water industries an immediate action to reduce NRW has been introduce which include 100% of billing through new billing system called 'S2B' and ensuring correct billing through close monitoring of individual consumption patterns, consumer supply meter change 'crash' programme, an integrated operation to stop pilferage of water, including disconnecting all squatters' supply and giving them proper metered supplies and the last one using water for fire-fighting or any other use from fire hydrants has to be charged. In addition, governance of human resources and assets are very important in water supply industries [5].

Based on the trend of technical efficiency scores among operators of water supply during the period under review, and in particular for the period 2007-2015, the establishment of PAAB and SPAN have a positive impact on the efficiency of water supply operators, particularly operators that was less efficient in its delivery system to consumers [24].

4.0 CONCLUSION

The establishment of SPAN & PAAB has a small but positive impact on the efficiency of state-owned water operators, especially among the operators that are less efficient before the establishment of SPAN-PAAB. Perlis water operator has achieved 100% efficient in their technical efficiency score from 2007-2015. It can be concluded that the establishment of SPAN-PAAB and its policies can improve the efficiency of state's water operators in the long run and will have a positive and significant impact on the efficiency of the state's water operator. As mention by previous Secretary General of the Ministry of Energy, Green Technology and Water, utility's performance will not only focusing solely on NRW but they also need to focus on monitoring the duration of water interruption together with demand management and complaint. The other indicator is to reduce per capita consumption for example to reduce consumption from 210 liter to 170 liter per capita per day. So specific monitoring and enforcement process may need to be introduced. Since NRW is one of the key performance index that has been used by SPAN to measure the efficiency and performance of water services in Malaysia, hence a holistic management approach has been introduce to overcome this problem. Involvement from NGO's and media in awareness education on NRW issues and public role are important [35].

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