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ESTABLISHMENT OF PERFORMANCE INDICATORS FOR MALAYSIAN WATER UTILITIES WITH THE PRESENCE OF UNDESIRABLE OUTPUT

Norbaizura Kamarudin[a,b*], Wan Rosmanira Ismail[b]

[a]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[b]School of Mathematical Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, UKM Bangi, Selangor, Malaysia

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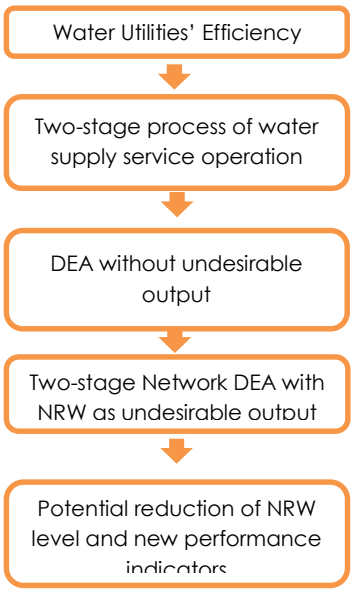
*Corresponding author
norbaizura@tmsk.uitm.edu.my

Graphical abstract



Abstract

In maintaining the efficiency of water supply services, it is crucial to monitor the performance of water utilities in a country. One of widely used tools to evaluate the performance of water supply services is Data Envelopment Analysis (DEA). However, prior DEA-related approaches for water sector performance have ignored the internal structure of water supply service operations; i.e. the water treatment process and water distribution process. Another neglected aspect is the presence of Non-Revenue Water (NRW) to be considered as an undesirable output in the water distribution process. This is in line with the goal to reduce the NRW level in water supply systems. Hence, this paper proposed a two-stage Network DEA with the presence of undesirable output to evaluate the performance of Malaysian water utilities. This proposed method advances the existing DEA-based approach on water utility performance measurement, where not only the potential reduced level of NRW can be determined, but, a new performance benchmarking indicator regarding the concept of efficiency and effectiveness of the water supply industry in Malaysia can be established from the same model.

Keywords: DEA model; NRW; performance indicators; water utilities

1.0 INTRODUCTION

Malaysian water sector reform has been initiated by the federal government in order to improve the water sector operational efficiency in the long term. Since then, as reported in World Bank 2012 [1], Malaysia has progressed well in term of providing clean water and satisfactory sanitation to its citizens. Furthermore, the Malaysian access rate for water supply and adequate sanitation were also above regional and world averages [1].

Despite the good records, Malaysian water sector is still facing many problems and operational efficiency is part of it. According to Ching [2], one of the main factors contributed to operational inefficiency is the incapability of water utilities to

reduce the high level of Non Revenue Water (NRW). The NRW issue affects the revenue collection to the water authority and seriously weakened the ability of water utilities to sustain their operations or to expand services to new area. As in 2007, the water supply services in most of the states were recorded losses and the average level of NRW was high, which approximately 40% [3].

Malaysian government also puts high priority on the NRW issue since it reflects the performance of water supply management in a country. According to Lambert et al. [4], high volume of water losses or NRW is a signal of an ineffective planning and construction, and also because of low operational maintenance activities. After all, Malaysian authority has contributed major investment in reducing these losses, therefore, it is crucial to monitor the performance of water utilities in order to boost the quality of their services and to enhance the operational efficiency. Hence, at the same time, the NRW problem could be resolved too.

In order to provide efficient water supply services and able to resolve the high level of NRW problems, this study attempts to give a different perspective from the existing water sector performance evaluation. Apart from that, a better understanding of water supply system that can be useful for policy making could be achieved. This paper starts with lack of appropriate performance measurement instrument to assess Malaysian water utility's efficiency. Next, followed by related literature reviews and the proposed methodology for the problem. Lastly, a brief conclusion and the direction of future research are presented at the ends of this paper.

2.0 MOTIVATION OF THE STUDY

Water sector management in Malaysia is now under the responsibilities of Ministry of Energy, Green Technology and Water Malaysia (KeTTHA) formerly known as Ministry of Energy, Water and Communication. The water sector division under KeTTHa after cabinet reshuffle in 2004, is responsible for national water services industry, which includes water treatment, distribution of safe drinking water and the treatment of municipal wastewater [5].

Despite the centralized water supply management system initiated by the Malaysian government through a series of amendments approved by Parliament regarding water supply services matter, the sector as a whole still lacks an effective assessment tool to evaluate the performance of the water supply service providers. The first measures of performance have been developed in 1994 by the Malaysia Water Association (MWA), where performance indicators for the water supply and wastewater sector in Malaysia were introduced in order to drive the water utilities to improve the quality of their services. The indicators assist water utilities to identify how far they are from best practice in each part of operations. There are four groups of category covered in the performance indicators, which are physical performance, operational performance, service performance, and financial performance [6].

The performance indicator also provides the opportunity for benchmarking and to set up a performance standard for the water supply industry. Malaysia is not the only country that used performance indicator as a benchmarking tool. In fact, partial indicators such as cubic meters per kilometer per day or percentage of NRW has been used as benchmarking methods in water distribution in various countries [7].

However, these partial indicators are said to be a partial performance measure which involves a single input or single output indicators [8]. To address the issue, another benchmarking tool that has lately become very popular in the water industry is a frontier-based techniques such as Data Envelopment Analysis (DEA) which can deal with multiple performance measures (inputs and outputs) in a single integrated model [9].

According to Romano and Guerrini [10], pioneered by Byrnes et al [11], hundreds of studies worldwide have used DEA models relating the performance of the water industry since the year of 1986. Most of the studies have multi-output and employed input-oriented DEA technique and using Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models [10].

Nonetheless, most of the above mentioned studies have ignored the internal structure of water supply service operations which can be described as a two-stage process; water treatment process (stage 1) and water distribution process (stage 2). Recently, the application of DEA representing a network process has become an important area of development [12]. Since, water supply services operations can be expressed as a two-stage network structure, where the outputs from the water treatment process (stage 1) become the inputs to the water distribution process (stage 2), this study attempts to employ the two-stage Network DEA model in order to optimize performance of water utilities and to obtain insights unavailable from the standard DEA approach.

Furthermore, NRW has become one of the famous issues affecting water supply services worldwide including Malaysia. For that reason, NRW is used as one of the Key Performance Indicators (KPIs) introduced by MWA in 1994 as one of the indicators of operational efficiency for water supply industry in Malaysia. However, Malaysian current policy sets a single NRW target as KPIs and the performance of each water utility is assessed against the target. Since this practice is not practical, DEA is one of the best method in order to determine the potential improvement level of NRW which enable targets to be set for each of the water utilities [13].

Nevertheless, most existing DEA-based water utility efficiency studies have either excluded the NRW or treated NRW inappropriately as a classical input

factor. Contrarily, NRW should be considered as an undesirable product in the water supply system.

In the light of the above reasons, there is a need to measure the quality performance of Malaysian water utility services representing the two-stage process of water supply service by incorporating the non revenue water (NRW) as undesirable output. This study is hoping to provide the best practices and new benchmarking indicator for water utilities operation and give direction to the water utilities manager. In addition, the optimal level of potential reduction of the current level of NRW for each inefficient water utility is needed, in order to improve the quality of their services. This is to align with the government's intention to monitor performance of a country's water supply management and at the same time, aiming to reduce the high level of NRW countrywide.

This study aims to develop a new performance measurement model that incorporates:

1. Internal structure of water supply service operation which involves two linked processes; water treatment and water distribution processes.
2. The presence of Non-revenue water (NRW) as undesirable output and establishment of optimal level for potential reduction.
3. Establishment of new performance benchmarking measures for water utilities in Malaysia.

3.0 A REVIEW OF RELATED RESEARCH WORKS

Performance measurement is a common practice to provide meaningful information for further improvement of an organization. Since the global water industry is confronting challenges in water management, such as water losses, through the years, many tools have been established to improve efficiency of water distribution systems. Assessment of water utility's performance has used several indicators vary from very straightforward measures to more advanced methods [14]. A number of studies on water utilities managerial efficiency assessment have used DEA as benchmarking techniques since 1980s. Figure 1 shows an illustration on water utility performance measurement using the traditional DEA model as reviewed in [10].

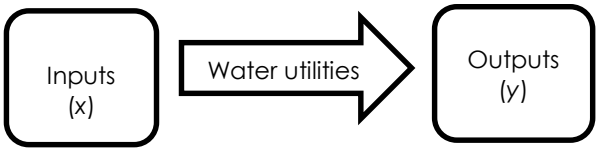


Figure 1 Traditional DEA on water utilities performance

Introduced by Charnes et al. [15], DEA is a model for measuring the relative efficiencies of a set of decision making units (DMUs). DEA deals with multiple inputs and outputs in a single integrated model to identify the best practice frontier for benchmarking and provides specific targets for improvement.

The standard DEA model will assume DMU as a one-stage production process that will turn input to the output. However, there are a large number of studies through research focuses on the evaluation of efficiency in multistage production process. Examples that can be seen is where the output of several stages has been set as intermediate products and used as either input to another level or as external output of the production process or both.

Among the first to deal with efficiency assessments in such processes was Färe and Grosskopf as in [16]. They treated the efficiency assessments as a network activity analysis model. It is an architecture of a two-stage production process whereby this process assumes the external inputs during the first stage of the process are converted to a several intermediate measures. Later on it is used again as inputs in the second stage to generate the concluding outputs.

In the water sector, there has also been a lot of research done using the standard DEA model and its variations. But the model used does not emphasize the relative internal structure of the steps characterize the operational performance of the water sector. As mentioned earlier, water supply services operations can be described in a two-stage link composition, where the outputs from the water treatment process become the inputs to the water distribution process, the recent paper proposed to employ two-stage Network DEA model for water utilities performance assessment.

Conventional benchmarking focused on the produced water and at the same time it ignores the loss of water when the water is distributed to the customers (NRW). There are only a few studies that have used NRW as an indicator of technical quality of this water service. But in those studies, the NRW has been considered as an input factor in the performance evaluation [14].

Picazo-Tadeo otherwise in his study took into account the loss of water as an undesirable output [14]. His research has used a different approach under the framework of the DEA model, namely the directional distance function (DDF) proposed by Chung et al. [17]. DDF serves to measure efficiency while merging undesirable output. This approach allows the desired output to be increased, while the undesired output is declining at the same time [17].

Kumar [18] also employed DDF to measure the performance of 20 urban Indian water utilities and concluded that benchmarking must credit utilities for improvements in service delivery and also for a reduction in unaccounted for water (UFW), another term for NRW. Figure 2 shows an illustration of water utility's performance using the DDF model as employed in [14] and [18].

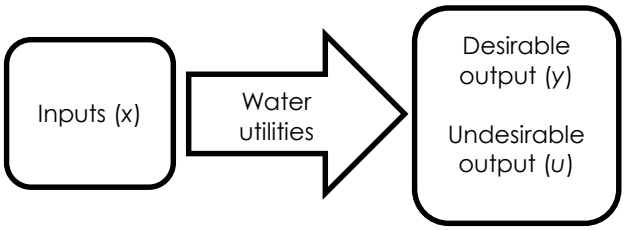


Figure 2 DDF Model of water utilities performance

While in Malaysia, most of the studies on water utility's performance have used the performance indicators approach such as in [2] and [19]. Mohammad Salleh [13] has argued the percentage of NRW as performance indicator that has been used widely in Malaysian water industry is not practical to evaluate the efficiency. Nevertheless, most studies on the efficiency of water utilities, especially in Malaysia have adopted the existing DEA. But mostly exclude the NRW factor [20], or NRW is considered not suitable as a standard input element in their performance evaluation conducted [8,13]. Summaries of some previous research on water sector performance measurement are as in Table 1. In contrast to the recent studies, a two-stage DEA model incorporating undesirable output measures is proposed to evaluate the performance of water utilities in Malaysia.

In addition, the new indicators to measure the efficiency and effectiveness of the water utility can be established simultaneously from the proposed two-stage DEA model in this study. The idea is based on Fielding [21] which developed the indicators that separate the measure of technical efficiency, service effectiveness and technical effectiveness of a public transit system. Fielding [21] defined the ratio of production to factor as technical efficiency, then, the ratio of consumption to production as service effectiveness and the ratio of consumption to production as technical effectiveness. The illustration of this concept shown in Figure 3.

Then, the concept by [21] is followed by Yu [22] and Chiou et al. [23]. They [22-23] modified the joint performance measurement concept by Fielding [21] into a two-stage network framework. Yu [22] employed Network DEA model to assess the technical efficiency, service effectiveness, and technical effectiveness of 40 global railways. The study [22], allowed a depiction of both production and consumption technologies in a joint framework that can be employed to estimate the three performance measures at the same time. Yu [22] defined efficiency measures as the relationship between resource input and produced output. While service effectiveness measure represents the relationship between producing services and services consumed. As for technical effectiveness, it represents the relationship between inputs and services consumed. Performance dimension of Yu's model formed a two-stage network DEA, which linked to the production process and consumption process. In fact, Yu [22] also incorporated environmental factors as undesirable output in the model.

While, Chiou et al. [23] used the integrated DEA approaches as a joint measurement of efficiency and effectiveness for non storable commodities as in case study of 39 intercity bus companies in Taiwan. The models, analyze the overall performance of non storable commodities under constant and variable returns to scale technologies.

Fielding [21] concept is composed of a sub-processes connected in series that is similar to the concept of a two-stage network DEA approach. The 'factors' in [21] can be characterized as input to produce the 'production' in the first stage, and the same 'production' is used to generate the 'consumption' in the second stage. Thus, the 'production' can be categorized as intermediate measures while 'consumption' can be described as the final output.

Table 1 Previous research on water sector performance assessment

Author	Country/Area	Approach	Remarks
Ching [2]	Malaysia	Performance Indicators	NRW as KPI
Munisamy [8]	Malaysia	DEA	NRW as input factor
Romano and Guerrini [10]	Italy	DEA	NRW excluded
Byrnes et al. [11]	USA	DEA	NRW excluded
Mohammad Salleh [13]	Malaysia	DEA	Reciprocal of NRW as output factor
Picazo Tadeo et al. [14]	France	DDF	UFW as undesirable output
Kumar [18]	India	DDF	UFW as undesirable output
Lee and Lee [20]	Malaysia	DEA	NRW excluded

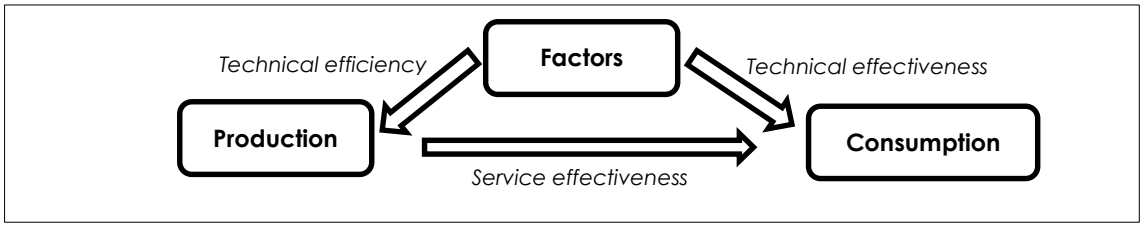


Figure 3 Joint performance measurements concept, revised from Feilding [21]

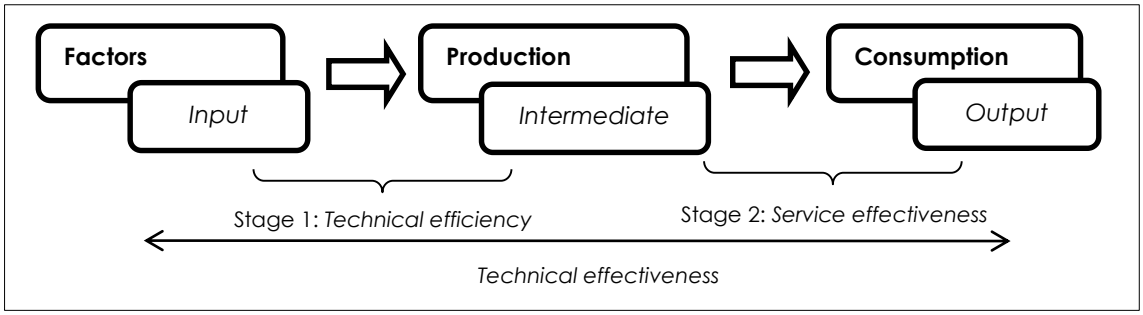


Figure 4 Two-stage joint performance measurements concept, revised from Feilding [21], Yu [22] and Chiou et al. [23]

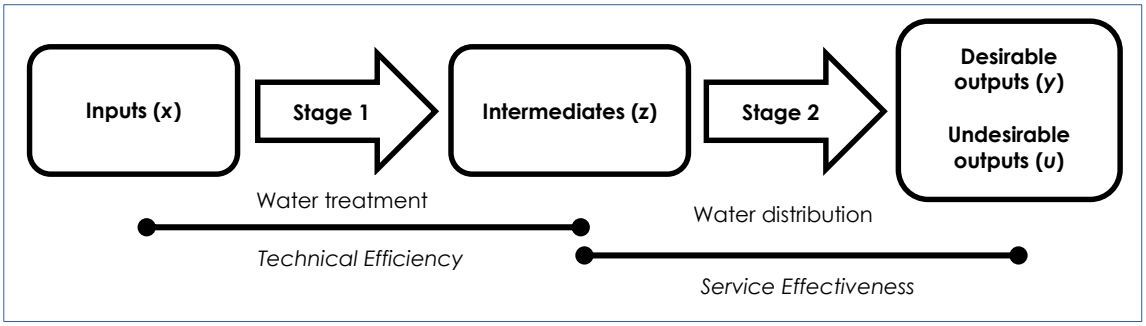


Figure 5 Conceptual framework for water utilities two-stage performance with undesirable output

Both Yu [22] and Chiou et al. [23] revised the Fielding [21] concept as a two-stage Network DEA approach as depicted in Figure 4. The joint framework concept by these studies [21-23], is similar to the concept of water supply services. The production process represents the water treatment process to produce clean water. While the consumption process is represented by the water distribution process where the clean water produced is consumed by the client. Hence, the present proposed two-stage DEA model allows us to establish the new performance indicators (efficiency and effectiveness measures) for Malaysian water supply services as shown in Figure 5.

4.0 PROPOSED METHODOLOGY

The proposed methodology in this paper will give a different perspective from the existing water sector performance assessment that considered the internal structure of water supply service operations, which link by two sub-process with the presence of undesirable output. In fact, the two-stage Network DEA concept was proposed and tested in our early work [24], but without involving the undesirable output factor. For this study, inputs in the first sub-process (water treatment process) for this network models are used to generate intermediate outputs and then become inputs in the second sub-process (water distribution process) where the final outputs produced involve both desirable and undesirable outputs as depicted in Figure 5. Furthermore, this model allows us to establish a different view of performance indicators of efficiency and effectiveness measures for the Malaysian water industry.

The proposed methodology in this paper will be carried out in several phases. The first phase is on selecting the factor variables involved in both stages. Next, the new performance measures are established through the proposed two-stage DEA model. Lastly, the optimal level for potential reduction of NRW will be determined and new performance indicators of technical efficiency and service effectiveness of Malaysian water industry will be established

simultaneously. Figure 6 demonstrates the development structure of the proposed model.

4.1 Phase 1: Selection of Factor Variables and Data Collection

Studies that applied DEA in water utility performance measurement presented several similarities in factor variable selection. Since none of the articles applied the two-stage DEA model to study water utilities, a new choice of input, intermediate, and output factors needs to be defined according to the two processes involved. Input factors should be selected by the factor that are used to generate intermediate outputs in the water treatment process. The same intermediate outputs, then become inputs in the next stage, which is the process of distributing the clean water to the customers. The final outputs were produced from the distribution process involve the desirable and undesirable outputs. The specific undesirable output of this study is NRW so that the optimal level for potential reduction of NRW can be determined. The data for all the chosen variables will be obtained from the Malaysian Water Industry Guide published by the Malaysia Water Association (MWA).

4.2 Phase 2: Model Formulation

The proposed conceptual framework as in Figure 5 is designed to establish the new performance measures for Malaysian water industry. At this phase, the model is formulated by integrating the two-stage DEA model and model which involve undesirable output such as DDF. The combination of the model needs to be formulated and then, the applicability and supremacy of the proposed model should be tested. This new performance measure will assess not only the overall performance of the water utility, but will determine the individual efficiency measures for both stages (water treatment and water distribution processes). This model should help in scrutinizing the sources of poor performance, whether is from either of the two processes or both. Furthermore, in line with the intention to reduce the NRW level, the issue is incorporated as an undesirable output in the proposed model.

4.3 Phase 3: Establishment of Proposed Performance Measures

The proposed model is not only resulting in the new performance benchmarking tool for evaluating the efficiency of Malaysian water utilities, but, the optimal level for potential reduction of NRW can also be determined from the analysis.

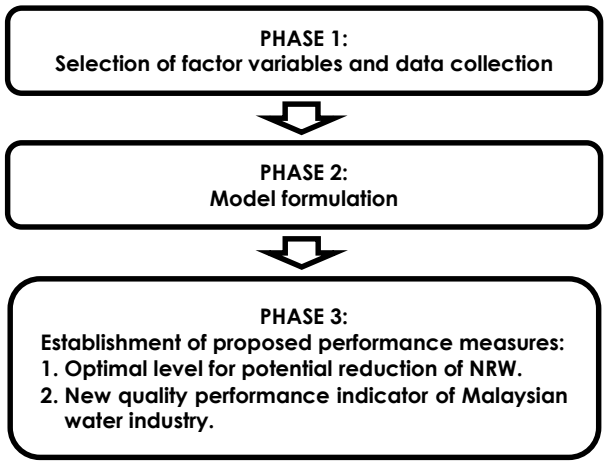


Figure 6 Development structure of the proposed study Furthermore, based on prior literatures [21-23],

The new quality performance indicators of Malaysian water industry, which are efficiency and effectiveness measures, can be established concurrently from the same proposed model (refer Figure 3, 4, and 5).

5.0 CONCLUSION

This study is currently in a preliminary stage and the task for phase 1 is almost complete. The next task is to proceed with the most crucial phase 2, where the development of the proposed efficiency model for performance measurement of the water sector. This new proposed model is the improvised version of the existing DEA efficiency measures where a two-stage DEA model is combined with models that include the undesirable output factor.

Once the proposed model is built up, the applicability and supremacy test will be performed. Analysis of the model is expected to guide the management of the water utilities in improving their business practice, especially in finding the best initiative to reduce the NRW level.

Finally, the new performance indicators derived from this study (efficiency and effectiveness measures), are practical and can be implemented in the Malaysian context in order to ensure the performance of the water supply service is always at a satisfactory level.

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