TASHKENT STATE UNIVERSITY OF ECONOMICS

International journal of topics

INNOVATION SCIENCE AND TECHNOLOGY

Scopus || Electronic journal specializing in Scopus

ISSUE 9

Acceptance of papers **September, 2025**

Acceptance of papers

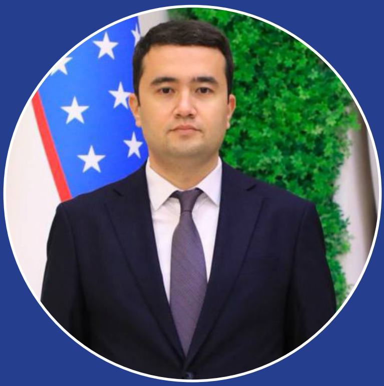
Published monthly

Topics

economics, technology, social sciences

ISSN 3060-5229

Electronic publication, Issue 9. 46 pages.
Approved for publication on September 1, 2025.



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EVALUATING AND IMPROVING THE EFFICIENCY OF DRINKING WATER SUPPLY (THE CASE OF SAMARKAND REGION)

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Abstract: This paper focuses on the evaluation of the efficiency of drinking water supply systems, which represent one of the critical components of sustainable socio-economic development. The study applies a multidimensional approach, incorporating technical, economic, environmental, and social indicators to assess the performance of water supply services. Key factors such as the extent of water losses, the proportion of the population with access to safe drinking water, the reliability of service provision, energy consumption levels, and the financial payback period of investments are examined in detail. The research emphasizes the importance of integrating these indicators into a comprehensive efficiency assessment model, enabling policymakers and stakeholders to identify strengths and weaknesses of the current system. Furthermore, the analysis highlights regional disparities in water supply services and outlines the necessity of adopting targeted strategies to address existing challenges. By linking national priorities with international standards, particularly the United Nations Sustainable Development Goal 6, the study provides practical recommendations for enhancing the effectiveness, sustainability, and equity of drinking water supply. The findings are expected to serve as a scientific basis for improving governance mechanisms, optimizing resource allocation, and supporting investment decisions in the water sector.

Key words: drinking water, water supply, efficiency assessment, sustainability, resource management, SDG 6, socio-economic development, policy evaluation.

INTRODUCTION

At present, the provision of drinking water is considered one of the essential prerequisites for sustainable development worldwide. Population growth, climate change, urbanization, and industrialization processes are significantly increasing the demand for water. In particular, in developing countries—including the Republic of Uzbekistan—the efficiency of drinking water supply systems remains low due to outdated infrastructure, insufficient financial resources, and high levels of water losses. Under such conditions, assessing the economic efficiency of drinking water supply services, identifying priority directions for improvement, and developing scientifically grounded solutions to the existing challenges become urgent issues of both theoretical and practical significance.

The main objective of this research is to scientifically substantiate the criteria and methods for evaluating the efficiency of drinking water supply services, to analyze the current system, and to develop proposals and recommendations aimed at enhancing economic efficiency in the water supply sector. Based on this objective, the following specific tasks were identified:

To study theoretical approaches to the evaluation of drinking water supply efficiency;
To conduct an economic analysis of the current state of the water supply system in Uzbekistan;
To determine the main indicators and methods applied in assessing efficiency;
To analyze the regional factors influencing the efficiency of drinking water services;
To elaborate proposals for improving economic efficiency within the water supply system.

Within the framework of the study, existing approaches to the evaluation of water supply efficiency are analyzed in depth, and an improved assessment model adapted to the conditions of Uzbekistan is proposed. This model takes into account regional disparities and economic differences across territories. Moreover, practical recommendations are developed on the basis of innovative approaches, focusing on reducing water losses, strengthening the financial sustainability of water utilities, and increasing the effectiveness of investments.

The outcomes of this research are expected to be widely applicable in the development of strategies aimed at enhancing efficiency in the drinking water supply sector, improving the governance of water resources, optimizing regional development programs, and ensuring the scientific justification of sectoral reforms. In the broader context, the study contributes to the achievement of sustainable development goals, particularly in ensuring access to clean water and sanitation, which remain among the global priorities set by the United Nations.

LITERATURE REVIEW

The evaluation of drinking water efficiency is scientifically grounded in multi-criteria analysis approaches. The initial conceptual framework was formed within the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 — "Ensure availability and sustainable management of water and sanitation for all." SDG indicators 6.1 and 6.4 cover sustainable water resource management and service quality (UN-Water, 2020).

Technical efficiency is assessed through indicators such as the reliability of water infrastructure, the level of water losses, the number of system failures, interruptions in water delivery, and energy consumption. A. Brikke and M. Bredero (2003), in their work "Key Performance Indicators for Water Supply", developed a system of technical indicators for drinking water systems, which is now widely applied in many countries. The WHO (2011) proposed the "Water Safety Plans" (WSPs) approach for assessing safety and technological reliability in water supply.

Economic efficiency is measured through tariff policy, the balance between service cost and quality, service delivery expenses, investment payback period, and consumers' ability to pay. The OECD (2011) introduced the "3Ts" concept to ensure the financial sustainability of the water sector: Tariffs, Taxes, and Transfers (international aid/funds). Global Water Intelligence (GWI, 2020), in its statistical reports, analyzes profitability, user costs, subsidy mechanisms, and private sector participation as factors influencing the economic efficiency of water supply services.

Ecological efficiency in water supply systems is evaluated based on reducing water source pollution, protecting water ecosystems, applying recycling practices, and adopting energy-saving technologies. ESCO Water Reports (2018–2023) present analyses on ecological monitoring and water ecosystem protection, developing criteria for assessing the environmental impact of water supply.

Social efficiency, according to reports by WaterAid (2020) and the UNDP, is measured through equal access to drinking water, gender-sensitive approaches, service quality, and user satisfaction levels.

In the context of Uzbekistan, there are several scientific studies focusing on the sustainability of the water supply system, regional disparities, and funding mechanisms. According to data from "O'zsuvta'minot" JSC, as of 2020 the overall water loss rate was around 35–40%, which is considerably higher than international standards. Local scholars such as M. Usmonov (2022) and Z. Ergashev (2021) have proposed recommendations for modernizing the drinking water system, economically justifying water tariffs, and improving subsidy mechanisms. Furthermore, the Presidential Decree of the Republic of Uzbekistan No. PQ–110, adopted on April 5, 2023, defined specific targets and projects for the development of drinking water infrastructure for the period 2023–2025.

RESEARCH METHODOLOGY

The methodological basis of the study relies on a combination of systematic and analytical approaches. A set of methods was applied, including:

System analysis method – to examine the structure and interrelations of the drinking water supply system as a whole;

Multi-Criteria Evaluation/Decision-Making (MCE/MCDM) method – to assess the efficiency of water supply services through multiple dimensions such as technical, economic, ecological, and social factors;

Statistical analysis method – to process empirical data, identify trends, and measure the reliability of indicators;

Expert evaluation method – to incorporate professional judgments and validate the proposed assessment model.

The assessment was conducted on the basis of criteria and indicators such as service reliability, water loss rates, energy consumption, cost recovery, tariff affordability, environmental sustainability, and social equity.

The research was carried out in several stages:

Formulation of the theoretical framework for efficiency assessment in water supply services;

Collection of relevant data from national statistics, institutional reports, and international organizations;

Analysis based on selected indicators, applying comparative and econometric methods where appropriate;

Development of a composite efficiency index, integrating technical, economic, ecological, and social dimensions;

Preparation of recommendations and conclusions derived from the analytical results.

The expected outcomes of the research include a scientifically substantiated efficiency assessment model for the drinking water supply sector, identification of priority areas for improving service delivery, and the development of practical proposals for enhancing the overall economic, environmental, and social effectiveness of water supply systems.

ANALYSIS AND RESULTS

Drinking water supply is a vital socio-economic system that ensures the continuous provision of safe, high-quality, and health-friendly water to the population, social sector institutions, and branches of the economy. It is one of the key components of modern state infrastructure, directly influencing the quality of life, the promotion of a healthy lifestyle, and opportunities for economic activity.

In the scientific literature, the essence of drinking water supply is explained from two main perspectives:

Social aspect – satisfying the fundamental needs of the population for life and health;

Economic aspect – ensuring the efficient use of water resources, maintaining the balance between service costs and prices, and guaranteeing economic sustainability.

The drinking water supply system performs the following core functions:

Selection and management of water sources – planning the use of underground and surface water resources while ensuring ecological safety;

Treatment and sanitary processing – applying modern technologies (filtration, chlorination, UV sterilization) to bring water to drinking quality standards;

Transportation and distribution – delivering water to consumers through pipelines, maintaining pressure levels, and ensuring uninterrupted supply;

Technical maintenance and monitoring – supervising the operation of pipelines, reservoirs, pumping stations, and other infrastructure facilities;

Water accounting and economic management – measuring water consumption, implementing tariff policies, managing investments, and modernizing infrastructure.

In contemporary approaches, the drinking water supply system is not only viewed as a set of technical facilities that deliver water, but also as a crucial element of sustainable development. Within the framework of the United Nations Sustainable Development Goals (SDGs), Goal 6 – “Clean Water and Sanitation” – emphasizes the universal provision of drinking water. This necessitates integrating national policies and strategies with ecological, social, and economic factors. In Uzbekistan, reforms in the drinking water supply sector are also directed toward improving the complex functions of the system based on modern approaches. For instance, the National Program for the Development of Drinking Water and Sanitation Services for 2021–2025 identifies universal access to safe drinking water, modernization of systems, and enhancement of efficiency as priority directions.

Efficiency is one of the fundamental concepts of economics, defined as the degree to which maximum results are achieved from existing resources or goals are reached with minimum costs. In economic interpretation, efficiency refers to the rational and purposeful use of labor, capital, natural resources, time, and other economic factors in production and service delivery. The economic meaning of efficiency is manifested in the following principles:

Evaluation of the ratio between results and costs – analyzing the amount of resources spent to achieve a specific outcome;

Obtaining maximum benefits with minimum costs – the core criterion of economic efficiency is precisely the benefit-to-cost ratio;

Degree of resource utilization – efficiency increases when resources are used rationally and without waste.

In economic literature, efficiency is generally considered in two main forms:

Technical efficiency – the indicator of obtaining the maximum possible output or service from available technological resources;

Economic (financial) efficiency – expressed through financial indicators such as profit, income, and profitability.

For example, in the drinking water supply system, efficiency is assessed not only by the increase in delivery capacity or the reduction of network losses, but also through indicators such as the economic return on resources, consumer affordability, and investment payback. The concept of efficiency plays a crucial role in economic management, as it serves as a key criterion in decision-making, strategy development, financing, and monitoring systems. In building a competitive economy, the optimal use of resources in every sector constitutes the foundation of sustainable economic development.

Water supply services represent a complex infrastructure system aimed at delivering drinking and technical water to the population, social sector institutions, and branches of the economy, as well as providing sewerage services. These services play a critical role in maintaining the standard of living, meeting sanitation and hygiene requirements, and supporting the effective functioning of economic activities.

Water supply services are generally divided into the following main types:

Centralized drinking water supply – a system that ensures the delivery of water through pipelines in cities and large settlements. Water is drawn from underground or surface sources, treated in specialized purification facilities, and then distributed to consumers via pipeline networks. Although this system requires high capital and operational expenditures, the service quality remains stable and under constant control.

Decentralized (autonomous) water supply – usually applied in rural areas and individual households through wells, artesian pumps, or water transportation. While the initial costs may be relatively low, the quality and safety of services are not always consistently guaranteed.

Technical (industrial) water supply – designed to meet the needs of industry and agriculture, utilizing water that does not meet drinking quality standards. Although technically and economically less costly, this system is subject to stricter ecological and safety requirements.

Sewerage and wastewater treatment services – include the collection, removal, and treatment of consumed and used water. Sewerage systems are based on advanced technologies and are of great importance from the perspective of environmental protection, requiring substantial long-term investments.

Efficiency Assessment of Drinking Water Supply

The assessment of the efficiency of drinking water supply refers to the quantitative and qualitative analysis of infrastructure conditions, financial resources, management systems, and service quality.

The methodological principles of assessment are as follows:

Comprehensive approach – conducting systematic analysis based on technical, economic, ecological, and social criteria;

Consideration of regional and functional differences – accounting for variations between urban and rural areas, as well as between public and private sectors;

Measurability and comparability of indicators – ensuring that all indicators can be expressed quantitatively and compared against each other;

Principles of sustainability and efficiency – emphasizing the effective use of resources in the long term.

Key Directions and Indicators of Assessment

Technical efficiency indicators – evaluate the physical condition of infrastructure, operational performance, and the level of service delivery. One of the critical measures is the water loss rate, expressed as the percentage difference between the volume of water produced and the volume actually delivered to consumers.

Economic efficiency indicators – analyze the financial sustainability of water supply services, cost-effectiveness, and the justification of service tariffs.

Ecological efficiency indicators – measure the level of environmental impact on water sources and ecosystems, waste management systems, and the methods of utilizing natural resources.

Social efficiency indicators – consider population access to water supply services, the degree of convenience, and consumer satisfaction with the services provided.

International standards based on SDG 6, WHO, and OECD guidelines provide an opportunity to evaluate the global efficiency, sustainability, and equity of drinking water and sanitation services. Global institutions such as the United Nations (SDG 6), WHO-UNICEF Joint Monitoring Programme (JMP), and OECD have developed indicator systems assessing water supply from different dimensions. The United Nations Sustainable Development Goal 6 emphasizes: “By 2030, achieve universal and equitable access to safe and affordable drinking water and sanitation for all.”

Table 1. Classification of Key Indicators[1]

№	Indicator Code	Definition
1	6.1.1	Proportion of population using safely managed drinking water services (%)
2	6.2.1	Proportion of population using safely managed sanitation services (%)
3	6.3.1	Proportion of safely treated wastewater (%)
4	6.4.1	Efficiency of water use (GDP per cubic meter of water use, $/m³)
5	6.4.2	Level of water stress (ratio of water withdrawal to available resources, %)

1 WHO & UNICEF. (2023). Progress on household drinking water, sanitation and hygiene 2000–2022: Special focus on gender. Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP).

6	6.5.1	Degree of integrated water resources management implementation (0–100 index)
7	6.a.1	Amount of international financial flows to water and sanitation services ($)
8	6.b.1	Degree of participation of local communities in water resources management

SDG 6 indicators evaluate not only the availability of drinking water but also:
water quality;
water reuse and recycling;
economic efficiency;
quality of governance;
equitable distribution.
The Joint Monitoring Programme (JMP), maintained by WHO and UNICEF, is the global monitoring system for drinking water, sanitation, and hygiene.

Table 2. Core Indicators for Drinking Water (Detailed for 6.1.1)[2]

№	Service Level	Definition
1	Safely managed service	Drinking water from a safe source, available at home, continuous and free from contamination
2	Basic service	Safe water source available within 30 minutes round trip
3	Limited service	Water collection requires more than 30 minutes per trip
4	Unimproved service	Water from open sources (rivers, canals) or contaminated wells
5	No service	No available water source

Additional indicators:
Water quality: microbiological safety, nitrate and heavy metal content;
Network reliability: frequency of interruptions (hours/day);
Household access: proportion of households connected to piped water.
According to OECD, water resources governance and service efficiency assessments are based on a system of political, economic, and managerial indicators.

Table 3. Main Indicator Blocks[3]

№	Dimension (Focus Area)	Indicators (Examples)
1	Effectiveness	Existence of water strategy, degree of achieving strategic targets
2	Efficiency	Ratio of water tariffs to costs, subsidy levels, affordability, return on investments
3	Trust & Transparency	Customer satisfaction, community participation, transparency in management
4	Water Loss Indicators	Percentage of identified technical and commercial losses in the network
5	Service Reliability	Share of uninterrupted services provided
6	Infrastructure Modernization	Share of upgraded water infrastructure facilities

Additional indicators:
Water quality: microbiological safety, nitrate levels, and heavy metal content;
Network continuity (hours/day);
Household connection rate to water supply.
The OECD has developed a system of political, economic, and governance indicators to assess the efficiency of water resource management and related services.
International indicators allow for the evaluation of drinking water supply not only in terms of availability, but also in relation to its quality, sustainability, economic justification, and governance standards. In scientific research, these indicators make it possible to conduct international comparisons, assess Uzbekistan's situation within a global context, and develop evidence-based recommendations.
The following scientific and practical methods are widely applied for an in-depth analysis of efficiency:

2 https://washdata.org
3 OECD. (2022). The water governance indicator framework: Measuring performance in water supply services. OECD Publishing

Table 4. Analysis of Achieved Efficiency through Scientific and Practical Methods[4]

№	Method Name	Description
1	SWOT Analysis	Identifying the strengths and weaknesses of the water system, as well as opportunities and threats
2	Data Envelopment Analysis (DEA)	Determining relative efficiency based on resources and outcomes (multiple objects compared)
3	Cost-Benefit Analysis (CBA)	Comparing the benefits and costs for each investment or project
4	Benchmarking	Comparative assessment with countries or regions that have advanced experience
5	Key Performance Indicators (KPI)	Identifying and monitoring key efficiency indicators in the water sector

Efficiency assessment of drinking water supply is usually carried out in the following stages:

Data collection – gathering technical, financial reports, statistics, and survey results;

Indicator system formation – selecting measurable indicators for assessment;

Analysis and diagnostics – evaluating the current state both quantitatively and qualitatively;

Comparative analysis – drawing conclusions by comparing across time, regions, and the international context;

Recommendation development – proposing specific measures aimed at improving efficiency.

Table 5. Real Analysis by Regions[5]

№	Indicators	Samarkand city	Pastdargom	Kattakurgan
1	Water coverage (%)	97	72	81
2	Water losses (%)	18	29	21
3	Payment discipline (%)	91	70	82
4	Continuity (hours/day)	24	16	20
5	Tariff (soums/m³)	900	900	900
6	Cost price (soums/m³)	1000	1100	950
7	Energy consumption (kWh/m³)	0.95	0.98	0.85

Table 6. Interregional Comparison of Efficiency Levels (Case of Samarkand Region)[6]

№	District/City	Technical Efficiency	Economic Efficiency	Social Efficiency	Overall Score (1–5)
1	Samarkand city	4.5	4.0	4.5	4.3
2	Urgut district	3.5	3.0	3.5	3.3
3	Kattakurgan city	3.0	2.5	3.0	2.8
4	Ishtikhon district	2.5	2.0	2.5	2.3
5	Narpay district	2.0	2.0	2.0	2.0
6	Pastdargom district	3.0	3.0	3.0	3.0
7	Bulungur district	3.0	2.5	2.5	2.7
8	Payariq district	2.5	2.0	2.0	2.2
9	Toyloq district	2.0	1.5	2.0	1.8
10	Qo‘shrabot district	2.0	1.5	1.5	1.7
11	Oqdaryo district	3.5	3.0	3.0	3.2
12	Jomboy district	3.0	2.5	2.5	2.7
13	Kattakurgan district	2.5	2.0	2.0	2.2

Evaluation by Districts in the Region (Based on Technical, Economic, and Social Criteria: 1 – low, 5 – high) The highest efficiency is observed in Samarkand city and Toyloq district.

4 OECD. (2022). The water governance indicator framework: Measuring performance in water supply services. OECD Publishing

5 “O‘zsuvta’minot” AJ Samarqand viloyati hududiy bo‘limlari hisobotlari (2023)

6 “O‘zsuvta’minot” AJ Samarqand viloyati hududiy bo‘limlari hisobotlari (2023)

The lowest efficiency is recorded in Qo'shrabot, Paxtachi, and Ishtikhon districts.

There are sharp disparities between districts in terms of technological and financial capacities, as well as the condition of infrastructure.

CONCLUSION AND RECOMMENDATIONS

The assessment of drinking water supply efficiency requires a systematic, criteria-based, and data-driven approach. This ensures not only a clear picture of the current state of the system but also creates the foundation for scientifically grounded decision-making aimed at its improvement. The results of the evaluation play a critical role in water resource management, investment planning, and ensuring principles of social equity.

Reliance on a reliable statistical information base is essential for the accuracy and scientific validity of the assessment. The integration of national and international databases will make analytical work more comprehensive and in-depth.

In Samarkand region, there are significant territorial disparities in drinking water supply. The difference between the urban center and some developed districts (Toyloq) and remote rural areas (Qo'shrabot, Paxtachi) reaches up to threefold. The root causes of inefficiency include technological obsolescence, financial shortages, and delays in implementing infrastructure development plans.

Recommendations for improving the efficiency of drinking water supply:

Adopt a regionally differentiated approach. Separate infrastructure programs should be developed for districts with low efficiency, ensuring a targeted approach tailored to local conditions.

Expand cooperation with donors and international financial institutions. Attracting foreign investment into drinking water projects can strengthen technical and financial capacities.

Introduce modern technologies. Remote-controlled systems for monitoring water pressure and consumption in real time will help prevent losses and improve efficiency.

Promote water culture among the population. Large-scale awareness and educational campaigns should be conducted, especially in water-scarce districts, to encourage responsible water use.

Ensure universal installation of water meters. This will enable better identification and regulation of water losses, while also encouraging consumers to save water.

Prioritize modernization in rural areas. This will reduce disparities between urban and rural areas in terms of water pressure and quality, ensuring equal access to services.

Introduce renewable energy solutions. In particular, powering pumping stations with solar panels will provide an environmentally friendly and economically efficient alternative.

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Proofreader: Zokir ALIBEKOV

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