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NETWORK DATA ENVELOPMENT ANALYSIS AS INSTRUMENT FOR EVALUATING WATER UTILITIES' PERFORMANCE

(Analisis Pengumpulan Data Rangkaian sebagai Instrumen untuk Mengukur Prestasi Utiliti Air)

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ABSTRACT

Measuring the water sector performance is essential in improving the quality of water supply services. Commonly, many countries have used performance indicators to benchmark the efficiency and effectiveness of their water management. One of the important performance indicators in determining the efficiency of water utility is to look at their ability to reduce the Non-Revenue Water level or more commonly known as NRW. The percentage of NRW indicates the level of water leakage experienced and can also be classified as undesirable output in the water supply system. On the other hand, Data Envelopment Analysis (DEA) has been widely applied as the instrument to measure water sector performance, but only as a single process or so-called black-box analysis. Since the production of water supply services can be expressed as a two-stage network process, this study attempts to use the Network Data Envelopment Analysis (NDEA) to measure water sector performance. One of DEA model variations is Slack-based Measure (SBM) model, where is subsequently been expanded to the network structure (Network Slack-based Measure, NSBM). This study was undertaken to apply the NSBM model incorporating the undesirable outputs to measure the efficiency, then, proposed as a new performance indicator and can also be used for the benchmarking of the water utilities specifically for Malaysian water industry. From this study, not only the overall performance of each water utility, but also which process should be the focus for those inefficient water utilities can be determined.

Keywords: network data envelopment analysis; performance measurement; undesirable output; water utilities

ABSTRAK

Pengukuran prestasi sektor air adalah penting bagi meningkatkan kualiti perkhidmatan bekalan air. Biasanya, kebanyakan negara menggunakan penunjuk prestasi untuk menanda aras kecekapan dan keberkesanan pengurusan air masing-masing. Satu daripada penunjuk prestasi yang penting bagi menentukan kecekapan sesebuah utiliti air adalah dengan melihat keupayaan mereka untuk menurunkan aras Air Bukan Hasil yang dikenali dengan singkatan NRW (*Non-Revenue Water*). Peratusan NRW menunjukkan paras kebocoran air yang dialami dan boleh dikelaskan sebagai output yang tidak diingini dalam sistem bekalan air. Dalam pada itu, Analisis Pengumpulan Data (DEA) telah digunakan secara meluas sebagai instrumen bagi mengukur prestasi sektor air, tetapi hanya melibatkan proses satu peringkat atau dipanggil analisis kotak hitam. Oleh kerana pengeluaran bagi perkhidmatan bekalan air boleh distrukturkan sebagai proses rangkaian dua-peringkat, kajian ini mencuba untuk menggunakan Analisis Pengumpulan Data Rangkaian (NDEA) untuk mengukur prestasi sektor air. Satu daripada variasi model DEA adalah Sukatan berasaskan Pemboleh ubah Lalai (SBM), yang kemudiannya telah dikembangkan kepada struktur rangkaian (Sukatan berasaskan Pemboleh ubah Lalai Rangkaian, NSBM). Kajian ini telah dilakukan bagi mengaplikasikan model NSBM dengan mengambil kira output tidak diingini bagi mengukur kecekapan, kemudiannya, dicadangkan sebagai penunjuk prestasi baharu dan boleh digunakan untuk tujuan penandaarasan utiliti air terutamanya bagi industri air di Malaysia. Daripada kajian ini, bukan sahaja prestasi keseluruhan bagi setiap utiliti air, malah proses mana yang perlu diberi lebih perhatian bagi utiliti air yang tidak cekap juga boleh ditentukan.

Kata kunci: analisis pengumpulan data rangkaian; pengukuran prestasi; output tidak diingini; utiliti air

1. Introduction

Sufficient clean water supply is very important because water is a basic human need. Water is also one of the most important sources in the food, services and energy production industry sectors. The management of national water resources as well as the distribution of water supply is given full attention by the authorities to meet all consumer demand.

However, in most places, especially in developing countries, clean and treated water distribution systems suffer from water loss and leakage crisis. The cause of this water crisis is not only just because of the shrinkage of water resources due to global warming and so on, but is believed to be caused by the inefficiency in managing the water supply system of a country. In fact, globally, the level of water loss is one of the most important indicators to measure the efficiency of the governing body or the water utility operator (Lambert *et al*. 1993; Garcia & Thomas 2001; Kingdom *et al*., 2006; Picazo-Tadeo *et al*. 2008; Van den Berg 2015; Vilanova *et al*. 2015; Zyoud *et al*. 2016).

The terms and definitions for leakage or loss of water are different according to country, but in Malaysia the term commonly used in the water supply sector is Non-revenue water which is disclosed as NRW. NRW is defined as the difference between the amount of water that has been supplied with the amount of water billed at the consumer premises meter. In other words, NRW is the clean and well-kept water that has been distributed in the water distribution system and reaches customers, but is not billed (Cawangan Bekalan Air Jabatan Kerja Raya Malaysia 1995).

According to Kim (2012), the problem of operational inefficiency in the water supply services sector is due to the inability of water utilities to reduce the high NRW level. The high NRW level indicates a very serious operation problem. It can be concluded that those who operate water supply systems efficiently often have a good distribution system and minimal water loss (NRW) quantity (Hasnul 2000).

Other studies also seconded that high water losses is the most relevant indicator of the inefficiency of water distribution systems (Vilanova *et al*. 2015). Furthermore, Van den Berg (2015) stated that a key to sustainable water management is to reduce the water losses because it helps to improve the financial health of the water utility and thus allowing it to invest in service quality improvements.

Thus, the NRW (water losses) aspect is important to be considered as one of the factors in measuring the efficiency of a water utility. This means that the performance measurement of water utility should also be seen how efficient they reduce NRW while optimizing the use of inputs to produce the desired output.

2. A Review of Related Research Works

In measuring the efficiency of water utility management, various methods and models have been used and introduced. There are many variation of this model starts from a very simple performance indicators (PI) to a more specific one which are based on production frontier. This model variation allows the authorities to benchmark the efficiency of water utility management. The most commonly used model for analyzing the performance of water industry companies is Data Envelopment Analysis (DEA). Byrnes *et al*. in 1986 was the first to use DEA in measuring the performance of the industrial water and then followed by many as in Romano and Guerrini (2011).

DEA developed by Charnes, Cooper and Rhodes in 1978 is a linear programming techniques to assess the relative efficiency of a set of corresponding units which is called as decision-making units (DMUs). DEA also deals with various performance measures i.e. the inputs and outputs in an integrated model to identify best practice boundaries for benchmarking purposes (Charnes *et al*. 1978).

The issue highlighted in this study is on the NRW. The process and distribution of treated and cleaned water from treatment plant to consumer will be separated into two sections i.e. authorized consumption water and water losses known as the NRW. Authorized consumption water is a billed water usage to the consumer to generate revenue to the water service provider. Water service provider also aims for a maximum revenue by minimizing NRW (water loss). Thus, authorized water consumption or revenue is regarded as desirable output whereas NRW is the undesirable output of the water supply system.

So far, NRW factor has been ignored in many prior studies which focus on water utility efficiency using DEA. Some has misinterpreted NRW as input factor where by they only considered input and desirable output variables (as in conventional DEA) while the NRW is suppose measured as undesirable output in the performance models (Picazo-Tadeo *et al*. 2008; Kumar 2010). As a result, the undesirable output presence in traditional DEA model becomes invalid. Thus, resulted to an unfair assessment.

A more enhance DEA model which can resolve the incorporation of undesirable output is established by Chung *et al*. (1997) and is known as Directional Distance Function (DDF). The DDF performance measures take account of the production of both desirable and undesirable outputs. Therefore, it is fit for the performance evaluation of water utilities because it divided the outputs from water supply system into two namely desirable (Revenue) and undesirable outputs (NRW). Due to the models functionality, Picazo-Tadeo *et al*. (2008) had applied and incorporated bad qualities as the undesirable output in his evaluation on the performance of water utilities. They measured the NRW or in his study called unaccounted-for water (UFW) as the water losses to explain the quality element of water service sector and agreed that water network losses can be considered as undesirable output. This is because UFW is also generated simultaneously during water distribution.

Kumar (2010) on the other hand deduced that benchmarking should credit the water utility for UFW reductions as well as improvement in their service delivery. He studied the Indian water utilities production technology in the urban area. He used DDF and integrates the delivered water and the UFW as an output factors to find ways to improve the water delivered and reduce UFW which is in line with the effort made by the water utilities.

However the weakness of the DDF model is similar to the non-radial size weakness. One of the drawbacks is that the resulting efficiency score is or is approaching weak efficiency. DMUs are not exactly defined, so it is difficult to compare with inefficient DMUs, making the DMU more complicated. Moreover, since input and output factors need to be taken into account separately, the results obtained from these two components may be inconsistent, this again leads to questionable DMU removal. One method for solving this problem is to use a Slack-based Measure (SBM) of efficiency in DEA or methods that are in line with SBM (Kao 2017).

Tone (2001) has popularized the SBM model in year 2001. The default variable requirement (slack) is the difference between the DMU units being evaluated with its benchmark or in other words, excess in input, or lack of output. Methods based on the default variable (slack) use the default variable to measure performance (Kao 2017). Later, Zhou *et al*. (2006) developed the SBM model proposed by Tone (2001) in order to combine undesired output. Compared to radial efficiency measurements, Zhou *et al*. (2006) empowered to discriminate higher.

It is also found that many previous studies in water supply processes has ignored its network structure. They do not take any attention in the activities among internal divisions or stages in the operations of water supply services. Hence, two-stage network structure suit really well to the water supply services internal operations. The water supply services operations are divided into two stage processes, where stage 1 is the water treatment process (i.e water is cleaned and treated) and stage 2 is the distribution process. By using the network structure model, beside the overall efficiency we can also get to know the performance of each process involve in the network. Hence, for the case of water supply services, the efficiency of the overall process as well as the efficiency of the water treatment process and the water distribution process can be determined.

Fare and Grosskopf (2000) has resolved these internal stages issues by using the network DEA (NDEA). The NDEA is the extended version of the former DEA models which measure the performance of players in productions that are vertically incorporated. It could also explain the efficiencies of stage related to the processes together with the overall efficiency in a single integrated framework. Thus far, there are only few studies on the water utilities' performance that apply the NDEA model.

For that reason, in our study, we are considering the jointly produced desirable outputs specifically the revenue on delivered water and NRW as the undesirable output in a two-stage network framework. So, the undesirable output (NRW) factor is incorporated into the NDEA. For the network structure DEA, we employed the network structure SBM (NSBM) and slot in the undesirable output factor into the model to evaluate the performance of water utilities.

The goal of this paper is to contribute in filling the empirical gap as there is notably lack of studies which integrates NRW as undesirable output while water utilities perform their management efficiency evaluation. To this point, no study have employed the NSBM approach to evaluate the performance of water utilities particularly in Malaysia. As mentioned earlier, water supply service operation can be expressed as in two-stage network structure, thus the NSBM analysis in this study signifies a two-stage network production technology. As the method is tested, our hope is that this study is relevant in providing essential information to water utilities to improve their current business practices, especially in finding the best initiatives to reduce NRW levels.

3. Methodology

Two-stage network models are the extension to the first generation of black-box DEA model. Fukuyama and Weber (2010) explained how the basic black-box DEA model have been extended into a two-stage network production process with undesirable outputs as depicted in Figure 1. Assume the inputs $x \in R_+^N$ are used to produce desirable outputs $y \in R_+^M$ and also undesirable output $b \in R_+^L$. The black-box technology set is as follows:

$$BT = \{(x, y, b) | x \in R_+^N \ can\, produce\ (y, b) \ \in R_+^{M+L}\} \tag{1}$$

Then, to set up a two-stage network technology, the $z \in R_+^Q$ is regarded as the vector of *Q* intermediate products. Fukuyama and Weber (2010) describe the two-stage network technology defined as per in Eq. (2) as follows:

$$NT = \left\{(x, y, b) \middle| \begin{array}{ll} x \in R_+^N \ can\ produce\ z \in R_+^Q & (Stage\ 1) \\ z \in R_+^Q \ can\ produce\ \ (y, b) \in R_+^{M+L} & (Stage\ 2) \end{array} \right\} \tag{2}$$

where the vector *z* intermediate product is determined endogenously. To illustrate this, Figure 1 shows the two-stage network production technology for Eq. (2). The production technology for Eq. (1) and Eq. (2) can be written in DEA model form. The black-box technology for Eq. (1) is then takes the form as follows:

$$BT = \{ (x, y, b) | x \geq \sum_{j=1}^{J} x_j \lambda_j ;\ \ y \leq \sum_{j=1}^{J} y_j \lambda_j ;\ \ b = \sum_{j=1}^{J} b_j \lambda_j ;\ \ \lambda \geq 0 \} \tag{3}$$

Let, there are $j = 1, \ldots, J$ units of DMU, each of them convert inputs $x_j \in R_+^N$, into intermediate products $z_j \in R_+^Q$ in the first stage, the same intermediate products are uses as inputs in the second stage to produce final desirable outputs $y_j \in R_+^M$ and undesirable outputs $b_j \in R_+^L$. While λ represent the nonnegative intensity vector.

The two-stage network technology (2) can be presented in DEA form. Let the intensity vectors for the two stages as $\lambda^1 = (\lambda_1^1, \ldots, \lambda_J^1) \in R_+^J$ dan $\lambda^2 = (\lambda_1^2, \ldots, \lambda_J^2) \in R_+^J$. The network production set for Eq. (2) in DEA form is as follows:

$$NT = \left\{ (x, y, b) \middle| \begin{array}{l} x \geq \sum_{j=1}^{J} x_j \lambda_j^1 ;\ \ y \leq \sum_{j=1}^{J} y_j \lambda_j^2 ;\ \ b = \sum_{j=1}^{J} b_j \lambda_j^2 ; \\ \sum_{j=1}^{J} z_j \lambda_j^1 \geq \hat{z} ;\ \ \sum_{j=1}^{J} z_j \lambda_j^2 \leq \hat{z} ;\ \ \lambda^1 \geq 0;\ \lambda^2 \geq 0;\ \ \hat{z} \geq 0 \end{array} \right\} \tag{4}$$

where $\hat{z}$ is determined endogenously in Eq. (4).

As proposed by Tone (2001), the overall analysis for the SBM black box is presented in Eq. (5),

$$SBM_{(x_o, y_o)} = \min_{\rho, \lambda, s^x s^y} \left\{ \rho = \frac{1 - \frac{1}{N} \sum_{n=1}^{N} \frac{s_n^x}{x_{no}}}{1 + \frac{1}{M} \sum_{m=1}^{M} \frac{s_m^y}{y_{mo}}} \middle| \begin{array}{c} x_o = \sum_{j=1}^{J} x_j \lambda_j + s^x ;\ \ y_o = \sum_{j=1}^{J} y_j \lambda_j - s^y ; \\ \lambda \geq 0,\ s^x \geq 0,\ s^y \geq 0 \end{array} \right\} \tag{5}$$

Next, Tone and Tsutsui (2009) extended the former SBM model by Tone (2001) into the network structure DEA called NSBM for the production potential sets in Eq. (4) as follows:

$$NSBM_o = \min_{\rho_o^*, \lambda^k, s^x{}_o^k s^y{}_o^k} \left\{ \rho_o^* = \frac{\sum_{k=1}^{K} w^k \left[1 - \frac{1}{Nk} \sum_{n=1}^{Nk} \frac{s^x{}_{no}^k}{x_{no}^k} \right]}{\sum_{k=1}^{K} w^k \left[1 + \frac{1}{M} \sum_{m=1}^{Mk} \frac{s^y{}_{mo}^k}{y_{mo}^k} \right]} \middle| \begin{array}{c} x_o^k = X^k \lambda^k + s^x{}_o^k \ \ (k = 1, \ldots, K) \\ y_o^k = Y^k \lambda^k - s^y{}_o^k \ \ (k = 1, \ldots, K) \\ Z^{(k,h)} \lambda^h = Z^{(k,h)} \lambda^k \ \ (\forall (k, h)) \\ e\lambda^k = 1 \ \ (k = 1, \ldots, K) \\ \lambda^k \geq 0,\ s^x{}_o^k \geq 0,\ s^y{}_o^k \geq 0,\ (\forall k) \end{array} \right\} \tag{6}$$

where they set $X^k = (x_1^k, \ldots, x_J^k) \in R^{Nk \times J}$, $Y^k = (y_1^k, \ldots, y_J^k) \in R^{Mk \times J}$ and $s^x{}_o^k (s^y{}_o^k)$ as the default input (output) variable vector. The notation on $\sum_{k=1}^{K} w^k = 1, w^k \geq 0\ (\forall k)$ dan w^k is then the relative weight for the *k* division which are determined based on its importance. The NSBM (2009) model is also recognized as the weighted and non-oriented NSBM model.

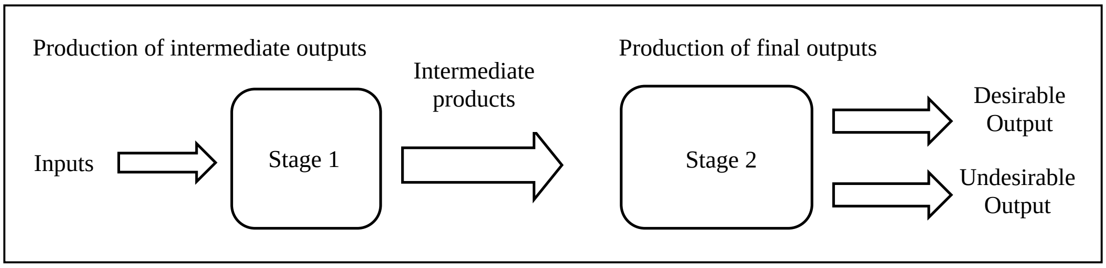

Figure 1: Two-stage network production technology

$$TT = \min_{\lambda^1,\lambda^2,s^{x1},s^{y2},\hat{z}} \left\{ \frac{w^1\left(1-\frac{1}{N}\sum_{n=1}^{N}\frac{s^{x1}_n}{x_{no}}\right)+w^2}{w^1+w^2\left(1-\frac{1}{M}\sum_{m=1}^{M}\frac{s^{y2}_m}{y_{mo}}\right)} \;\middle|\; \begin{array}{c} \sum_j x_j\lambda_j^1 = x_o - s^{x1}, \\ \sum_j y_j\lambda_j^2 = y_o + s^{y2}, \\ \sum_j z_j\lambda_j^1 = \hat{z}, \\ \sum_j z_j\lambda_j^2 = \hat{z}, \\ b_o = \sum_{j=1}^{J} b_j\lambda_j^2, \\ \lambda_j^1 \geq 0\ (\forall j),\ \lambda_j^2 \geq 0\ (\forall j), \\ s^{x1} \geq 0,\ s^{y2} \geq 0 \end{array} \right\} \tag{7}$$

Next Fukuyama and Weber (2010) combined the undesired output element into the model in Eq. (6) which introduced two-tiered structured namely the two divisions and is a case of independent network connection. The model is then marked as TT by Fukuyama and Weber (2010) and it is similar to the model in Eq. (7) where $s^{x1} = (s^{x1}_1, \ldots, s^{x1}_N) \in R^N_+$ and $s^{y2} = (s^{y2}_1, \ldots, s^{y2}_M) \in R^M_+$ are the default variables related to divisions 1 and divisions 2. Weighting related to this division when added together will be unity that is $w^1 + w^2 = 1$.

In the framework of this model, undesirable outputs are not included in the objective function of the model in Eq. (7), but the undesirable output is included in division 2 and is one of the constraints in technology related situations where undesired output is not generated.

Huang *et al*. (2014) in their model, incorporated an undesired output into the objective functions. The NSBM model with undesirable output (UO) by Huang *et al*. (2014) is known as NSBM-UO. The NSBM-UO model is as follows:

$NSBM - UO$

$$= \min_{\lambda^k, s^{xk}, s^{yk}, s^{bk}, \hat{z}} \left\{ \frac{\sum_{k=1}^{K} w^k \left[1 - \frac{1}{Nk}\sum_{n=1}^{Nk}\frac{s^{xk}_{no}}{x^k_{no}}\right]}{\sum_{k=1}^{K} w^k \left[1 + \frac{1}{M_k + L_k}\left(\sum_{m=1}^{Mk}\frac{s^{yk}_{mo}}{y^k_{mo}} + \sum_{l=1}^{Lk}\frac{s^{bk}_{lo}}{b^k_{lo}}\right)\right]} \;\middle|\; \begin{array}{c} x^k_o = X^k\lambda^k + s^{xk}_o\ \ (k = 1, \ldots, K) \\ y^k_o = Y^k\lambda^k - s^{yk}_o\ \ (k = 1, \ldots, K) \\ b^k_o = B^k\lambda^k + s^{bk}_o\ (k = 1, \ldots, K) \\ Z^{(k,h)}\lambda^h = Z^{(k,h)}\lambda^k\ \ (\forall (k,h)) \\ e\lambda^k = 1\ \ (k = 1, \ldots, K) \\ \lambda^k \geq 0,\ (\forall k) \\ s^{xk}_o,\ s^{yk}_o,\ \ s^{bk}_o \geq 0, (\forall k) \end{array} \right\} \tag{8}$$

where $X^k = (x^k_1, \ldots, x^k_J) \in R^{Nk\times J}$, $Y^k = (y^k_1, \ldots, y^k_J) \in R^{Mk\times J}$, $B^k = (b^k_1, \ldots, b^k_J) \in R^{Lk\times J}$ as well as s^{xk}_o, s^{yk}_o and s^{bk}_o are the default input variable vector, desired output and undesired output and finally the $\sum_{k=1}^{K} w^k = 1, w^k \geq 0\ (\forall k)$ and w^k are regarded as the relative weight for the division of *k* which is determined based on its importance.

For this study we use the model in Eq. (8) as an instrument to measure the water utilities' performance.

3.1. *Water utilities' efficiency assessment*

The motivation for this study is the application of network DEA to modelling water utilities. In addition, there are also undesirable output factor as by-product to desirable output of water system provider. The used of DEA in water industry performance measurement is pioneered by Byrnes *et al*. in 1986 and then followed by many from 1986 to 2008 as reviewed in Romano and Guerrini (2011). However almost the reviewed studies considered a DMU as a single process, although there are studies that includes the undesirable output factor such as Unaccounted for water (UFW) as in Picazo-Tadeo (2008) and Kumar (2010).

The authors earlier works have attempted to measure the water utilities performance in a network process (Norbaizura *et al*. 2015) and have incorporated Non-revenue Water (NRW) as undesirable output in the network structure of water system services (Norbaizura & Wan Rosmanira 2016; Norbaizura *et al*. 2018). Those earlier works have used different variation of NDEA approach, yet, not the NSBM model.

The structure of water supply service operations in a two-stage network framework is depicted as in Figure 2. The selection of inputs, intermediate products, desirable and undesirable outputs for this study are as shown in Figure 2. In the first stage (water treatment process), water utilities utilize inputs such as operation costs (in Malaysian Ringgit, RM) and raw water resources (in Million liters per day, MLD) to produce a volume of cleaned and treated water (in Million liters per day, MLD) as intermediate product, that become input to the stage 2 (water distribution process) together with another input which is length of pipes (kilometers, KM), where desirable output, revenue generated from water delivered (in Malaysian Ringgit, RM) is produced along with undesirable output, which is NRW (in Million liters per day, MLD). While, Table 1 shows the observed data for 14 Malaysian water utilities according to each state for year 2014.

The first thing to verify is that the results of the NSBM-UO model should meet both properties as in the Huang *et al*. (2014) model. The first is that if a DMU is efficient overall, all divisions of the DMU should also be efficient. Second, the NSBM-UO model should have at least one efficient DMU in each division.

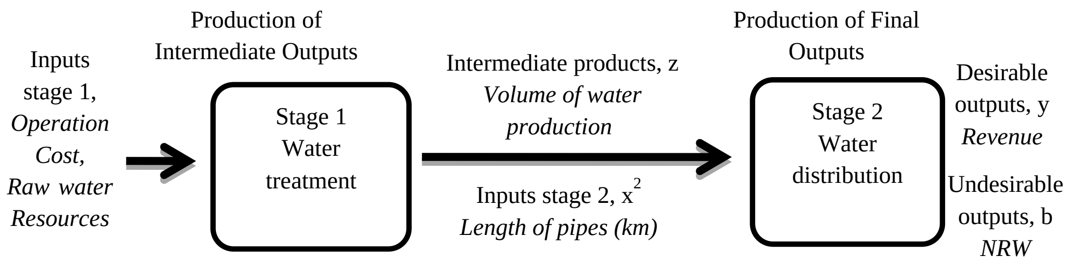

Figure 2: Two-stage network production for water utilities with undesirable output

Table 1: Data set for 14 states in 2014

DMU	OPEX (RM)	Raw Water (MLD)	Water Production (MLD)	Pipe Length (KM)	Revenue (RM)	NRW (MLD)
Johor	736,167	1,683	1,640	20,898	853,527	426
Kedah	260,748	1,388	1,294	11,770	290,591	596
Kelantan	80,276	493	445	6,698	98,410	220
Labuan	27,752	71	69	506	16,241	20
Melaka	157,696	732	478	4,851	184,292	102
Negeri Sembilan	176,535	870	744	8,575	187,948	267
Pulau Pinang	199,037	1,152	995	4,335	278,504	182
Pahang	251,605	1,183	1,108	10,307	153,056	588
Perak	228,555	1,283	1,237	11,325	350,333	379
Perlis	25,249	228	216	1,877	34,019	121
Sabah	446,482	1,196	1,196	15,031	224,508	618
Sarawak	230,398	1,368	1,192	11,797	263,605	381
Selangor	1,727,899	4,648	4,593	27,251	2,023,915	1,545
Terengganu	126,321	664	605	8,397	123,939	188

4. Results and Discussion

After the NSBM-UO model is applied to the water data, the findings are shown in the Table 2. The NSBM-UO model efficiency score is shown in the second column, followed by the efficiency score for each stage of the process i.e. Division 1 column for the first stage process, and Division 2 column for the second stage process. The overall rank for each state is shown in the last column.

The results obtained can empirically confirm that both properties of the model have been fulfilled or vice-versa. From the Table 2, only two states are efficient with score 1. The efficiency score in both divisions for both states (Labuan and Selangor) are also efficient with score 1. It shows that the first and second property are fulfilled, and the result suppose to show in every division there is at least one efficient DMU. Thus, this proves empirically for water data that both of the properties of the NSBM-UO model by Huang *et al*. (2014) has been fulfilled.

The efficiency score obtained from the NSBM-UO size model is used for removal purposes. Starting with a score of 1 is the highest rank. The lower the score score, the lower the rank of DMU involved. The fifth column ranks the overall score of NSBM-UO in the second column. Labuan and Selangor share the first rank because both have efficient DMUs compared to others. The state with the lowest score is Pahang, and can be deduced that Pahang is not managing its water supply efficiently in Malaysia compared to other states. In the case of inefficient state, it may make Labuan and Selangor as benchmarks or best practices for improvement purposes.

Other information that can be obtained by using this NSBM-UO model, we can describe the efficiency score for each division separately. For example, the Johor state is not efficient in the first division of the water treatment process, but is efficient in the second division of the water distribution process. While in Perlis it is efficient in the water treatment process, but is not efficient during the water distribution process. With this information, an inefficient DMUs can focus more on other problematic process related.

Table 2: Performance of each state using NSBM-UO model for 2014

State	**NSBM-UO Score**	**Division 1**	**Division 2**	**Rank**
Johor	0.896	0.792	1.000	4
Kedah	0.364	0.486	0.270	9
Kelantan	0.309	0.476	0.182	11
Labuan	1.000	1.000	1.000	1
Melaka	0.703	0.462	0.944	5
Negeri Sembilan	0.363	0.480	0.267	8
Pulau Pinang	0.951	0.901	1.000	3
Pahang	0.212	0.281	0.162	14
Perak	0.509	0.652	0.384	7
Perlis	0.595	1.000	0.384	6
Sabah	0.235	0.335	0.161	13
Sarawak	0.356	0.470	0.263	10
Selangor	1.000	1.000	1.000	1
Terengganu	0.293	0.421	0.188	12
Average	0.556	0.625	0.515	

5. Conclusion

In this paper, we firstly reviewed the works related to the measure of DEA and network DEA. The elaboration from the black-box technology into the network technology measure and incorporating the undesirable output factor is discussed.

We choose to employ the network SBM model as a new measure for efficiency and tested to measure the performance of water utilities in Malaysia. The results indicate the efficiency level of each water utilities and give some insights which division or process should be focused in order to achieve efficiency for those inefficient DMUs.

This result can help the authority to evaluate and monitor progress of the water utilities to ensure efficient and effective implementation of any program for giving best quality for country water supply sector.

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