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Assessing the quality of service to customers provided by water utilities: A synthetic index approach

María Molinos-Senante[a,b,c,*], Trinidad Gómez[d], Rafael Caballero[d], Ramón Sala-Garrido[e]

[a] Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Chile
[b] Facultad de Arquitectura e Instituto de Estudios Urbanos y Territoriales, Pontificia Universidad Católica de Chile, El Comendador 1916, Santiago, Chile
[c] Centro de Desarrollo Urbano Sustentable CONICYT/FONDAP/15110020, Av. Vicuña Mackenna 4860, Santiago, Chile
[d] Departamento de Economía Aplicada (Matemáticas), Universidad de Málaga, Campus El Ejido, 29071, Málaga, Spain
[e] Departamento de Matemáticas para la Economía y la Empresa, Universidad de Valencia, Campus dels Tarongers, 46022, Valencia, Spain

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ABSTRACT

Currently, water and sewer companies face the challenge of improving their quality of service to customers (QSC). Performance indicators are essential to monitor and benchmark the QSC of water companies; however, individual indicators do not provide a holistic evaluation of the quality of water and sewer services provided to customers. This study proposes an innovative QSC index based on distance-function techniques that makes it possible to compare changes in the QSC of water companies among locations and temporal periods. A case study assesses changes in QSC for a sample of Chilean water and sewer companies from 2007 to 2014. The results show that in spite of the efforts made by the water regulator, QSC has remained almost constant over a number of years, with 2010 having the best performance. The methodology proposed in this study is useful for water regulators to benchmark water companies when developing policies that prompt QSC improvements.

1. Introduction

The formulation and adoption of international policies, such as the Millennium Development Goals by United Nations, have significantly increased access to water and sewer services. Globally, the proportion of people using improved drinking-water sources increased from 76% in 1990 to 91% in 2015, while the proportion of people using basic sanitation increased from 54% to 68%. Moreover, in developed countries, access to water and sewer services is almost universal (Unicef and WHO, 2015). In this context, an important current challenge is to improve the sustainability and quality of water and sewer services to customers (Maziotis et al., 2016).

Because water and sewerage companies (WaSCs) generally operate as natural monopolies (Hyman and Hyman, 2001), water regulators are responsible for monitoring their compliance with quality standards. By benchmarking the quality of service to customers (QSC) that WaSCs provide, regulators could create incentives for regulatory compliance and improvements (Pinto et al., 2016). Moreover, in such countries as England and Wales, benchmarking is used to set water tariffs (Triebs et al., 2016). Benchmarking involves performance comparisons, usually based on performance indicators (PIs). As reviewed by Haider et al. (2014) and Nogueira Vilanova et al. (2015), water agencies and regulators have defined a large number of PIs to evaluate the performance of WaSCs, including QSC issues.

Previous studies (e.g., Andersen and Fagerhaug, 2002; Alegre et al., 2006) have shown the usefulness of PIs for assessing the performance of WaSCs. However, this approach has the notable shortcoming of not allowing for holistic assessments of the problem (Pinto et al., 2016). Thus, it is difficult to interpret a set of PIs, given that they do not all have the same importance (Molinos-Senante et al., 2016a). A possible way to solve this limitation is to aggregate the PIs into a synthetic indicator that reflects the multidimensional nature of the performance assessment (Nafi et al., 2015).

The literature illustrates that in the framework of water and sewer industry, synthetic indicators have primarily been developed to evaluate the overall performance of WaSCs and their sustainability. To this end, several methods have been employed, such as data envelopment analysis (DEA) (Romano and Guerrini, 2011; Guerrini et al., 2015), analytic hierarchy processing (Molinos-Senante et al., 2015), goal programming synthetic indicators (Molinos-Senante

* Corresponding author at: Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Chile.
E-mail addresses: mmolinos@uc.cl (M. Molinos-Senante), trinidad@uma.es (T. Gómez), rafael.caballero@uma.es (R. Caballero), ramon.sala@uv.es (R. Sala-Garrido).

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et al., 2016a), and additive aggregation (Marques et al., 2015). Despite the widespread development of synthetic indicators to evaluate holistically the performance of WaSCs, to the best of our knowledge, only two studies have used this approach to assess the quality of service provided by water utilities. Karnib (2015) aggregated four quality of service indicators (network coverage, water consumption, continuity of water supply and water quality) into a single quality of service index using a fuzzy inference approach. His empirical application focused on four areas in Lebanon from 2000 to 2014. In the second study, Pinto et al. (2016) proposed a methodological approach based on the ELECTRE TRI-nC method to aggregate a set of quality of service indicators into a quality of service index. In a case study of the Portuguese water industry, sixteen indicators (grouped into three categories: protection of user interest, operator sustainability and environmental sustainability) were aggregated into a single index.

It should be highlighted that neither of the studies by Karnib (2015) or Pinto et al. (2016) focused specifically on QSC since their assessments involved other quality of service indicators not related to customers. However, as WaSCs regulations consolidate and the industry becomes technologically mature, QSC issues become even more relevant. English and Welsh water regulators have introduced incentives for WaSCs to improve their QSC (Ofwat, 2010). Moreover, several studies (Kumar and Managi, 2010; Molinos-Senante et al., 2016b) have shown that ignoring QSC when assessing the efficiency of WaSCs penalizes companies that provide better QSC, since the "low-cost" and low-quality WaSCs are rated as efficient. Hence, in order to change the behavior of WaSCs and increase their motivation to improve QSC and to support decision-making of water regulators, it is important to evaluate QSC holistically.

In this study, we therefore proposed an innovative QSC Index (QSCI) based on the concept of distance functions (Shephard, 1970), since it allows for aggregating multiple QSC indicators into a single QSCI (Whittaker et al., 2015). The case study focused on 19 main Chilean WaSCs during 2007–2014. Estimating QSCIs allowed us to assess changes in QSC for each WaSC from 2007 to 2014.

Although there have been several empirical studies that used synthetic indicators to evaluate the performance and sustainability of WaSCs holistically, none of them focused specifically on QSC issues. This study, therefore, presents a pioneering and novel approach to assess the quality of water and sewer service to customers across years using a synthetic index. The proposed QSCI could be very useful for water regulators: (i) to support decision making when introducing incentives for WaSCs to improve QSC; (ii) to monitor global QSC trends in WaSCs; and (iii) to verify the effectiveness of existing policies. In other words, measuring QSC holistically will allow water regulators to make critical decisions and, if needed, implement corrective measures to improve QSC over time.

2. Methodology

The proposed methodology for evaluating changes in QSC was based on the concept of metric benchmarking and the water quality index introduced by Whittaker et al. (2015). Metric benchmarking enables companies to monitor their performance over time and compare it to the performance of other companies (Nogueira Vilanova et al., 2015). The water quality index proposed by Whittaker et al. (2015) is based on the use of distance-function techniques to aggregate multiples variables into a single index. However, these authors neither compared nor evaluated water quality among multiple locations; rather, they applied the water quality index over time in a single location. To overcome such limitations, the methodological approach proposed by Whittaker et al. (2015) was extended in this study to evaluate and compare QSC across years of a set of water companies.

Following the economic production theory (Färe et al., 2004), a set of water companies that have the technology for a given production process is defined as

$$T = \left\{(x, y) : xcanproducey\right\} \tag{1}$$

where $x \in \Re^N$ represents the vector of inputs and $y \in \Re^M$ the vector of outputs. Given that the objective of water companies is to maximize QSC, following Lovell and Pastor (1999) and Whittaker et al. (2015), service quality indicators (e.g., water supply continuity, water supply pressure, wastewater treatment quality) are the outputs to be maximized, and all inputs are set equal to one.

The Shephardís distance function (Shephard, 1970) estimates the distance from the outputs vector to the benchmark, which in this case study is the water company with the best QSC:

$$D_o(y, 1) = \min\left[\theta : \left(1, {}^{y}\!/\!_{\theta}\right) \varepsilon T\right] \tag{2}$$

This output distance function characterizes the output possibility set using the maximum equiproportional expansion of all outputs consistent with the technology set T. In this study, the output distance function provides information about the potential improvement of the set of quality of service indicators for each water company, compared against the water company with the best quality of service.

Following the pioneering approach by Caves et al. (1982), a quantitative index can be calculated as

$$Q\left(y^j, y^k\right) = \frac{D_o\left(y^j, 1\right)}{D_o\left(y^k, 1\right)} \tag{3}$$

where y^j and y^k are two output vectors to be compared. As highlighted by Whittaker et al. (2015), this index (Eq. (3)) is especially useful for comparing changes in the performance of production units (water companies) among locations and temporal periods. Hence, in this study, we focused on assessing changes over time in the QSC of a set of WaSCs. In doing so, we measured the ratio of two distance functions (Eq. (3)) using period t technology as a reference (Molinos-Senante et al., 2014). However, the choice of the reference frontier can be either that of time period t or that of time period $t+1$. In order to avoid an arbitrary selection between base years, the QSCI was defined as the geometric mean of both periods (Färe et al., 1994):

Accordingly, the QSCI is defined as (Eq. (4)):

$$QSCI(y_t, y_{t+1}) = \sqrt{\frac{D_o^t(y_{t+1}, 1)\, D_o^{t+1}(y_{t+1}, 1)}{D_o^t(y_t, 1)\, D_o^{t+1}(y_t, 1)}} \tag{4}$$

The QSCI is interpreted as follows: (i) QSCI > 1 indicates an improvement in the service quality over time; (ii) QSCI < 1 indicates a worsening of service quality across years analyzed; (iii) QSCI = 1 indicates that the service quality to customers has not changed.

Following previous studies (Graham, 2009; Ali and Klein, 2014; Molinos-Senante et al., 2016c), the distance functions in Eq. (4) were calculated using a DEA method based on a linear programming approach. One of the main advantages of DEA models is that the weights applied to each indicator when constructing the QSCI are endogenous, i.e., they are determined intrinsically when the optimization problems are solved (Cooper et al., 2011). This means that weights are not externally assigned or subject to regulator bias, but are instead calculated from the data themselves (Deilmann et al., 2016).

The change in the QSC of each WaSC is computed, following Caves et al. (1982) and Lovell and Pastor (1999), by solving the