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# Performance evaluation of water supply service providers: a review with a focus on Brazil

Heloisa Pimpão Chaves [a,*], Thelmo de Carvalho Teixeira Branco Filho[b], Rui Cunha Marques [c] and Tadeu Fabrício Malheiros[d]

[a] Exact and Technological Sciences Center, Federal University of Acre, Campus Universitário - BR-364 km 4, Distrito Industrial, Rio Branco-AC, Brazil
[b] Faculty of Law, Federal University of Rio Grande, Km 8 Avenida Itália Carreiros, Rio Grande-RS, Brazil
[c] Lusófona University, RCM2+, Campo Grande 376, Lisboa, Portugal
[d] School of Public Health, University of São Paulo, Avenida Doutor Arnaldo, 715, São Paulo-SP, Brazil
*Corresponding author. E-mail: heloisa.chaves@ufac.br

HPC, 0000-0002-8135-6417

## ABSTRACT

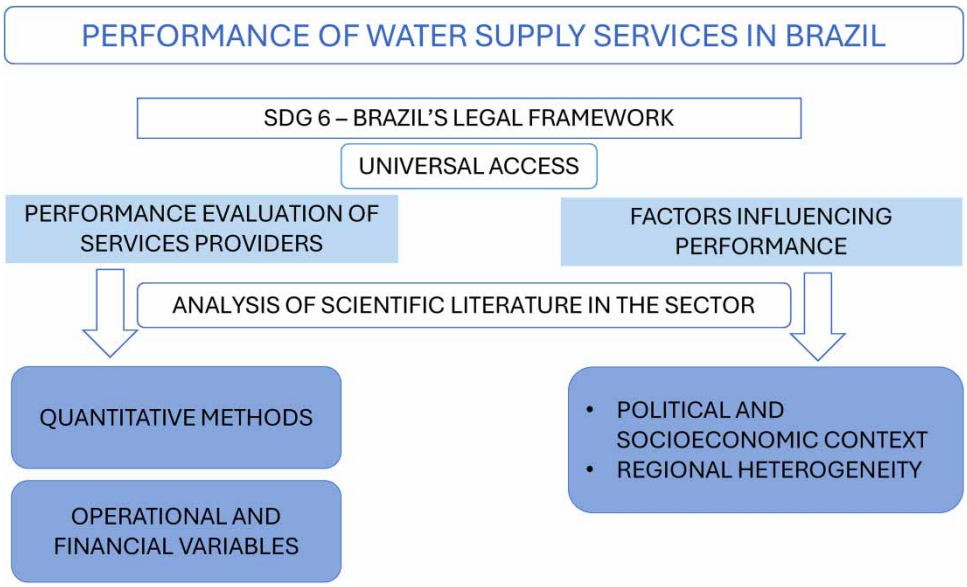
This study aimed to analyze recent scientific literature concerning performance evaluation in the water supply sector, focusing on Brazil, and investigate factors that could influence its performance. For this purpose, we conducted a systematic literature review, following a series of steps to identify approaches, methodologies, and contexts into which the studies were developed. The search revealed that the studies focused on different management models and market structure issues. In addition, they also showed that the performance of service providers can be influenced by political and socioeconomic context and geographic aspects. A gap was identified concerning the qualitative studies since most used econometric methods mainly aimed at technical and financial efficiency. Also, social and service user perspectives received limited academic attention. To face the challenges in water provision in Brazil, tools, such as those related to performance evaluation, are essential for sufficient system management and can guide decision-makers and service providers.

**Key words:** Brazil, management, performance evaluation, water supply

## HIGHLIGHTS

- Quantitative methods are the most widely used in performance analysis.
- Social and user aspects were little explored in the research.
- The performance of service providers can be influenced by factors such as political and socioeconomic context and geographic aspects.

## GRAPHICAL ABSTRACT




## 1. INTRODUCTION

Access to drinking water is a human right recognized by the United Nations, 'a condition for the full enjoyment of life and other human rights' (UN 2010). As part of a city's infrastructure, water supply and sanitation services are of paramount importance for public health, the environment, and economic development and are strictly linked to the concept of sustainable development, which, according to the report 'Our Common Future,' known as Brundtland Report, consists of 'development that meets present needs, without compromising the ability of future generations to meet their own needs.'

In 2000, the United Nations Millennium Summit brought world leaders together to discuss and set targets for an equal development. Thus, the Millennium Development Goals (MDGs) were established to combat poverty and hunger and improve access to education, among others. The MDGs encouraged countries to look for ways to reduce inequalities and thus achieve the set targets.

Recognizing the success of the MDGs and acknowledging the need to develop a joint agenda at the global level to achieve a more sustainable development model, the 17 Sustainable Development Goals (SDGs) were established in 2015 by the UN with ambitious goals to be met by 2030. The SDGs are interconnected to each other and seek an egalitarian development, considering everything from environmental to socioeconomic aspects. SDG 6 is intended to ensure the availability and sustainable management of water and sanitation for all. Goals 6.1 and 6.2 refer to universal and equitable access to safe drinking water and adequate sanitation and hygiene for all (UN 2015).

The SDGs are important in a scenario where 26% of the global population still does not have access to drinking water, corresponding to around 2 billion people (UN 2023). Tayyab *et al.* (2022) pointed out that water scarcity seriously threatens sustainable development and human well-being and is one of the main factors preventing the continuity of activities and economic growth.

Lack of access to water is also a reality for many Brazilians, especially those in extreme poverty. Studies based on information from the Consumer Expenditure Survey of the Brazilian Institute of Geography and Statistics (IBGE) show that 51.7% of the country's population below the poverty line did not receive water regularly – daily and in adequate quantity in 2018 (Instituto Trata Brasil 2021).

In Brazil, the water sector has experienced significant challenges. It has been the focus of political debates, especially about the approval and implementation of the new regulatory framework, Law No. 14026, enacted on July 15, 2020, constituting the so-called new Legal Framework for Basic Sanitation in Brazil, which amended several laws such as Law No. 11.445/2007 and Law No. 9.984/2000 (Brazil 2007, 2020; ANA 2022).

Among the changes brought by the new law, there are issues inherent to ownership, contracts, regulatory standards, and others (Brazil 2020). Besides, the law established in its Article 11-B the requirement that contracts for the provision of public

sanitation services must define universal access targets that guarantee the service of 99% of the population with drinking water and 90% of the population with sewage collection and treatment until December 31, 2033. This percentage refers to the population served by each provider.

In this context, the objective of this study is to conduct a systematic review to analyze recent scientific literature concerning performance evaluation in the water sector, with a focus on Brazil. We aim to investigate the approaches, methodologies, and contexts to which these studies are applied and identify factors that could influence performance.

Although other reviews have been developed in Brazil (e.g., Ensslin *et al.* 2015; Reis *et al.* 2017) they centered on bibliometric aspects, and our focus, in addition to compiling and updating the research developed in the area, is to identify aspects inherent to water management and supply that may explain the Brazilian context. To contribute to this field of knowledge, we intend to answer the following questions: (i) What methods are used to evaluate the performance of service providers? (ii) What variables have been used to measure performance? and (iii) What factors can influence performance?

After this brief introduction, the paper is organized as follows: Section 2 summarizes some essential concepts, Section 3 explains the methods used in the research, and Section 4 provides the results and discussions. Lastly, the conclusions and recommendations for future studies are presented.

## 2. MANAGEMENT AND PERFORMANCE IN THE WATER SECTOR

It is essential to clarify the definition of 'basic sanitation' in Brazil, which, according to the national legal framework, is the set of public services, infrastructure, and operational facilities for the drinking water supply, sanitation, urban cleaning, and solid waste management, and stormwater management (Brazil 2020). This study focuses on water supply, given the goals of universalization established in the legal framework, as well as the SDGs, especially SDG 6, of the United Nations.

The proper management of these services is supported by the fundamental principles defined by the legal framework, among which universal access and adequate service provision, completeness, coordination with other policies, efficiency and economic sustainability, transparency of actions, and safety, quality, regularity, and continuity (Brazil 2020) are essential.

However, the effectiveness of the current implementation of public policies is still far from placing Brazil among the countries with good performance in the sector (Leite *et al.* 2022). The situation of basic sanitation in Brazil presents worrying data concerning access to quality water and adequate sewage treatment. Data from 2021 show that almost 34 million are not supplied with treated water (MDR 2022).

Water service management in Brazil is defined by the aspects of planning, regulation, provision, inspection, and social control (Brazil 2020). According to Antunes (2011), adequate management is a critical issue that needs to be understood and investigated, allowing for a more efficient use of resources and investment.

Regarding the provision of services in Brazil, there are currently several management models. They are classified according to their legal status, such as direct administration, autarchy, mixed-capital company, public company, private company, and social organization. They can also be categorized according to coverage, which can be regional (providing several municipalities, bordering or not), micro-regional (providing fewer municipalities, bordering or not), and local providers (serving a single municipality). There are also providers classified in line with the type of service provided: water supply, sanitation, or both (MDR 2022).

Several variables, including exogenous variables such as the scope of activities provided, ownership, regulation, purchased water, surface water, peak factor, customer density, and residential customers, can influence service providers' performance (Carvalho & Marques 2011). Understanding these factors is essential for establishing guidelines and aiding decision-making. In this context, performance assessment models are essential tools (Ensslin *et al.* 2015).

Measuring and evaluating the performance of water and sanitation services play a vital role in guaranteeing the effectiveness and efficiency of these services. Initially, it is worth mentioning the concept of these two fundamental dimensions of performance, as defined by Neely (2005), with effectiveness being the way in which the customer's demands are met and efficiency being the measure of how economically the company's resources are used in providing a certain level of customer satisfaction. The author then conceptualizes performance measurement as the process of quantifying the efficiency and effectiveness of action (Neely 2005).

Thus, water and sanitation services need to evaluate and measure performance for various reasons, including improving management, efficiency, communication with customers/users, self-promotion, and the requirements of regulatory authorities (Seppälä 2015).

Baptista & Alegre (2009) defined performance evaluation as an approach that allows the evaluation of the efficiency or effectiveness of a process or activity through the production of performance measures. Alegre *et al.* (2009) pointed out that performance evaluation became a common practice, especially from the 1990s onwards, with different objectives and various methods and techniques.

## 3. METHODS

The instrument used to map published studies on the topic was the systematic literature review (SLR), which, according to Levy & Ellis's (2006) definition, consists of a sequence of steps to collect, know, understand, apply, analyze, synthesize, and assess the quality of existing literature to provide a solid foundation for a research topic or method.

The SLR is characterized by following a protocol, which other researchers can reproduce. This SLR followed the 17-item checklist proposed by PRISMA-P 2015 (Moher *et al.* 2015), which is categorized into three main sections: administrative information (title, registration, authors, amendments, and support), introduction (rationale and objectives), and methods (eligibility criteria, information sources, search strategy, study records, data items, outcomes, prioritization, risk of bias in individual studies, synthesis, meta-bias(es), and confidence in cumulative evidence).

These items were followed and adapted for the purpose of this study, covering all relevant information. The study was conducted in three phases, as can be seen in Figure 1. The administrative information and introduction items were defined in Phase 1, and the methods were described in the other Phases (2 and 3).

The protocol was defined in Phase 1. The systematic review presents studies carried out between 2000 and 2023, comprising pertinent milestones of Brazil, such as the publication of Law No. 11.445/2007 and, more recently, its update through Law No. 14.026/2020.

The databases defined were Scopus and Web of Science, which have been consolidated in developing literature reviews (Galvão & Ricarte 2019; Paul & Criado 2020), as well as Google Scholar, which, according to Galvão & Ricarte (2019), is recommended for Latin American themes and those related to local communities.

The search used terms and logical operators that varied according to the databases. The definition of search strings was made with the combination of keywords linked to the research theme, resulting in these keywords: *performance analysis, performance evaluation, performance assessment, management, benchmarking, performance indicators, efficiency measurement, water supply and sanitation, drinking water*, and *water sector*.

The following inclusion criteria were defined: (i) related to management and performance analysis of the water sector in Brazil and (ii) papers published in journals, books, and doctoral theses.

Phase 2 was carried out in five steps, as follows. Initially, in STEP 1, a search was conducted using the selected search engines, resulting in 299 papers. In STEP 2, these papers' titles, abstracts, and keywords were carefully reviewed to apply the inclusion criteria, which narrowed the selection down to 38 papers. So, duplicate papers were identified and removed (STEP 3), resulting in 29 papers.

Following this, in STEP 4, these papers were read in full, and 15 studies cited by the authors were identified. These studies possibly used different keywords and thus did not appear in the initial search. They were also included in the SLR. Therefore, STEP 5, the final list of studies read in full included 44 papers, was carried out using the qualitative data analysis software MAXQDA 24, which allows for the coding of readings, the grouping of publications, word frequency analysis, and other functionalities, ensuring a comprehensive understanding and analysis of the literature.

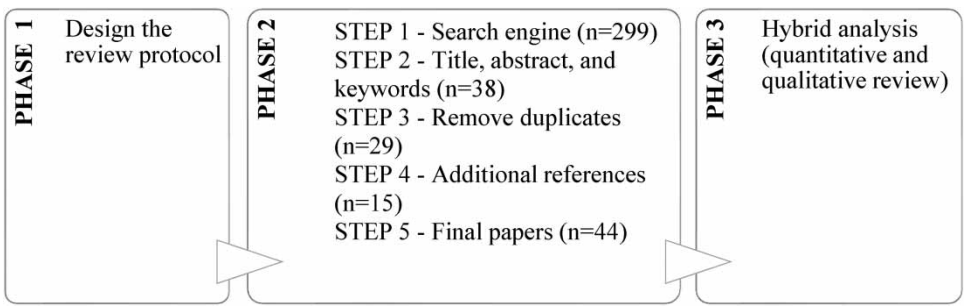



**Figure 1** | Stages of research (*n* represents the number of papers).

The last phase of the SLR, Phase 3, consisted of analyzing and summarizing the main results obtained regarding the water providers' performance and analysis of results concerning the Brazilian sector. The research methods used were hybrid, including quantitative and qualitative analyses. The quantitative methods indicated the date of publication, the name of the journals of publication, and the number of publications by journal. The qualitative analysis made it possible to detail the methodologies, variables, and indicators used in the research and list the factors that can influence the performance of water providers.

## 4. RESULTS AND DISCUSSION

### 4.1. Quantitative review

The database search was carried out in November 2023, and 299 results were found, most of which were in the Web of Science database (162 results). After applying the inclusion criteria, 44 publications related to the performance evaluation of water providers were selected in the following steps.

The oldest publication in the period sought was the work of Tupper & Resende published in 2004, in volume 12 of the journal *Utilities Policy*. Figure 2 displays the publications by year. The year with the most publications was 2019.

Regarding the journals of publication, the Journal *Utilities Policy* stands out with seven publications, followed by the *Revista Engenharia Sanitária e Ambiental* with five publications, as seen in Table 1.

### 4.2. Study's characteristics

The review includes studies on water sector performance assessment in Brazil at various scales and using different methodologies (see Table 2 and Appendix A). Research in this field has exhibited a higher tendency toward using quantitative approaches rather than qualitative analyses. These results are in line with the findings of Reis *et al.* (2017).

Vilanova *et al.* (2015), Ensslin *et al.* (2015), Reis *et al.* (2017), and Cetrulo *et al.* (2019) conducted similar literature reviews that focused on the water and sanitation sector.

Vilanova *et al.* (2015) reviewed and contextualized the literature on performance measurement and indicators for the water sector. They presented international cases, including Brazil's National Sanitation Information System (SNIS). Ensslin *et al.* (2015) focused their research on developing a portfolio of scientific literature on performance evaluation in water and sanitation companies. Fourteen relevant papers on the subject were identified. Reis *et al.* (2017) also carried out a bibliometric

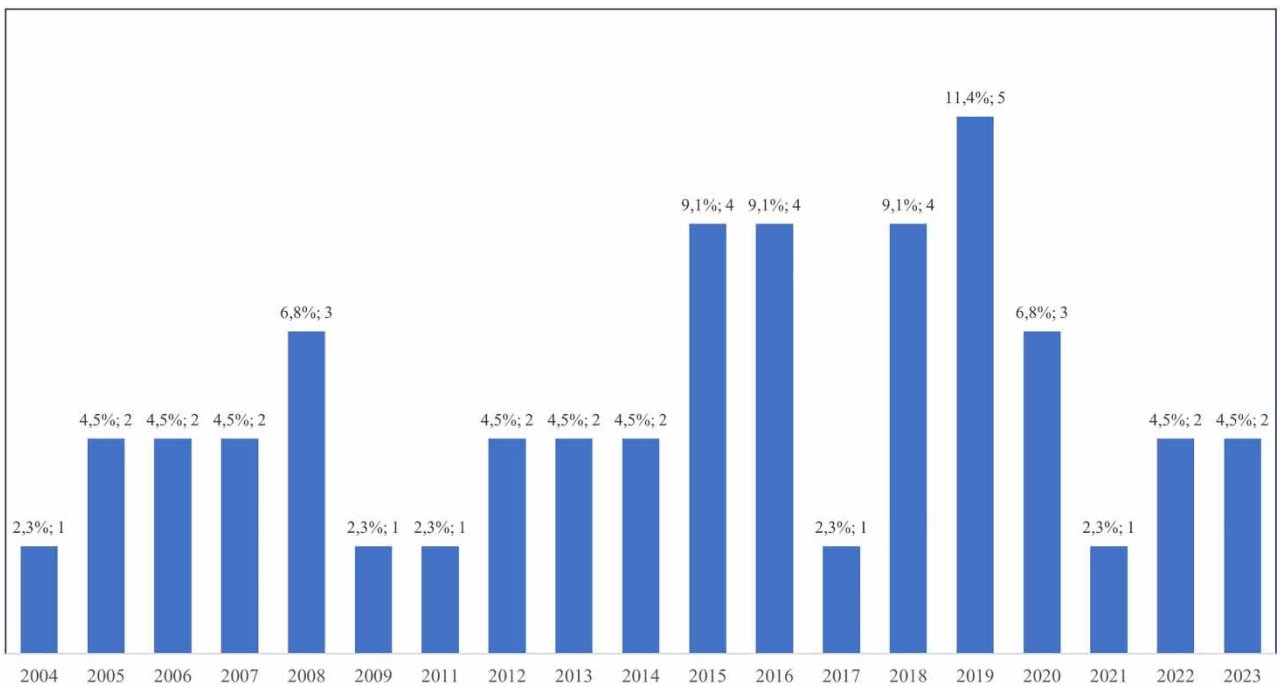



**Figure 2** | Publications per year.

**Table 1** | Number of publications per journal

| Journal | Number of publications |
|---|---|
| *Utilities Policy* | 7 |
| *Engenharia Sanitária e Ambiental* | 5 |
| *Water Policy* | 3 |
| *Socio-Economic Planning Sciences* | 3 |
| *Planejamento e Políticas Públicas* | 2 |
| *Others*[a] | 24 |
| **Total** | **44** |

[a]Others refer to another 24 journals that published one paper each.

**Table 2** | Classification of publications by the methodological approach

| Approach | Quantity |
|---|---|
| Bibliographic reviews | 4 |
| Qualitative | 6 |
| Quantitative | 30 |
| Hybrid (qualitative–quantitative) | 4 |

study on Brazil and international publications about water and sanitation; they mapped and analyzed the content of publications between 1994 and 2015. The literature review conducted by Cetrulo *et al.* (2019) focused on quantitative studies in developing countries, including Brazil.

In our study, differing from previous reviews, we sought to explore and synthesize the data from research on the performance of water supply service providers in Brazil to identify the characteristics of the studies and the methodologies used. We also sought to identify factors that could influence the performance of these providers.

Table 2 shows that six studies used qualitative methods. These studies conducted case studies and employed tools such as documentary analysis, surveys, or interviews. Additionally, hybrid studies, which combined qualitative and quantitative methods, were also used. Since quantitative studies were the majority, they will be described in more detail below.

Table 3 shows that 30 publications used quantitative methodologies. The papers were grouped according to the methodology used, as shown below.

Regarding the methodology used, 47% (14 publications) of the studies adopted efficiency measurement techniques through econometric models, emphasizing Data Envelopment Analysis (DEA). These techniques allow for the comparison of a company or service's performance concerning those that define the efficient frontier and, therefore, represent the best practice observed.

There are two main approaches to estimating such boundaries: the parametric approach and the non-parametric approach. Parametric studies use an econometric function for production or cost (profit) technology, and non-parametric studies use mathematical programming to define the technology that reflects the production conditions of the sample in question (González-Gómez & García-Rubio 2008; Abbott & Cohen 2009; Berg & Marques 2011).

According to Cavalcanti *et al.* (2020), DEA efficiency measurement papers in the basic sanitation sector are not scientifically uniform regarding the criteria for choosing input and output variables, a fact observed in the papers included in this SLR. Furthermore, the DEA method approach also varies between constant returns to scale (initial CCR by authors Charnes, Cooper, and Rhodes). When inputs are increased by a certain amount, outputs will also increase by the same amount. Additionally, it includes variable returns to the scale (BCC proposed by Banker, Charnes, and Cooper) (Tupper & Resende 2004; Sampaio & Sampaio 2007; Carvalho & Sampaio 2015).

Statistical analyses were used in 11 papers, with the following methods used: factor analysis (Alencar Filho & Abreu 2005); principal component analysis, dendrogram determination, and one-way multivariate analysis of variance (Heller *et al.* 2006);

**Table 3** | Main characteristics of the quantitative studies

| | Authors | Country/region | Sample years | Number of units in the sample | Methodology used |
|---|---|---|---|---|---|
| 1 | Alencar Filho & Abreu (2005) | Brazil | 2003 | 26 | Statistical |
| 2 | Barbosa *et al.* (2016) | Brazil | 2005–2013 | 41 | DEA |
| 3 | Bezerra *et al.* (2019) | Brazil | 2012–2016 | 186 | Statistical |
| 4 | Carvalho & Sampaio (2015) | Brazil | 2006 and 2012 | 29 | DEA |
| 5 | Carvalho *et al.* (2015) | Brazil | 2001–2011 | 4,900 | DEA |
| 6 | Carvalho *et al.* (2023) | Brazil | 2006–2015 | 156 | DEA |
| 7 | Cavalcanti *et al.* (2020) | Brazil | 2008 and 2016 | 1,001 and 1,628 | DEA |
| 8 | Cetrulo *et al.* (2020) | Brazil | 2010 | 77 | DEA |
| 9 | Faria *et al.* (2007) | Brazil | 1998–1999–2001 | 231–275–280 | Statistical |
| 10 | Ferro *et al.* (2011) | Several[a] | 2003–2008 | 482 | SFA |
| 11 | Ferro *et al.* (2014) | Brazil | 2003–2010 | 127 | SFA |
| 12 | Heller *et al.* (2006) | Brazil | 1998 | 600 | Statistical |
| 13 | Heller *et al.* (2012) | Brazil | 2008 | 5,106 | Statistical |
| 14 | Malta *et al.* (2019) | Brazil | 2011–2016 | 5 | Statistical |
| 15 | Medeiros & Rodrigues (2019) | Brazil | 2013 | 325 | DEA |
| 16 | Mundim & Volschan Jr (2020) | Brazil | 2015 | 5,136/2,336[b] | Statistical |
| 17 | Nauges & van den Berg (2008) | Several[a] | 1996–2004 | 27 | SFA (translog-cost function) |
| 18 | Pereira & Marques (2022) | Brazil | 2019 | 2,160 | DEA |
| 19 | Pinheiro *et al.* (2016) | Brazil | 2000–2005–2010 | 217–422–1,203 | Statistical |
| 20 | Rossoni *et al.* (2015) | Brazil | 2008–2010–2013 | 5,493 | Statistical |
| 21 | Sabbioni (2008) | Brazil | 2000–2004 | 180/340 | SFA |
| 22 | Sampaio & Sampaio (2007) | Brazil | 1998–2003 | 36 | DEA |
| 23 | Scaratti *et al.* (2013) | Brazil | 2010 | 53 | DEA |
| 24 | Scriptore & Toneto Jr (2012) | Brazil | 2010 | 968 | Statistical |
| 25 | Seroa da Mota & Moreira (2006) | Brazil | 1998–2002 | 104 | DEA |
| 26 | Souza *et al.* (2008) | Brazil | 2002–2004 | 342 | SFA |
| 27 | Tourinho *et al.* (2022) | Brazil | 2019 | 448 | DEA |
| 28 | Tourinho *et al.* (2023) | Brazil | 2012–2019 | 283 | DEA |
| 29 | Tsagarakis (2018) | Several[a] | 2013–2016 | 1,898 | Statistical |
| 30 | Tupper & Resende (2004) | Brazil | 1996–2000 | 20 | DEA |

DEA, Data Envelopment Analysis; SFA, Stochastic Frontier Analysis.
[a]Research that has studied several countries, including Brazil.
[b]5,136 water service providers and 2,336 sanitation service providers were used.

*t*-tests, Mann–Whitney (Faria *et al.* 2007); stepwise step-down multiple comparison methods (Heller *et al.* 2012); Ordinary Least Squares (Scriptore & Toneto Júnior 2012); Shapiro–Wilk tests, Chi-square and multiple comparisons test – *z*-test (Rossoni *et al.* 2015); Kolmogorov–Smirnov, Hausman and Wald tests (Pinheiro *et al.* 2016); Pearson's correlation method (Tsagarakis 2018; Malta *et al.* 2019); and TOPSIS multi-criteria analysis (Mundim & Volschan Jr 2020). In addition, five studies used the non-parametric Kruskal–Wallis tests (Heller *et al.* 2012; Rossoni *et al.* 2015; Pinheiro *et al.* 2016) and the Kolmogorov–Smirnorv normality test (Faria *et al.* 2007; Pinheiro *et al.* 2016).

Table 4 summarizes the variables and indicators used in the performance evaluation of water and sanitation providers. Vilanova *et al.* (2015) cited that indicators are generally categorized according to their nature to represent different aspects of systems performance and management. In our study, the variables identified were grouped into operational and economic-financial categories.

**Table 4** | Variables used in the studies with quantitative methodology

| | Variable/indicator | Frequency |
|---|---|---|
| **Operational** | Water and sanitation services coverage (percentage) | 21 |
| | Water losses (percentage or by connection) | 14 |
| | Network length (water/wastewater) | 12 |
| | Number of connections (water/wastewater) | 12 |
| | Water measurement (index of micro/macro) | 10 |
| | Wastewater collected/treated (volume) | 9 |
| | Water produced (volume) | 8 |
| | Billed water (volume) | 8 |
| | Number of customers/economies (water/wastewater) | 7 |
| | Population with water/wastewater (habitants) | 6 |
| | Water consumed (by connection/per capita) | 5 |
| | Water quality | 4 |
| | Urban population | 2 |
| | Population density | 2 |
| | Other[a] | 9 |
| **Economic-financial** | Costs and/or expenses | 20 |
| | Labor (number of employees /expense) | 12 |
| | Non-revenue water | 7 |
| | Electrical energy (expense/consume) | 5 |
| | Water/wastewater tariff | 4 |
| | Staff productivity | 4 |
| | Investments | 4 |
| | Margins | 3 |
| | Financial performance | 3 |
| | Revenues | 3 |
| | Default | 2 |
| | Degree of indebtedness | 2 |
| | Return on equity | 2 |
| | Other[a] | 20 |

[a]Other refers to variables or indicators found in just one paper.

Among the operational variables, we highlight the use of indicators that describe the coverage of water and sanitation services, in percentage. Another highlight is the indicators related to water losses (in percentage or by connection) and the network length (water distribution or wastewater network), which is given in kilometers.

Regarding water quality, indicators were used relating to fluoridation, compliance of residual chlorine samples, turbidity, total coliforms, and others relating to operational control at water treatment plants such as the use of jar tests, criteria for washing filters, and automated control of the dosage of chemical products.

In the DEA and SFA methods, variables are used as inputs and outputs for the models. According to Molinos-Senante *et al.* (2015), choosing these variables is a critical decision due to the complexity that characterizes the industry. As these models have a greater focus on economic analysis, it was observed that variables related to costs and expenses predominated in the indicators identified. The operational costs of the water and sanitation systems were especially considered as input. Another frequent input was labor, either in the number of employees or in expenses with salaries. Regarding outputs, the number of customers, the number of water/wastewater connections, and the volume of water supplied were used.

It is important to note the indicators utilized in other papers included different aspects of analysis. Rossoni *et al.* (2015) and Medeiros & Rodrigues (2019), for example, used the Municipal Human Development Index (IDH-M).

The variables adopted reflect the tendency of most studies to focus on operational and financial performance. Social aspects and user perception have been little explored, such as customer satisfaction and willingness to pay. This fact is also pointed out by Dumontier *et al.* (2016), who mention that indicators such as equity and accessibility are marginalized in studies, making it difficult for water operators to pursue broader social, political, and environmental goals.

Heller *et al.* (2012) and Arruda *et al.* (2016) took into account indicators that portray the user's view and consider the number of complaints about the lack of water or its quality. Tsagarakis (2018) explored the relationship between the operating

cost coverage index and customer complaints about water and wastewater services in several countries, including Brazil. With a qualitative approach, the study of Vinturini *et al.* (2021) assessed the perception of the citizens of the city of São Mateus, in southeast Brazil, concerning the water supplied by the locals and investigating the availability of other alternative sources.

The existence of a master plan, or basic sanitation plan, was a factor analyzed by Heller *et al.* (2009) and Medeiros & Rodrigues (2019). Medeiros & Rodrigues (2019) also considered the existence of inter-municipal consortium (whose main purpose is to provide services related to the sector for the municipalities that have signed up to the agreement) and the proportion of hospitalizations due to waterborne diseases.

Heller *et al.* (2009) used specific indicators related to water resources, such as the protection of these resources and the existence of a government concession instrument that allows water abstraction.

Most studies use data from the SNIS, the most important statistical information system in the Brazilian basic sanitation sector. The operational, administrative, financial, and quality information are provided annually by the providers themselves on a voluntary basis, from which the system calculates the indicators. Although there are initiatives such as the '*Acertar*' project, which aims to develop certification methodologies, not all the information available on the SNIS has been audited.

### 4.3. Performance of water supply services in Brazil

Over the years of research (2000–2023), with different approaches and focuses, several studies were carried out on performance evaluation in Brazil.

Regardless of the method used, the research focuses on factors that influence service providers' performance in some way, particularly on issues related to different management models and market structures. Such approaches are more apparent in quantitative studies, as also noted by Cetrulo *et al.* (2019) and Tourinho *et al.* (2022).

Several studies investigate the performance of operators with different management models (public versus private ownership) and analysis, comparing the scope of service provision by local or regional operators and those providing water and/or sanitation services. Performance is also influenced by density (variations in the number of connections, length of networks, and treated volume).

Providers operating locally were considered more efficient by Carvalho & Sampaio (2015), Ferro *et al.* (2014), Carvalho *et al.* (2015), Arruda *et al.* (2016), Pereira & Marques (2022), and Tourinho *et al.* (2022). Seroa da Motta & Moreira (2006) concluded that regional operators enjoy the economies of scale and greater investment capacity associated with their larger size but may not be able to translate this into greater overall efficiency and tariff reductions. The author also cited that the local operators, on the other hand, face political pressure from municipal users and enjoy lower local prices for labor, land and other inputs, so they tend to be more efficient and charge lower tariffs than regional types.

In contrast, Sampaio & Sampaio (2007), Sabbioni (2008), and Faria *et al.* (2007) stated that regional firms are more efficient in terms of economies of scale. Faria *et al.* (2007), however, did not categorically state that one group is better than the other in all aspects analyzed.

Heller *et al.* (2009) identified the good technological performance of municipalities when integrated into a broader system, which they pointed out as the potential for using inter-municipal consortia and the consequent gain in scale.

Bezerra *et al.* (2019) pointed out that there is no relationship between the efficiency of water supply systems in the Brazilian *Agreste* region and the number of inhabitants in the municipalities, as the average values of the indicators do not vary significantly.

As for economies of scope, Nauges & Van den Berg (2008) and Carvalho *et al.* (2015) pointed out that utilities that provide both water and sanitation services were more efficient than those that only provide water. As Nauges & Van den Berg (2008) highlighted, economies of scope may emerge from the collaborative sharing of production activities featuring indivisible fixed costs, which are not uniquely associated with each service, and/or from the complementarity of the expenses within production activities. The results of Barbosa *et al.* (2016) indicate that for water and sanitation services, economies of scale and scope were achieved by service providers with residential customers, and for water supply services, density savings were identified.

As to ownership analysis, results diverge regarding private participation in the sector. Some publications found no evidence that private ownership increases efficiency (Seroa da Mota & Moreira 2006; Souza *et al.* 2008; Barbosa *et al.* 2016; Pereira & Marques 2022; Tourinho *et al.* 2022), and others concluded that private operators were more efficient than public ones (Scriptore & Toneto Jr 2012; Ferro *et al.* 2014; Carvalho & Sampaio 2015; Pinheiro *et al.* 2016).

Furthermore, studies show that the performance of service providers can be influenced by external factors such as regulatory aspects. The studies by Tupper & Resende (2004) and Ogera & Phillipi Jr (2005), dated before the publication of Law No. 11.445/2007, emphasized the importance of a regulatory framework for the efficiency of service providers. Strengthening the regulation of the services is highlighted as fundamental to advances in performance (Scriptore & Toneto Jr 2012. Arruda *et al.* 2016; Dias *et al.* 2018; Turini *et al.* 2019; Cavalcanti *et al.* 2020; Mundim & Volschan Jr 2020).

However, after the legal framework was published in 2007, publications identified that even the creation of new regulatory agencies has not guaranteed high levels of efficiency (Carvalho & Sampaio 2015; Barbosa *et al.* 2016). Additionally, it was pointed out that service providers were more efficient before the implementation of the regulatory framework (Carvalho & Sampaio 2015; Carvalho *et al.* 2015).

It was identified that factors such as the political and socioeconomic context (Sampaio & Sampaio 2007; Paludo & Borba 2013; Scaratti *et al.* 2013; Rossoni *et al.* 2015), the existence and implementation of public policies (Ogera & Phillipi Jr 2005; Rossoni *et al.* 2015; Medeiros & Rodrigues 2019; Turini *et al.* 2019), and lack of technical capacity (Arruda *et al.* 2016), influence the performance of water service providers in Brazil.

Brazil is a country with large dimensions and distinct characteristics among its macroregions. Tourinho *et al.* (2022) pointed out that it is important to evaluate these differences in the water service performance, and some authors have studied this topic. Tupper & Resende (2004) considered that, although water and sanitation operators are more homogeneous than those in other sectors, such as telecommunications, there may be critical regional heterogeneities to be considered in the performance evaluation process.

These regional specificities have been the subject of several studies, most of which consider that geographical location influences the provision of water and sanitation services (Sampaio & Sampaio 2007; Ferro *et al.* 2014; Carvalho & Sampaio 2015; Rossoni *et al.* 2015; Cavalcanti *et al.* 2020; Pereira & Marques 2022; Tourinho *et al.* 2022; Tourinho *et al.* 2023). One exception was Barbosa *et al.* (2016) who found no statistical difference in the efficiency levels among regions.

Studies by Sampaio & Sampaio (2007) and Cavalcanti *et al.* (2020) demonstrated that the South and Southeast regions exhibit higher efficiency and productivity growth, while the North and Center-West regions tend to display lower efficiency. The analysis by Ferro *et al.* (2014) suggests that despite the absence of regional differences in cost structures, there are variations in efficiency levels and their dispersion across regions.

Furthermore, Carvalho & Sampaio (2015) identified that the North region was the only one to register a decrease in productivity during the period studied (2006 and 2011), while the Southeast region saw the largest overall increase in productivity. Rossoni *et al.* (2015) highlighted that the legal nature of service providers varies by region, with private companies predominating in the North and state-owned companies in the Northeast and the South.

Pereira & Marques (2022) and Tourinho *et al.* (2022, 2023) reinforced the existence of regional heterogeneity in water supply and sanitation services. Pereira & Marques (2022) pointed out that factors such as socioeconomic development, climate, colonial past, and heterogeneous immigration distribution contribute to the observed asymmetries.

About this topic, the results showed that Southeast and South regions perform the best, while the Northeast and North face challenges in terms of efficiency and coverage, highlighting the need for targeted public policies to mitigate these regional disparities.

Whatever the focus or approach used, we can cite some common challenges identified in the literature, especially regarding the choice of variables to be considered in the analysis, the sample size, and the reliability of the data, considering that most of the studies used information from the SNIS. These aspects require caution in generalizations and conclusions.

## 5. CONCLUSIONS

This review aims to analyze how scientific research has been developed in performance evaluation in the water sector, more specifically in Brazil, and identify the factors that could influence it.

Regarding the characteristics identified in this review, there was a gap in the number of qualitative studies, as most of the studies used econometric methods to evaluate performance and were mainly focused on technical and financial efficiency. This was reflected in the variables used, with operational and financial variables prevailing over others. Other important factors that have received limited academic attention relate to social aspects, such as affordability and the user's perspective on the services provided, including their engagement and satisfaction.

Research has shown that political and socioeconomic context and regulatory and geographic aspects influence the water sector in Brazil. The presence of diverse institutional arrangements led to different performances, with different perspectives, particularly concerning the legal status (public or private) and scope of the services (local or regional operators). This highlights the crucial role of adequate management and robust regulation in ensuring the sector's functioning.

When comparing different research studies, it is crucial to recognize that the differences in scope, variables, methodology, and database represent significant limitations, once the entire context in which the research was conducted influences the performance evaluation results.

Moreover, many studies in Brazil utilize the SNIS database, which is the largest database of the sector in the country. Nonetheless, it is important to be aware of its limitations in terms of data reliability. The information it provides is self-reported by the providers and lacks certification.

The factors influencing the provision of drinking water supply services identified in this study help to understand the scenario in Brazil and highlight some important aspects to be considered in the management of the systems, such as the political and socioeconomic context and regional heterogeneity, to ensure effective access to drinking water to the Brazilian population. Furthermore, tools such as performance evaluation play an important role and can guide and support decision-makers and service providers for an effective approach to this service.

Future studies should explore some important questions, considering the outcomes of this review, such as the use of qualitative or even hybrid methodologies, and the inclusion of social and service user aspects in performance evaluations. By incorporating these aspects, the analysis can provide other points of view, paths, and instruments to contribute to the debate on universal access to drinking water.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

## CONFLICT OF INTEREST

The authors declare there is no conflict.

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