

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

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

NORBAIZURA KAMARUDIN¹, WAN ROSMANIRA ISMAIL² & MUHAMMAD AZRI MOHD¹

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 cekat juga boleh ditentukan.

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

References

- Cawangan Bekalan Air Jabatan Kerja Raya Malaysia. 1995. Laporan Industri Air Malaysia 94/95.
- Charnes A., Cooper W.W. & Rhodes E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* **2**(6): 429-444.
- Chung Y. H., Färe R. & Grosskopf S. 1997. Productivity and undesirable outputs: A directional distance function approach. *Journal of Environmental Management* **51**(3): 229-240.
- Fare R. & Grosskopf S. 2000. Network DEA. *Socio-Economic Planning Sciences* **34**(1): 35-49.
- Fukuyama H. & Weber W. L. 2010. A slacks-based inefficiency measure for a two-stage system with bad outputs. *Omega* **38**(5): 398-409.
- Garcia S. & Thomas A. 2001. The structure of municipal water supply costs: application to a panel of French local communities. *Journal of Productivity Analysis* **16**(1): 5-29.
- Hasnul M.S. 2000. Evaluation of non-revenue water and leakage in public and private water supply systems. Unpublished PhD Thesis. Heriot-Watt University, Edinburgh.
- Huang C., Ho F. N. & Chiu Y. 2014. Measurement of tourist hotels' productive efficiency, occupancy, and catering service effectiveness using a modified two-stage DEA model in Taiwan. *Omega* **48**: 49-59.
- Kao C. 2017. *Network Data Envelopment Analysis: Foundations and Extensions*. Boston, MA: Springer.
- Kim C. T. 2012. *Malaysian Water Sector Reform: Policy and Performance*. The Netherlands: Wageningen Academic Publishers.
- Kingdom B., Liemberger R. & Marin P. 2006. The challenge of reducing non-revenue water in developing countries. How the private sector can help: A look at performance-based service contracting. Water Supply and Sanitation Board Discussion Paper Series, Paper No. 8. <https://siteresources.worldbank.org/INTWSS/Resources/WSS8fin4.pdf>. (8 November 2018)
- Kumar S. 2010. Unaccounted for water and the performance of water utilities: An empirical analysis from India. *Water Policy* **12**(5): 707-721.
- Lambert D., Dichev D. & Raffiee K. 1993. Ownership and sources of inefficiency in the provision of water services. *Water Resources Research* **29**: 1573-1578.
- Norbaizura K., Wan Rosmanira I. & Mohd M. A. 2015. Malaysian Water Utilities Performance Using Two-Stage DEA. *International Journal of Applied Physics and Mathematics* **5**(1): 60-66.
- Norbaizura K. & Wan Rosmanira I. 2016. Establishment of performance indicators for Malaysian water utilities with the presence of undesirable output. *Jurnal Teknologi* **78**(4-4): 99-105.
- Norbaizura K., Wan Rosmanira I. & Mohd M. A. 2018. Network Russell-based measure with undesirable outputs: Empirical study on Malaysian water utilities' performance. In *AIP Conference Proceedings* 1974(1), p. 040024. AIP Publishing.
- Picazo-Tadeo A. J., Sáez-Fernández F. J. & González-Gómez F. 2008. Does service quality matter in measuring the performance of water utilities? *Utilities Policy* **16**(1): 30-38.
- Romano G. & Guerrini A. 2011. Measuring and comparing the efficiency of water utility companies: A data envelopment analysis approach. *Utilities Policy* **19**(3): 202-209.
- Tone K. 2001. A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research* **130**(3): 498-509.
- Tone K. & Tsutsui M. 2009. Network DEA: A slacks-based measure approach. *European Journal of Operational Research* **197**(1): 243-252.
- Van den Berg C. 2015. Drivers of non-revenue water: A cross-national analysis. *Utilities Policy* **36**: 71-78.
- Vilanova M. R., Filho P. M. & Perrella Balestieri J. A. 2014. Performance measurement and indicators for water supply management: Review and international cases. *Renewable and Sustainable Energy Reviews*.
- Zhou P., Ang B. W. & Poh K. L. 2006. Slacks-based efficiency measures for modeling environmental performance. *Ecological Economics* **60**(1): 111-118.
- Zyoud S. H., Kaufmann L. G., Shaheen H., Samhan S. & Fuchs-Hanusch D. 2016. A framework for water loss management in developing countries under fuzzy environment: Integration of Fuzzy AHP with Fuzzy TOPSIS. *Expert Systems with Applications* **61**: 86-105.

¹Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA
40450 Shah Alam
Selangor DE, Malaysia
E-mail: norbaizura@tmsk.uitm.edu.my*,
azri@tmsk.uitm.edu.my

²School of Mathematical Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 UKM Bangi
Selangor DE, MALAYSIA
E-mail: wrismail@ukm.edu.my

* Corresponding author