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Review Article

Key Factors in Improving the Sustainable Performance of Urban Drinking Water Services

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Abstract

Water is a basic element for human survival, yet although 71% of the Earth's surface consists of water, only 1% of it is accessible to humans. Climate change, urbanization, and environmental issues are challenges experienced by the efforts of drinking water services in urban areas. In addition to providing sufficient drinking water, drinking water services must also pay attention to energy use and carbon emissions. This study aims to determine the factors that impact the sustainable performance of drinking water services in urban areas. The research method was conducted using bibliometric analysis. The analysis was conducted on 50 reputable articles with a publication period of 2013-2023, with the keywords urban water and municipal water. According to previous research, the water supply system in urban areas can be divided into three sub-systems: raw water, water treatment, and distribution. If associated with sustainability, the factors can be divided into economic factors, such as affordability, continuity, and quantity. Environment: pollution and carbon emissions. Social: accessibility and customer behavior. Most previous studies have focused only on economic aspects, further studies are needed to integrate all these factors into a performance measurement system to help decision-makers align strategic targets into operation level activities.

Keywords: Bibliometric analysis; sustainable development; urban water; water service

1. Introduction

Water, energy, and food are essential elements needed to fulfill basic human needs. They are closely related to the development of economic and social aspects in a region (Gaiffe et al., 2023). The availability of water, energy, and food is strongly influenced by climate change, population growth, economic development, and changes in technology and land use (Krueger et al., 2020). Global challenges, including climate change and the use of non-renewable natural resources, are ultimately forcing industry players to adopt sustainable operational practices (Hariadi et al., 2023). As such, water can be considered a fundamental need for all human beings on this planet. Concern for the availability and sustainability of water resources is essential to supporting and ensuring human survival. Research in this area is urgently needed to provide knowledge on the importance of water as an essential and irreplaceable element in human life.

Two main facts confirm that water is an essential element in human life. First, about 71 percent of the Earth's surface is covered by water, and the Earth's oceans hold about 96.5 percent of the total water content on the planet (Live Science, 2010). Secondly, the human body is designed to receive and hold large amounts of water. The composition of the human body consist 70 percent water (Kuriyan, 2018). As a basic human need, water is currently experiencing conditions where its availability cannot meet the necessary needs. The need for clean water is not only about the amount of water obtained (quantity) but also about the ease of getting it (accessibility), continuity, and affordable prices (affordability) (Gaiffe et al., 2023). These four indicators have been defined by the World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) in 2021 based on the Sustainable Development Goals to assess water services (Gaiffe et al., 2023). In addition, six aspects can influence people's views on the quality of water services: network, water quality, price, complaint handling, convenience disrupted by network repair, and smooth service (José Antonio et al., 2022). The impact of a population and residential density on an area determines vulnerability to water availability. Efforts must be made to improve the population's behavior for water availability and public health (Birawida et al., 2021; Hussien et al., 2018).

The process of providing clean water begins with the provision of water sources upstream. Water supply sources can be obtained from various sources: surface water, desalinated seawater, bottled water from outside the area, and rainwater harvested (Aberilla et al., 2020; Ghimire et al., 2017). In addition, hydrogeological aspects can be a factor that can be considered in determining water sources (Eftimi et al., 2023). In this stage, pollution can interfere with the availability of water sources. Pollution can come from various sources, including industrial waste and agricultural runoff (Bera and Banik, 2019a). The quality of river water greatly affects the feasibility of water for public consumption. Various methods of measuring river water quality have been developed to ensure that the water is suitable for consumption and meets public health standards .Urban water sources are also affected by weather factors. Variables such as maximum rainfall intensity, number of dry days in a period, and rainfall density will affect the availability of raw water (García-Haba et al., 2023).

The high speed of community growth without good planning of the water pipeline network will make it difficult to maintain and detect water leaks (Hu et al., 2021), (Cen et al., 2023). Connecting several settlements through a centralized network, thus providing better access to water sources, is one option that can be used in addition to the decentralized option (Agbaba et al., 2023). The socio-technical approach is a consideration in urban drinking water management. This is because it involves the complexity of the relationship between social and technical elements and the importance of cross-sectoral cooperation (Ramírez-Agudelo et al., 2021). One of the important pillars of urban drinking water management is infrastructure management (Manny, 2023). In addition, understanding the factors that influence urban metabolism can be used to design policies and plan campaigns to introduce sustainable resource management in urban areas (Voskamp et al., 2020). The next stage in urban water supply activities is processing raw water into clean water ready for consumption by customers. Determining the optimal production schedule in various scenarios will be very helpful in dealing with fluctuations in water demand and the availability of raw water supply (Aminur et al., 2008). In addition to providing sufficient clean water for urban communities, urban water supply systems must also pay attention to energy use and the resulting carbon footprint (Hsien et al., 2019).

A factor often overlooked is consumers' price of the water they consume. A mismatch between water pricing and the actual cost of water services can lead to over-utilization of water resources. This will be especially problematic in areas experiencing water shortages. Where over-utilization of water can deplete water resources, it will compromise sustainability. The quality of river water greatly affects the feasibility of water for public consumption. Various methods of measuring river water quality have been developed to ensure that the water is suitable for consumption and meets public health standards

(Syafrudin et al., 2023). Urban water management aims to include water metering and pricing to improve water conservation and strengthen climate resilience (Ahmed et al., 2022). Also, the right price can provide enough profit for urban water managers to finance their operational costs.

People's behavior in using water must also be considered. The community must be educated about using water wisely. Currently, education is not only done in conventional ways but also in a more interesting way, for example, with a simulation game. This game improves people's understanding of water-related issues, especially climate change, resource scarcity, and environmental damage in the water industry (Khoury et al., 2023). The provision of drinking water for urban communities is not limited to investment and infrastructure. It requires a management system to ensure sustainable stakeholder services (Gaiffe et al., 2023). The novelty of this research lies in the different factors that will be investigated. Based on the literature review results, research on drinking water services in urban areas usually considers the factors of accessibility, quantity, continuity, affordability, pollution, water tariffs, and carbon emissions. In general, only economic or environmental aspects are considered in previous research. In contrast, this research will develop a performance measurement system by integrating all these factors. The result will be a more comprehensive understanding of the influence of factors such as accessibility, quantity, continuity, affordability, river pollution, carbon emissions, behavior and policy on urban water supply systems. Figure 1 shows the performance measurement system's current state and an overview of the desired creative solution.

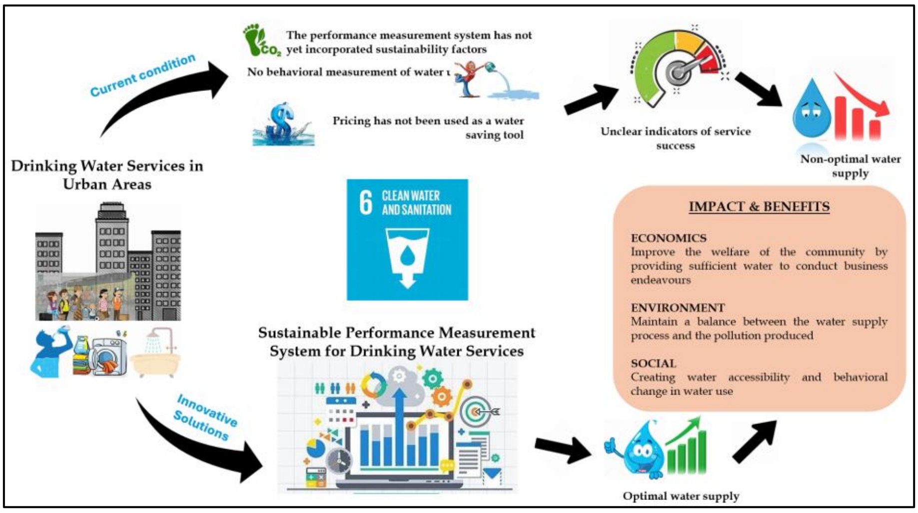

Figure 1. Factors measured in urban water service

2. Methods

The method used in this research is a qualitative method with a literature study approach. In bibliometric studies, data can be obtained from primary, secondary, or tertiary journals covering a certain period and analyzed from various perspectives (Donthu et al., 2021). This analysis can include documents by country or region, type of document, and year of publication, as well as various other aspects. The research focused on the factors that influence the performance of urban water services. Understanding this will help the parties concerned improve the quality and efficiency of the services they provide (José Antonio et al., 2022).

2.1. Bibliometric Analysis

This study used the Scopus search engine to find research using the keyword urban water or municipal water from 2013 to 2023. Within this period, there were 503 research publications on the subject. The Scopus database is the main source for assessing scientific research because it can index scientific literature comprehensively. Scopus provides accurate information about the metadata of each scientific article, including publication date, abstract, references, and other fields. As one of the largest data centers, Scopus offers detailed and reliable data for scientific research evaluation (Soesanto and Handalani, 2023).

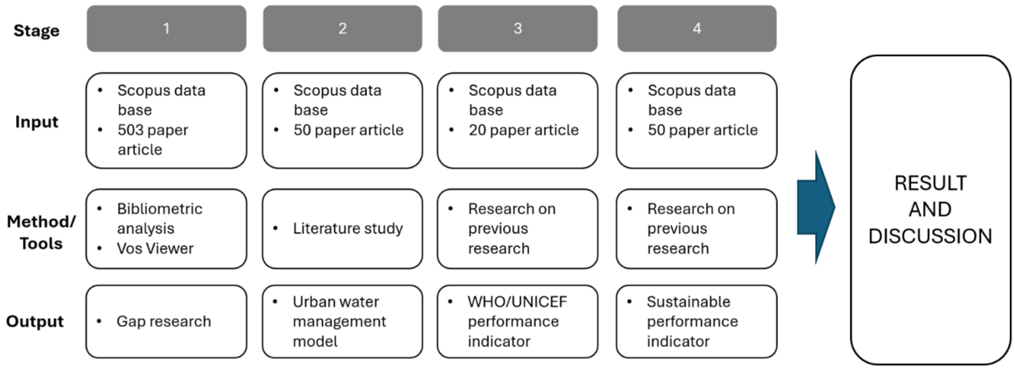

Figure 2. Data collection and data analysis flow

This study utilized a specific method to analyze the development of research on the performance measurement system for urban water supply services. The primary tool employed for this analysis was Vos Viewer, a software used for constructing and visualizing bibliometric networks (Soesanto and Handalani, 2023). Through this approach, the research aimed to provide insights into the trends and advancements in the performance measurement of water supply services in urban areas over a specified period. Figure 2 shows the bibliometric analysis flow.

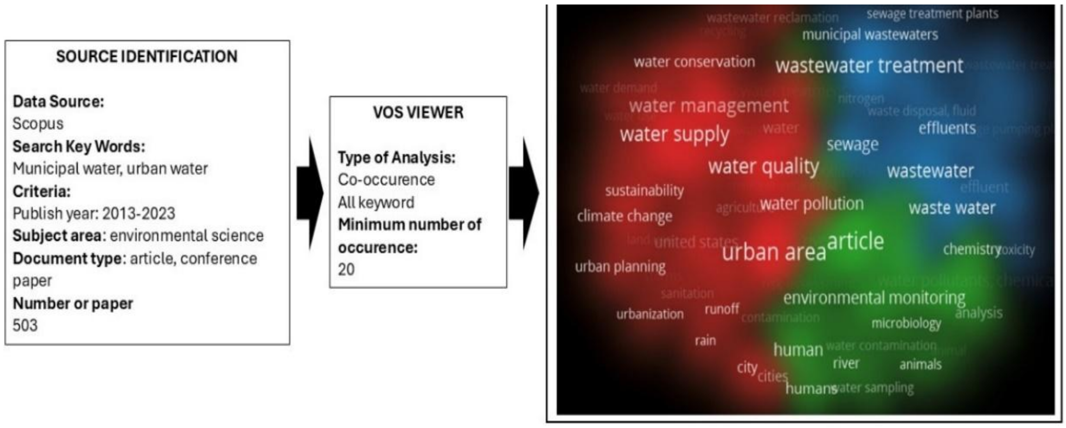

Figure 3. Bibliometric analysis flow

Figure 3 illustrates the results of the bibliometric analysis, which underscores a notable gap in research related to the theme of "performance measurement" in the field of urban water services. Bibliometric analysis can reveal the gaps left by previous studies (Donthu et al., 2021). This highlights the limited attention given to evaluating performance in this area, indicating a critical need for further study and exploration.

3. Result and Discussion

After conducting a literature study of 50 journals on the theme of water in urban areas with publication years 2013-2023, the development of research on clean water in urban areas is as follows. Table 1 also shows that 2023 research on water in urban areas has increased significantly from previous years. Using the results of the literature review of the 50 articles, the urban water supply system can be divided into three sub-systems (Al-Juaidi and Al-Shotairy, 2020), namely:

1. Raw water: a sub-system related to water sources.
2. Treatment: a sub-system that processes water sources into clean water.

3. Distribution: a sub-system that delivers clean water from processing to consumers.

Table 1. Publication year of the journal

Jurnal	2013	2014	2015	2017	2018	2019	2020	2021	2022	2023	Total
American Society of Civil Engineers (ASCE)			1								1
Applied Energy			1								1
Applied sciences										1	1
Built Environ						1					1
Cogent Engineering			1								1
Desalination and Water Treatment							1				1
Eng										1	1
Environment and Urbanization Asia	1										1
Environment Reserach Letter							1				1
Gaceta Sanitira								1			1
Hydrology										1	1
International Journal of Disaster Resilience in the Built Environment									1		1
Journal of Civil Engineering										1	1
Journal of Cleaner Production				2	2	2	2	3	2	6	19
Resources, Conservation & Recycling						1					1
ScienceDirect					1						1
Sustainability								1		1	2
Sustainable Cities and Society				1				1		1	3
Technological Forecasting & Social Change									1		1
Water								1		1	2
Water Research							3			2	5

Jurnal	2013	2014	2015	2017	2018	2019	2020	2021	2022	2023	Total
Water Resources Management							1				1
Water Supply						1					1
World bank group		1									1
Total 1	1	3	3	3	5	8	7		4	15	50

3.1. Urban Water Management Performance Indicator

The four water and sanitation-related indicators were established by the World Health Organization (WHO) and UNICEF in 2021 as part of their efforts to support the achievement of Sustainable Development Goal (SDG) 6.1, which focuses on ensuring universal and equitable access to safe and affordable drinking water. These indicators provide an important benchmark for evaluating the quality, availability, and accessibility of drinking water services globally (Gaiffe et al., 2023).

By aligning with SDG 6.1, these indicators aim to provide a comprehensive framework for monitoring progress in water service delivery. These indicators emphasize the importance of addressing access gaps, improving water security, and ensuring sustainable management of water resources (Gaiffe et al., 2023).

1. Accessbility

The proportion of buildings in a cluster that have access to water supply indicates the level of infrastructure that meets minimum water demand standards. This indicator plays an important role in evaluating the quality of water supply in the area.

2. Quantity

The average volume of water delivered per person per day, calculated in liters, is a key indicator to measure the efficiency and availability of water supply. This data shows the extent to which people's basic water needs are being met. It helps to determine the carrying capacity and critical water index by calculating the water demand and water availability in an area and the ratio of water availability and demand (Harfadli and Ulimaz, 2020).

3. Continuity

According to when translated into operational activities, this indicator refers to the duration of time the pump works to meet clean water needs. The availability of raw water is a key element that greatly affects the effectiveness and sustainability of meeting these needs.

4. Affordability

The price paid by a household for clean water reflects the cost charged based on the amount of water consumption used. Factors such as the tariff per liter, government policies, and accessibility of the water source affect the price. Furthermore, this research will explore the linkages between previous journals that focus on three main criteria: case studies, water supply systems and clean water indicators. The case studies described in the previous literature provide an understanding of the application of water supply system concepts and practices in various conditions, both in urban and rural areas.

In addition, this research will also analyze the indicators used to evaluate the quality and sustainability of water supply. In addition, by referring to previous research, it is expected to find relevant patterns in water management that can be applied to improve a more effective water supply system.

Tabel 2. Related to case studies, water supply systems and clean water indicators.

Author	Research Object	Research Result	Raw Water	Treatment	Distribution	Accessi bility	Quan tity	Conti nuity	Afford ability
(Gaiffe et al., 2023)	Customer satisfaction	Performance standards		√	√	√	√		
(Krueger et al., 2020)	Water source	Performance standards	√	√	√	√		√	

Author	Research Object	Research Result	Raw Water	Treatment	Distribution	Accessi bility	Quan tity	Conti nuity	Afford ability
(José Antonio et al., 2022)	Customer satisfaction	Performance standards	√	√	√	√	√	√	√
(Bera and Banik, 2019b)	Water source	Policy	√					√	
(Huang et al., 2023)	Water supply system	Operational improvements	√	√	√	√	√	√	
(Aggarwal et al., 2013)	Operational performance	Policy	√	√	√			√	
(Hussien et al., 2018)	Water source	Policy	√	√			√	√	
(Eftimi et al., 2023)	Water source	Policy	√					√	
(Ramírez-Agudelo et al., 2021)	Water supply system	Policy	√	√	√	√		√	
(Rybicki et al., 2022)	Water source	Performance standards	√	√	√	√	√		
(Agbaba et al., 2023)	Water source	Policy	√	√	√	√	√	√	
(Fernández Rodríguez and Pardo, 2023)	Water supply system	Operational improvements			√		√		√
(Cen et al., 2023)	Water supply system	Operational improvements			√	√	√		
(Hsu et al., 2022)	Operational performance	Operational improvements			√		√		
(Nicollier et al., 2022)	Water source	Policy	√	√		√		√	
(Lamy et al., 2021)	Water source	Policy	√	√			√	√	
(Wanjiru and Xia, 2015)	Water source	Policy	√	√			√	√	
(Fan et al., 2017)	Behavior	Policy	√					v	
(Soriano and Rubió, 2019)	Water source	Policy	√					v	
(Erban and Walker, 2019)	Water supply system	Policy		√	√			v	

Out of the 20 articles reviewed, the research objects are categorized as follows: 2 articles examine customer satisfaction, 10 focus on water sources, 5 investigate water supply systems, 2 explore operational performance, and 1 article looks into behavior. These articles address a wide range of topics crucial to understanding the water supply sector, such as assessing customer satisfaction, evaluating the availability and quality of water sources, and analyzing the functioning of water supply systems. Regarding the research results, 4 articles concentrate on performance standards, 12 discuss policy-related issues, and 4 focus on operational improvements, indicating the emphasis on enhancing both policy frameworks and operational efficiency.

In addition, a literature study of 50 journals on the theme of water in urban areas with publication years 2013-2023. The literature review's results obtained factors that affect the performance of sustainable services for urban drinking water supply systems. Table 3 shows the number of research articles that discuss these.

Table 3. Sustainable performance factors

Factor	Sustainability	Number of articles
Affordability	Economy	4
Quantity	Economy	17
Continuity	Economy	28
Pollution	Environment	5
Carbon emissions	Environment	2
Accessibility	Social	14
Customer Behavior	Social	7

Urban water management divided into three sub-systems: raw water, water treatment, and distribution (Al-Juaidi and Al-Shotairy, 2020). In addition to providing drinking water that meets the community's needs, drinking water services in urban areas must also pay attention to excessive energy use and prevent pollution from being generated. Previous studies have tried to integrate sustainability issues as a measured factor. Gaiffe et al. (2023) have recently shown that affordability will ensure the price paid by the community is affordable, continuity ensures the continuity of water supply to the community, and quantity will guarantee the minimum amount of water needed. Combining the three factors results in the growth of a healthy and sustainable economy. From the Environmental issue, the river water pollution factor threatens the existence of proper raw water from the water treatment side (Soriano and Rubió, 2019). Carbon emissions generated from water treatment activities are a factor that pollutes the environment (Pericault et al., 2023). The ease of obtaining drinking water will ensure that every individual in the community has the same opportunity to access drinking water. Customer behavior that may result in wasteful water use is also a factor that must be considere (Dey et al., 2022).

Figure 4 shows in detail the relationship between the various sub-systems involved in the water treatment process, as well as the factors that influence each stage in the system. Each sub-system, from raw water collection, filtration process, treatment, to the distribution of clean water to consumers, is interrelated and influenced by various factors. These factors include the quality of the raw water used, the technology applied in treatment, existing water management policies, and the condition and capacity of the infrastructure that supports the entire system. The relationship between these sub-systems is critical to creating a water treatment system that is efficient, sustainable, and able to optimally meet the needs of the community.

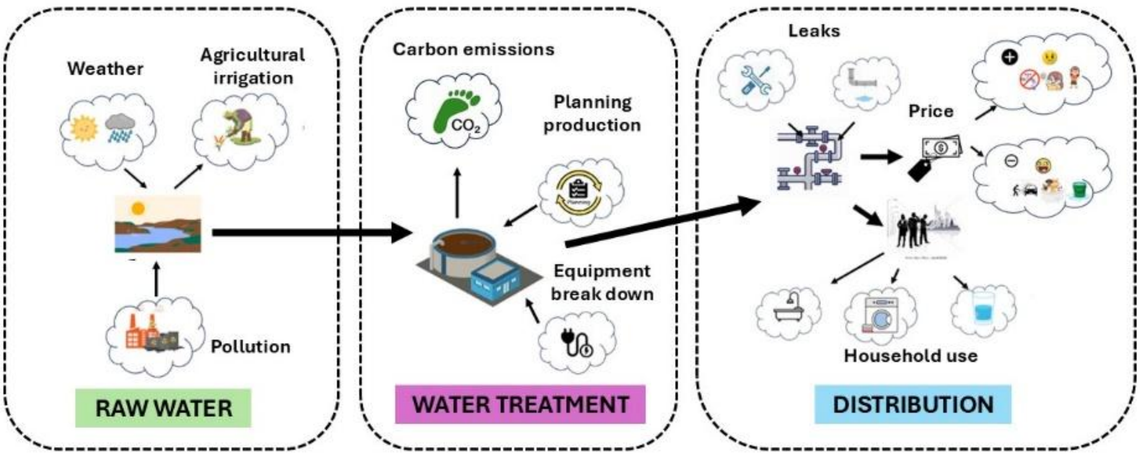

Figure 4. Urban water management

4. Conclusions

Previous studies have only discussed a few factors in their research. Further studies incorporating all sustainable performance factors need to be conducted. From a practical perspective, a balanced and integrated framework will enable decision-makers to capture the important elements that need to be considered in assessing an operation's implementation (Sari et al., 2021). This study aims to provide valuable insights into developing a sustainable performance measurement system, ensuring a more efficient and comprehensive approach to evaluating and improving organizational results. By establishing a robust framework, the study aims to bridge the gap between strategic objectives and operational activities, enabling decision-makers to effectively translate long-term goals into measures that can be implemented at the operational level. This alignment promotes better resource allocation, accountability, and continuous organizational improvement. Ultimately, this study is expected to contribute to sustainable practices by offering tools and methodologies that facilitate the integration of performance measurement into day-to-day operations

Future research will take decisive steps to enhance our understanding of key factors. First, we will establish clear performance indicators for each identified factor. This crucial process will involve validating these indicators through expert consultations to ensure their relevance and accuracy. Once we have defined and validated the performance indicators, we will assign appropriate weights to each one. This weighting will create a robust foundation for a comprehensive measuring instrument. This instrument will be essential in assessing and monitoring the performance of the identified factors, providing a clear and in-depth understanding of the conditions under study. As a result, this research is poised to deliver a more accurate and effective assessment method.

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