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Challenges and Innovations in Designing Underground Reservoirs for Urban Water Management

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Abstract

Drawing on the technical, environmental and social aspects of underground reservoirs, this research investigates their potential to improve urban water management. The study identifies main issues in reservoir design and deployment, analyses effectiveness of existing solutions to drought and flooding problems, and compares the application of new technologies and materials in the field, as well as considers views and attitudes of involve parties and citizens. The study used both quantitative and qualitative methods of data collection for surveys were conducted using a structured questionnaire among a diverse sample. The result implies that although underground reservoirs are agreed to be successful for water storage and flood control, technical issues like long term operation is also a critical issue. Smart monitoring systems as well as sustainable materials are as recognised as exceptional enablers of optimised operations as well as concentration. There is, therefore, general consensus that people's participation is central to the enhancement of system implementation in the projects and that community involvement has a major impact on project success. The conclusion of the paper adds to human symbolisation expertise by correlating technical design, environmental sustainability, and stakeholder impressions with efficiency of water systems in the urban context. Recommendations drawn from the study are then presented to the urban planners and policy makers especially on the use of technology in planning, designing for site and citizen engagement in the planning processes.

Keywords: Cost effective, Sustainable, Bio – concrete, Sub-surface reservoir, Flood mitigation, Ground water, Environmental, Climate change, Infrastructure

INTRODUCTION

Urban Waste Management System: An Overview

Contemporary cities have issues managing water supply and demand due to increasing urban populations and climate change. By 2050, 67% of the global population will reside in urban areas, exerting pressure on water infrastructure [18]. Consequently, cities worldwide confront water scarcity, flooding, and water quality challenges threatening human health, economic stability, and environmental integrity [20]. Rapid urbanization is intricate. Urbanization transforms natural water recharge zones, such as wetlands and forests, into urban landscapes, exacerbating surface runoff and flooding [68]. The expansion of impermeable surfaces diminishes aquifer recharge, exacerbating the water crisis. Climate change exacerbates droughts and extreme weather events due to shifting precipitation patterns [1]. Subsurface reservoirs might address these challenges. Abdeldayem et al., (2020) assert that these subterranean storage structures for excess rainfall or treated water offer flood mitigation during

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inclement weather and water supply during droughts [28]. Both Tokyo and Singapore have a few good urban water management stories to tell. The Metropolitan Area Outer Underground Discharge Channel in Tokyo has reduced flood harm and improved the water table stock [15]. Optimization of subsurface reservoirs in urban construction contributes to solving water problems and improves sustainable water utilization.

Water management strategies prioritized in urban-centric nations are becoming inadequate for addressing the challenges arising from heightened urbanization, population expansion, and climate change. Old structures represent systems that use open roof topped water storage facilities and piped surface water supply system that do not meet water demand making them prone to pollution and volatilization [58]. New more created surfaces comprises originally of non-impervious areas that prevent the infiltration and soaking of natural water in rainy seasons and does not allow water recharging when a dry climate is being experienced [41]. Therefore, the need to enhance more efficient and cost - effective technologies of water storage become imperative. Water availability has become unpredictable today, especially because of global warming which lengthens the durations of dry seasons and increases the frequency of flooding situations [54]. This has fostered the need for systems that offer water storage and with and impact towards the disasters and the allocative space. Groundwater sources are more sustainable and proven to be safe, easy to utilize and less costly for water storage in the cities. It reduces water evaporation, prevents floods and aids in water recharge so it does qualify to be called sustainable development. Contemporary urban ventilation systems present several challenges such as lack of focus on urban challenges, high costs of construction, complicated maintenance and little involvement by users in decision making about the facilities. This means that filling these gaps with, for example, the use of new ideas and approaches for water sustainability is crucial since the research is very important when it comes to urban areas.

This initiative is specifically based on water and flood practices, which are two problems associated with the increase of the population of the modern world and climate change, particularly in the development of urban areas. According to the guidelines provided by the authors in the study by Slekyanzi et al., (2024), more than half of the global population is threatened by water shocks making subsurface reservoirs a sustainable source for the expansion of urban cities. Therefore, given the emphasis on design interventions and stakeholder interpretations within this study, it is intended to provide policy-relevant information to policymakers and urban strategists. A study shows that it is plausible to capture more floodwater and store water during the dry season, with subterranean reservoirs applied consequently in Tokyo and Singapore [10]. This study also shows there is a gap in understanding and assessment by the public and professionals on the sustainability of the supporting infrastructure needed in the creation of sustainable environments. It offers guidance for incorporating photogenic effective subsurface reservoirs into urban planning, sustainable environments, and long-term urban performance.

The study exclusively focuses on primary data obtained from professionals engaged in urban water management, including urban planners, engineers, and key stakeholders actively participating in the management of water in urban environments. It examines and assesses the utilization and implementation of underground reservoirs concerning water scarcity and flooding challenges, including the function and design of subterranean reservoirs for these issues. The research focuses on the examination of urban water issues arising from urban expansion and climate change in designated urban locations (2021). Despite the advantages of innovative methodologies, the research fails to consider rural or industrial water systems. Moreover, it is restricted by the number of participants and the data they provide, thereby constraining cross-geographical generalization.

Urban Water Management Challenges

Impacts of Urbanization on Water Systems

Figure 1: Smaller cities and towns in many regions are recording faster growth in slum populations than major cities [63].

Urbanization has significantly transformed water systems, increasing the demand for water resources and altering natural hydrological cycles. Nearly 70% of the global population is expected to reside in urban areas, intensifying pressure on existing water infrastructure [63]. Although the percentage of the urban population residing in slums decreased somewhat from 25.4 to 24.2 percent between 2014 and 2020, the absolute number of slum inhabitants persists in rising due to escalating urbanization. In 2020, over 1.1 billion urban inhabitants resided in slums or comparable circumstances [63]. The population growth rate has exerted significant strain on urban water supplies, resulting in competition among human, industrial, and agricultural water demand.

Moreover, the impermeable surfaces in the metropolitan region have markedly diminished, encompassing woods and other wetlands, which are essential for natural water penetration and aquifer replenishment. Consequently, impermeable materials like concrete pavements and asphalt, exacerbating surface runoff have supplanted these surfaces during heavy rainfall events, as emphasized by Huang et al. in 2024. The diminished infiltration capability decreases water storage in aquifers, leading to both water scarcity and an increased danger of flooding in metropolitan areas [19].

Climate Change and Water Resource Stress

Regular and severe weather conditions present an additional challenge to the management of water resources in urban areas owing to climate change. The Intergovernmental Panel on Climate Change (IPCC) states that rising average temperatures, together with alterations in the frequency of rainy days, affect the characteristics and prevalence of droughts and floods globally [2]. The consequences appear to be more significant in metropolitan areas due to substantial population demands and centralized water delivery systems.

Cities like Cape Town and Chennai have experienced significant water scarcity; during the 2018 water crisis in Cape Town, the city was on the brink of "Day Zero." Conversely, Jakarta and Bangkok persistently face flooding challenges due to inadequate drainage infrastructure and elevated sea levels [12]. The two extremes illustrate the necessity for robust strategies to manage water in urban areas due to the challenges of both shortage and unregulated floods.

Need for Sustainable Water Solutions

The elements presented illustrating the realities of the water-related situation in metropolitan settings emphasize the significance of sustainable policies to regulate demand and supply and their environmental impacts. Lit blocks are extensively utilized in contemporary society, and subterranean reservoirs have demonstrated efficacy in addressing the aforementioned issues. Subterranean storage systems surpass surface reservoirs due to reduced evaporation, efficient space utilization in densely populated regions, and mitigation of excessive rainfall impacts during storms [70].

Implementing sustainable water management in urban design is essential to achieve long-lasting sustainable outcomes. In addition to traditional systems, business/partitioned subterranean reservoirs, when combined with smart sensors for monitoring and operations, provide a forward-thinking answer to the water challenges faced by modern communities. They also facilitate Aquifer Recharge, hence reducing reliance on the central Water Supply System. Integrated Water Resources Management (IWRM) aims to utilize water resources efficiently and sustainably [38].

This section illustrates the necessity of planning and integrated aquatic solutions, especially subterranean reservoirs, for the resilience of urbanization, acknowledging the connectivity and impact of dual shocks: urbanization and climate change on water systems. It not only helps ease existing problems but also prevents issues from going into the domain of sustainability, which makes its area very important in the context of urban water management.

Underground Reservoirs: An Overview

Definition and Functionality

Underground reservoirs are human-made structures designed for subterranean water storage and serve as ecologically sustainable solutions for urban water issues. These reservoirs consist of substantial concrete or steel tanks or tunnels that retain and subsequently employ rainwater from precipitation, stormwater, or pre-treated water [31]. They are subterranean, enabling their placement in densely populated urban areas due to the spatial limitations associated with surface reservoirs.

In an effort to understand the work duties of subsurface reservoirs, they may be defined into a basic two forms. The delivery of portable water, management of is irrigation and water storage systems. They are notably efficient in moving surplus rainfall during a storm, thus augmented flood control in developed metropolitan regions. Simultaneously, it functions as a water reservoir: That is, water may be stored in such sources at any given point in time or during a certain period of time when demand for the water is relatively low [27]. Due to their multiple uses, subsurface reservoirs form a critical element in planning water distribution in modern urban society.

Current Practices and Applications

Numerous locations have used various modifications to integrate subsurface reservoirs to meet their water requirements. Notable civil engineering projects include Tokyo's Metropolitan Area Outer Underground Discharge Channel, designed to mitigate flooding in a major global city (He et al., 2024). This specialized deep basement infrastructure comprises five underground silos and one central water route, significantly mitigating flood catastrophes in the Tokyo Metropolitan region since its implementation [45].

Similarly, Singapore's Marina Barrage utilizes subterranean water reserves for flood management and water supply objectives. A system gathers water from an extensive drainage region for distribution and manages floods during the rainfall season. Marina Barrage has been acknowledged as a model of sustainable urban water management, demonstrating that technical solutions may simultaneously address issues of water scarcity and floods [8]. Similar to other case studies, these exemplify the viability of subterranean reservoirs for urban environments and their adaptability to geographical and climatic variations.

Benefits and Limitations

Subterranean reservoirs offer several benefits compared to conventional water storage methods. They initially enhance space usage, which is crucial in urban regions characterized by constrained and costly space. The subterranean sites of cities provide online water storage without impacting surface infrastructure such as highways, parks, and open spaces [. Secondly, they significantly reduce evaporation in open water storage systems, prevalent in both rural and developed nations. These techniques facilitate the reintroduction of water into aquifers, enhancing regional water sustainability [35].

Nevertheless, the subterranean reservoirs seem to obscure transparency. These systems are costly to construct because of engineering, excavation, and resource utilization. The combination of capital expenditures, maintenance, and operating costs, without mitigating measures, escalates the entire expense level, necessitating professional skills and advanced tools and technology. Constructing these structures to endure the pressures and strains inherent in urban areas is challenging [4].

Enhanced alternatives can be transferred below; subterranean reservoirs provide specific advantages over surface capacity but present challenges, hence a simpler but more advantageous development of above-water storage systems. When appropriately planned, financed, and equipped with contemporary technology, they can mitigate flood intensities and address water supply deficiencies.

Conceptual Framework

Figure 2: Conceptual Framework. (Source: Author)

This research aims to evaluate several issues, including technical design and infrastructure support, environmental aspects and concerns, cost and affordability, and public perception of urban water management.

Consequently, Technical Design and Infrastructure are crucial in evaluating the operational efficiency of subsurface reservoirs. The management of excess water storage and flood protection infrastructure may rely on system design, engineering, and information technology, including smart sensors and automated systems [43]. What is the necessity of sustainable design tailored particularly for urban environments?

Environmental Sustainability investigates the impact of subterranean reservoirs on ecological objectives. These techniques mitigate surface water runoff, replenish groundwater, and diminish evaporation, promoting sustainable urban development [49]. According to the IPCC and WHO (2020), climate mitigation also seeks to enhance water supply and urban rainwater management in response to increasing shortages.

The creation, maintenance, and long-term performance of subterranean reservoirs are analyzed in terms of economic feasibility. Significant construction costs are common; however, investments in flood damage mitigation and reliable water supply might warrant these expenses [21]. Policymakers and urban planners require this variable to evaluate project feasibility.

This indicates that stakeholder perceptions significantly influence the acceptance and implementation of subsurface reservoirs. Urban design, engineering, policymaking, and public stakeholders must perceive these systems as advantageous and sustainable. Nygaard et al. (2021) assert that stakeholder engagement enhances the adoption of water management innovations by tailoring them to area requirements. These metrics offer a comprehensive theoretical framework for evaluating subsurface reservoir performance and suitability as urban water management alternatives [42].

Innovations in Underground Reservoir Design

Advanced Materials and Technologies

Contemporary materials and technology have improved tubular reservoirs, resulting in distinctive subterranean containers. Intelligent sensors and automation are employed to enhance performance and structure. Intelligent sensors track water levels, flow, and infrastructure to facilitate maintenance and resource management [25]. They predict and regulate water surges throughout the rainy season, enhancing flood management.

Advanced composite materials, such as high-strength concrete and corrosion-resistant metals, enhance durability and reduce maintenance requirements. Nanotechnology coatings facilitate leak prevention and enhance the durability of reservoir walls [57]. Prefabricated modular construction conserves time and resources. Methodologies enhance the durability of urban subterranean reserves.

Case Studies of Innovative Projects

Due to the distinct challenges related to water management in certain locations, the designs need suitable innovation. The Metropolitan Area Outer Subterranean Discharge Channel in Tokyo is renowned as a premier example of innovative engineering for subterranean water management. This system employs reinforced silos and advanced monitoring systems to manage severe flooding and thereby reduce losses in the metropolitan area [9].

Similarly, Singapore's Marina Barrage integrates advanced technology with many functionalities. Automation systems regulate water level management, facilitate flood control, and ensure water supply in reservoirs. This has garnered praise for its ingenuity and use in urban water resource management, ensuring reliability in an area with limited water resources [69]. All these case studies indicate the necessity for tailored site-specific design on subsurface reservoirs and advanced technologies to enhance the outcomes.

Future Trends

Technological advancements are expected to enhance the flexibility of urban water storage re-establishment during the next five years. Machine learning and artificial intelligence are employed to modify water service supply by changeable demand and anticipated occurrences [14]. These technologies will enhance water management and decision-making processes.

This study indicates that bio-concrete and recycled aggregates are utilized in construction projects to mitigate environmental effects. Recently designed green infrastructure amalgamates underground water systems with vegetative surfaces [53]. They enhance urban quality by advocating for water management objectives.

Advanced pumping and filtering technology represents a significant breakthrough. The former reduces operational costs and improves subsurface reservoir sustainability, while the latter promotes reservoir availability. In a progressively urbanized society, emerging technologies will profoundly influence water management systems to address climate change [56]

Advancements in materials, technology, and design are enhancing the efficiency of underground reservoirs, rendering them optimal for urban water management. Contemporary techniques assist urban areas in addressing water challenges responsibly, facilitating a sustainable future.

Public and Stakeholder Perceptions

Importance of Stakeholder Engagement

The rationale of subsurface reservoirs and the execution processes necessitate the engagement of the relevant parties. Decision-makers, civil engineering specialists, urban planners, and the public are all significant contributors to the feasibility and desire to implement these projects. The engagement of stake-holders aids in assessing the alignment between the design and objectives of subterranean reservoirs and the requirements of the urban environment [33]. Regulators and financiers establish investment policies, while engineers assess technological feasibility and public support, ensuring the ongoing utilization of these systems. Engagement not only enhances the fundamental principle of implementation efficiency but also fosters a shared sense of responsibility and trust.

Public Perception of Underground Reservoirs

Underground reservoirs are broadly acknowledged owing to a shift in public attitude. The understanding of their roles and benefits, such as in flood management or sustainable water usage for urban populations, is comparatively inadequate. Evidence indicates that individuals are more inclined to endorse such initiatives when they recognize the advantages related to their water security and climate adaptation [24]. Nonetheless, disputes around elevated building expenses and potential environmental disturbances continue to hinder popular acceptance. All these challenges necessitate educational initiatives and interactions with the groups who seek information.

Addressing Stakeholder Concerns

Social difficulties emerge, encompassing environmental repercussions, anticipated costs, and perceived advantages of subterranean reservoirs. Environmentalists may contest the presumed environmental ramifications of erecting structures referred to as First Nations' archaeology or Indigenous nations' terraforming [23]. Consequently, engineers and urban planners need to address these issues by providing substantial evidence of the long-term benefits associated with reduced flood damage, enhanced access to water supplies, and greater sustainability. Transparent discussions on the required maintenance, associated expenses, and necessary procedures in the event of a tragedy can alleviate difficulties.

Strategies for Effective Collaboration

For the pipeline to function effectively, it is imperative to build confidence and transparency in the planning and processes concerning subsurface reservoirs. The researcher observes that proficient management of stakeholders' interests necessitates regular meetings, stakeholder engagement in decision-making, and the establishment of feedback mechanisms. Incorporating cultural elements, such as involving local populations in the design process and offering frequent project updates, may be effective in fostering trust. The Marina Barrage project in Singapore demonstrates that effective initial and ongoing communication with stakeholders contributes to successful implementation and support [29].

It is essential to identify and connect with the public and stakeholders to elucidate and garner support for subterranean reservoirs to ensure their efficacy. The inclusion of all stakeholders from the first phases of a project enhances project outcomes and fosters a sustainable system for managing water in urban environments.

Research Gaps

Identified Gaps in Existing Literature

Nevertheless, a survey of the existing literature reveals several gaps that require addressing this subsurface option for the effective and sustainable management of metropolitan centers in the industrialized world. Initially, there exists a limited sensitivity to urban surroundings and diverse interests among stakeholders, including policymakers, engineers, and the general populace. Numerous studies emphasize technological and environmental solutions that facilitate implementation, but prospective stakeholders and their perceptions are frequently regarded as peripheral factors [60].

Secondly, there is a deficiency of long-term performance data about the consequences of subterranean reservoirs in diverse metropolitan environments. Contemporary real-world instances, such as Tokyo's Metropolitan Area Outer Underground Discharge Channel, demonstrate efficacy just in the short term as a flood management strategy [40]. Nonetheless, their enduring durability, maintenance, and adaptability to various metropolitan requirements remained uncertain.

Research fails to offer a definitive understanding of technical, environmental, and economic challenges. Previous studies have examined the aforementioned characteristics individually; however, their influence on the productivity and lifetime of subterranean reservoirs remains largely unexplored [51].

Importance of Addressing These Gaps

This paper aims to provide a comprehensive analysis of UGR concerning urban water management. The integration of stakeholder perspectives enhances the understanding of public and expert opinions and facilitates broader community involvement in policy decision-making [52]. It also evaluates performance throughout utilization concerning stability, sustainability, viability, and adaptability in use within the urban built environment.

The findings of this research are crucial for evaluating subsurface reservoirs using an integrated approach that incorporates technical, environmental, and economic metrics. This technique may augment the fundamental academic literacy for research endeavors and provide pragmatic implications beneficial to urban planners and policymakers regarding the enhancement of sustainable and resilient water management in urban environments [65]. The inadequacies are outlined to ensure the feasibility of more effective and contextually appropriate designs and implementations of subsurface reservoirs in the future.

This section addressed topics and developments related to underground reservoir infrastructure within urban water systems, encompassing design challenges, innovations, and potential opportunities. The challenges of water shortages and flooding necessitate sustainable solutions, influenced by population increase, urbanization, and intensified climate change. Analyst the operational mechanisms of subsurface reservoirs, their advantages and disadvantages, as well as innovative technologies and contemporary materials that might enhance their efficiency and suitability for urban applications. Tokyo and Singapore demonstrated their capabilities in urban water system systems. The section emphasized the significance of public and stakeholder engagement during adoption to mitigate resistance. Emphasize environmental, economic, and social responsibilities to get stakeholder support. The inadequacy of research on urban-specific concerns, the absence of historical performance data, and the deficiency of a comprehensive approach render this study pertinent. Consequently, the conceptual framework assesses subsurface reservoirs from technical, environmental, economic, and stakeholder perspectives. This study will assist policymakers and urban planners in developing sustainable and resilient water management systems for urban populations by addressing these gaps, yielding both practical and theoretical advantages.

MATERIALS AND METHODS

This section briefly outlines the researcher's approach to delineating the dynamics of obstacles and innovation in the development of underground reservoirs for urban water management. Consequently, it establishes the research philosophy, methodology, design, data collection techniques, sampling procedures, and analytical approaches utilized to fulfill the study objectives. The research has been quantitative to derive inferences from stakeholder opinions and technical data while maintaining reliability and validity. This facilitates the formulation of a strategy to address the research gaps identified in this work.

The research is grounded on positivism, which asserts that truth exists outside and can be discovered. This research uses measurement of identified concerns and development of improvements for subterranean storage or reservoir, particularly adopting the positivist epistemology [72]. As a result, this helps to solicit stakeholder views with survey questions considering technological and economic as well as environmental issues.

Interpretivism captures an epic perspective on processes while positivism wants the hypothesis formation and generalizability of results to meet the purpose of the study. This data enables establishment of a sphere of dependability and repeatability in the viability and implementation assessment of underground reservoirs in urban areas (Mohandes, et al., 2024). This research philosophy uses science to address the research gaps and improve practical and theoretical understanding.

This study quantitatively analyzed the development challenges and concepts of subsurface reservoirs at a numerical level to achieve statistical results. Thus, the study objectives are to assess both subjective experiences and objective outcomes by means of quantification of the findings in order for them to be applicable to the overall community of the subject. This approach improves the collection of structured questionnaire data, estimates the liberalization of technologies, offers a cost-benefit test, and measures acceptance by society.

Quantitative work is more appropriate for this research as it assumes suitability in subsurface reservoir hypothesis testing and understanding of stakeholder perceptions. Qualitative research mainly focuses on analyzing the data, and on the other hand, quantitative research provides more accurate results concerning the objectives of the study [39]. This method aids the study's objective of implementing the present theory and addressing the purported deficiencies in the literature, rather than advancing the urban water management theory.

This study uses survey data to present a contextual analysis of underground reservoir development and challenges related to water distribution in urban environments. Exploratory research is optimal for examining novel phenomena, such as stakeholders' opinions of reservoir designs utilizing developing technology [61]. This constructive technique facilitates the identification of novel patterns and the necessary discoveries in the pursuit of research objectives.

Exploratory research effectively full-fill the study objective by elucidating the technical, environmental, and economic dimensions of subsurface reservoirs. The design is methodically employed to gather measurable data, stakeholder feedback, and technological requirements for the implementation of new trends. This study design is distinctive due to its integration of technical methodologies and qualitative insights from stakeholders. The concept links major catastrophic urban water management issues to research and may enhance practical solutions. Kushwaha (2024) [26].

This research utilizes questionnaires to deliver statistical assessments of the experiences and advancements attained in subsurface reservoir design. Survey research necessitates extensive collaboration, maybe facilitated by questionnaires, likely including planners, engineers, or policymakers [30]. The framework is systematically employed to compile technical, environmental, and economic data for quantitative research analysis.

The survey employs closed-ended Likert scales to evaluate stakeholders' perspectives. The research has also explored recent technological difficulties and community acceptability of subsurface reservoirs. Online surveys were deemed efficient and readily accessible [37]. It encompasses stakeholders' viewpoints and potential discrepancies in local subsurface reservoir development with significant reliability and relevance.

The target demographic for this study comprises those involved in the urban water system, including planners, engineers, politicians, and anyone interested in water management in urban settings. The sample comprised 50 persons to mitigate subjectivity in the data processing; this sample size was deemed sufficient for variety. The existing number of respondents seems adequate to analyze the distribution of opinions and trends within the specified target audiences and to conduct fundamental statistical tests to address the proposed research topics [17].

This research involved the use of non-probability sampling and more specifically purposive sampling in order to sample the most appropriate volunteers for the study. This technique is justified because it enabled the authors to get information from the insiders engaged in the design or implementation of subsurface reservoirs [47,48]. Therefore, the research focuses on this special population to ensure the creation of quality data in the use of understanding the technical, environmental, and economic effects of creating subsurface reservoirs.

Survey data has been examined using SPSS to provide valid statistical inferences. The study methodologies encompass Pearson correlation analysis, multiple regression analysis, and frequency analysis. These methodologies provide empirical data on variable interactions and are hence most appropriate for quantitative research such as this study [34].

Econometric methods, including regression analysis, have been employed to examine technological constraints and stakeholder views about the effectiveness of water management in urban environments. Intermediate data analysis is utilized to quantify the correlation between environmental sustainability and stakeholder acceptance by employing the coefficient of determination as outlined by Baah et al. (2021). This research uses analytical tools to uncover issues and advances in subsurface reservoir design. They consolidate stakeholder concerns and establish technology foundations for concepts [6].

Concerning the latter criteria, the authors employed a survey instrument and evaluated its reliability by administering it to a subset of participants to examine the consistency of their responses to the questions [3]. This method not only popularized the survey but also sought to eliminate ambiguity and errors. The survey's validity was confirmed by aligning the planned questions with technical, environmental/external, and internal economic concerns that corresponded with the study goals [32]. The measures were used to minimize sampling bias; participants were guaranteed anonymity, therefore providing authentic responses to the enquiries; response bias was mitigated by the application of a standard Likert scale. The reliability and significance of the study's findings are enhanced overall.

The study adhered to these principles to assure the credibility of the participants. In each survey, assent from the student participants was acquired following the completion and signing of a written consent form. The students were informed the intended and actual purpose of the study and were informed of their rights to opt out of the study at their own discretions [22]. To ensure participant's identity was protected, the collected information was coded and all recorded responses was ensured to be kept very secure. Privacy controls and matters met needs of over 95 percent of data organizations and regulations that protect both electronic and physical copies from unauthorized access. The study followed ethical measures by Creswell to limit participant sensitivity and risks that participants encounter [46].

This section describes the method used in this study including the choice of positivism epistemology, the quantitative research strategy and the exploratory study aimed at identifying challenges and coming up with subsurface reservoir design. The study focused on data collecting technique, which involved using a survey and a respondent rate of 50 people. In the current tutorial, the notions of regression and subsequent data analysis with a focus on correlation as well as frequency analysis using the SPSS, reliability, validity, and ethicalities were explained. It implies that the above approaches are appropriate for the study's objectives of offering real and usable information. This section build upon and analyze the findings generated from this methodological approach and research objectives of the study.

Table 1. Table Caption – Capitalize All Words Like a Title.

		Count	Column N %
Age	Under 18	0	0.0%
	18-24	25	24.8%
	25-34	53	52.5%
	35-44	17	16.8%
	45+	6	5.9%
Gender	Male	52	51.5%
	Female	41	40.6%
	Prefer not to say	8	7.9%
Education	High School	4	4.0%
	Undergraduate	48	47.5%
	Post Graduate	45	44.6%
	Diploma	4	4.0%

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The studies concerning the demographic profile reveal that it is generally young participants since 77.3% of them are between 18 and 34 years old. Male represents a majority of 51.5% of the respondents while females represent 40.6% and 7.9% are not sure about their gender preference. Importantly, education levels of respondents suggest that sample is highly educated with 47.5% having an undergraduate, 44.6% postgraduate education. High school education or diploma is the most educated (8 percent) level of education among Jamaica's population. This demographic structure has a suggestion of a young population, likely a more educated population and thus one that would likely be more knowledgeable in regard to the subject matter of study. These attributes ensure the basis of reliable responses however, further research could target gender and especially age corpus diversification.

Frequency Analysis

This approach provides insight into the participants' overall perception of the effectiveness of urban water management. A total of 79.3% expressed agreement or strong agreement with the adequacy of current urban water systems in addressing water scarcity, with the majority expressing confidence in the existing infrastructure. Similarly, 80.2% of respondents approved the infrastructure's performance during heavy rains in preventing flooding in neighbouring areas, while 13.9% expressed displeasure, showing potential for further enhancement.

Table 2. Efficiency of Urban Water Management frequency table.

Efficiency of Urban Water Management			
		Count	***Column N %***
Urban water management systems in my city effectively address water scarcity challenges.	Strongly Agree	35	34.7%
	Agree	45	44.6%
	Neutral	8	7.9%
	Disagree	10	9.9%
	Strongly Disagree	3	3.0%
The current urban water infrastructure efficiently prevents flooding during heavy rainfall.	Strongly Agree	40	39.6%
	Agree	41	40.6%
	Neutral	6	5.9%
	Disagree	11	10.9%
	Strongly Disagree	3	3.0%
Subsurface reservoirs significantly contribute to sustainable water management in urban areas.	Strongly Agree	40	39.6%
	Agree	33	32.7%
	Neutral	14	13.9%
	Disagree	12	11.9%
	Strongly Disagree	2	2.0%
The implementation of advanced technologies has enhanced the efficiency of urban water management systems.	Strongly Agree	40	39.6%
	Agree	42	41.6%
	Neutral	8	7.9%
	Disagree	9	8.9%
	Strongly Disagree	2	2.0%
Urban water management practices in my city are well-aligned with sustainable development goals.	Strongly Agree	41	40.6%
	Agree	31	30.7%
	Neutral	15	14.9%
	Disagree	10	9.9%
	Strongly Disagree	4	4.0%

Distribution of participants by nation about the percentage of voluntary remarks on underground reservoirs and water management Participants have reported a 72.3% global acceptance of subsurface reservoirs for sustainable water management. Advanced technological solutions in water management receive significant endorsement, with 81.2% of participants acknowledging their role in enhancing system efficiency, indicating a necessity for further research.

Regarding alignment with the notion of sustainable development, 71.3% of participants exhibit positive attitudes; nevertheless, 18.9% remain ambivalent or dissenting, indicating significant disparities in awareness and practical implementation. Substantial data indicates advancements in the administration of urban water systems; nonetheless, there is also evident dissatisfaction necessitating focused changes and the enhancement of overall sustainability.

Table 3. Technical Design and Infrastructure frequency table.

Technical Design and Infrastructure			
		Count	***Column N %***
The design of subsurface reservoirs in urban areas meets the needs of water storage and flood mitigation.	Strongly Agree	37	36.6%
	Agree	40	39.6%
	Neutral	9	8.9%
	Disagree	14	13.9%
	Strongly Disagree	1	1.0%
The integration of smart technologies improves the operational efficiency of underground reservoirs.	Strongly Agree	45	44.6%
	Agree	32	31.7%
	Neutral	15	14.9%
	Disagree	8	7.9%
	Strongly Disagree	1	1.0%
Technical challenges significantly influence the long-term reliability of underground reservoirs.	Strongly Agree	41	40.6%
	Agree	38	37.6%
	Neutral	10	9.9%
	Disagree	9	8.9%
	Strongly Disagree	3	3.0%
Urban water infrastructure designs are adequately tailored to local environmental conditions.	Strongly Agree	33	32.7%
	Agree	40	39.6%
	Neutral	15	14.9%
	Disagree	10	9.9%
	Strongly Disagree	3	3.0%

The view regarding the favourable perception of subsurface reservoir designs appears to be broadly positive with 76.2% endorsing the statement indicating that there is an adequate provision in this respect for water storage and flood control The remaining 14.9% Therefore express concerns and thereby providing a scope for improvements. High approval is granted to integrate smart technologies with 76, 3% respondents agree that the use of smart technologies helps to enhance operations efficiency; while 14, 9% of the respondents are having no opinion. Thus, technical problems are accepted as one of the potential hurdles in long term reliability of the underground reservoirs, 78.2% admitted that, need better solution to control these problems. Ideas concerning adaption of designs to the local conditions, 72.3% are satisfied or somewhat satisfied and only 12.9% disagree that make the level of satisfaction moderate not very high. The role and evolution of urban water infrastructure is most successfully met in terms of technical and design relevance while key challenges to inform its current advancement lie in the arenas of technical reliability and fit with local conditions.

Table 4. Environmental Sustainability Frequency Table.

Environmental Sustainability			
		Count	***Column N %***
Urban water infrastructure designs are adequately tailored to local environmental conditions.	Strongly Agree	33	32.7%
	Agree	40	39.6%
	Neutral	15	14.9%
	Disagree	10	9.9%
	Strongly Disagree	3	3.0%
Underground reservoirs play a vital role in replenishing groundwater resources.	Strongly Agree	54	53.5%
	Agree	36	35.6%
	Neutral	5	5.0%
	Disagree	4	4.0%
	Strongly Disagree	2	2.0%
The use of sustainable materials in reservoir construction reduces environmental impacts.	Strongly Agree	44	43.6%
	Agree	40	39.6%
	Neutral	8	7.9%
	Disagree	7	6.9%
	Strongly Disagree	2	2.0%
Subsurface reservoirs contribute to reducing evaporation and conserving water resources.	Strongly Agree	36	35.6%
	Agree	44	43.6%
	Neutral	9	8.9%
	Disagree	11	10.9%
	Strongly Disagree	1	1.0%
Urban water management systems effectively balance environmental preservation and water usage.	Strongly Agree	44	43.6%
	Agree	42	41.6%
	Neutral	7	6.9%
	Disagree	7	6.9%
	Strongly Disagree	1	1.0%

The paper establishes a robust basis for an optimistic perspective on environmental sustainability in urban water management. A slight majority (72.3%) of respondents concur that infrastructure designs account for local environmental conditions, while 12.9% expressed reservations. There is unanimous consensus that subterranean reservoirs are the most acknowledged factor for groundwater replenishment, with 89.1% endorsement. A notable factor with a high appreciation index is the use of sustainable elements, as 83.2% of respondents expressed concern regarding reduced environmental destruction. In relation to the conservation of water via subterranean reservoirs, 79.2% of respondents expressed support, while 11.9% remained critical. Regarding the preservation or utilisation of urban water systems, 85.2% of respondents had a favourable opinion. These outcomes signify continuous progress in sustainability while highlighting areas for additional improvement.

Table 5. Stakeholder Perception frequency table

Stakeholder Perception			
		Count	*Column N %*
Stakeholder engagement significantly influences the acceptance of underground reservoirs in urban areas.	Strongly Agree	37	36.6%
	Agree	41	40.6%
	Neutral	13	12.9%
	Disagree	8	7.9%
	Strongly Disagree	2	2.0%
Public perception is a critical factor in the successful implementation of urban water management systems.	Strongly Agree	42	41.6%
	Agree	38	37.6%
	Neutral	10	9.9%
	Disagree	8	7.9%
	Strongly Disagree	3	3.0%
The involvement of local communities enhances the effectiveness of urban water management initiatives.	Strongly Agree	46	45.5%
	Agree	38	37.6%
	Neutral	8	7.9%
	Disagree	8	7.9%
	Strongly Disagree	1	1.0%
Stakeholders perceive underground reservoirs as a sustainable solution for urban water challenges.	Strongly Agree	41	40.6%
	Agree	39	38.6%
	Neutral	10	9.9%
	Disagree	10	9.9%
	Strongly Disagree	1	1.0%

This investigation demonstrates the significance of key preferences in shaping stakeholder perceptions in urban water management. 77.2% of respondents concur on the significance of stakeholder participation in the approval of subsurface reservoirs. The public's perception is significant, since 79.2% of respondents indicated that it affects successful implementation. The efficacy demonstrated by local communities in their involvement is significantly supported at 83.1%, demonstrating that their contribution in enhancing project success is greatly recognised. Over three-quarters of stakeholders, specifically 79.2%, regard subsurface reservoirs as a sustainable alternative. Approximately 10 percent remain either noncommittal or critically noncommittal, indicating a necessity for enhanced communication and dialogue from management to comfort these employees and elucidate perceived issues.

Table 6. Economic Feasibility frequency table.

Economic Feasibility			
		Count	**Column N %**
The costs of constructing and maintaining underground reservoirs are justified by their benefits.	Strongly Agree	47	46.5%
	Agree	36	35.6%
	Neutral	6	5.9%
	Disagree	10	9.9%
	Strongly Disagree	2	2.0%
Advanced technologies used in urban water management systems are cost-effective in the long run.	Strongly Agree	42	41.6%
	Agree	41	40.6%

	Neutral	9	8.9%
	Disagree	8	7.9%
	Strongly Disagree	1	1.0%
Financial investments in urban water management systems lead to significant economic benefits.	Strongly Agree	42	41.6%
	Agree	40	39.6%
	Neutral	11	10.9%
	Disagree	6	5.9%
	Strongly Disagree	2	2.0%

Table 7. Correlation Analysis.

Correlations						
		Efficiency of Urban Water Management	***Technical Design and Infrastructure***	***Environmental Sustainability***	***Stakeholder Perception***	***Economic Feasibility***
Efficiency of Urban Water Management	Pearson Correlation	1	.796**	.738**	.621**	.627**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001
	N	101	101	101	101	101
Technical Design and Infrastructure	Pearson Correlation	.796**	1	.809**	.737**	.749**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001
	N	101	101	101	101	101
Environmental Sustainability	Pearson Correlation	.738**	.809**	1	.806**	.795**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001
	N	101	101	101	101	101
Stakeholder Perception	Pearson Correlation	.621**	.737**	.806**	1	.748**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001
	N	101	101	101	101	101
Economic Feasibility	Pearson Correlation	.627**	.749**	.795**	.748**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	
	N	101	101	101	101	101
***. Correlation is significant at the 0.01 level (2-tailed).*						

The findings indicate substantial evidence supporting the economic viability of urban waste management systems. A majority of respondents (82.1%) believe that the expenses associated with the construction and maintenance of underground reservoirs are justified, with many expressing confidences in the viability of these reservoirs. Furthermore, 82.2% regard sophisticated technology as a cost-effective approach in the long term, contributing to the economy's pursuit of sustainable innovation. Globally, there is a prevalent positive sentiment surrounding financial investments in water systems, with 81.2% believing these investments can yield substantial economic gains. In contrast, a minor proportion (7–11%) exhibit either neutrality or a negative disposition towards EVZs, indicating the presence of deficiencies in the economic rationale for EVZs that necessitate additional scrutiny.

Correlation Analysis

The results indicate a robust positive association among the diverse variables related to urban water management. The strongest correlation is observed between Technical Design and Infrastructure and Environmental Sustainability, with a value of $r = 0.809$ at $p = 0.001$. This indicates that effective technical design of infrastructure, particularly concerning water, positively correlates with enhancements in environmental conditions such as water replenishment and reduction of loss.

A substantial positive correlation is seen between the Efficiency of Urban Water Management and Technical Design and Infrastructure ($r = 0.796$, $p < 0.001$) as well as Environmental Sustainability ($r = 0.738$, $p < 0.001$). These results underscore the significance of proficient design and implementation of sustainable solutions to improve the efficiency of water management systems. Similarly, Stakeholder Perception demonstrates a significant correlation with all other variables, particularly Environmental Sustainability, with a coefficient of 0.806, $t = 29.14$, $p < 0.001$. This indicates that stakeholder engagement and public endorsement of water management systems are strongly associated with perceived environmental efficacy.

This quantification verifies that Technical Design and Infrastructure Influence Economic Feasibility as a critical component of sustainability, demonstrating a correlation of $r = 0.749$ at $p < 0.001$, while environmental sustainability exhibits a correlation value of $r = 0.795$ at $p < 0.001$. A direct correlation exists between the Efficiency of Urban Water Management and Economic Feasibility, with findings indicating $r = 0.627$, $t = 7.175$, $df = 75$, $p < 0.001$. This suggests that effective water management in urban settings necessitates consideration of economic concerns.

Regression Analysis

The model summary indicates that the predictors—Economic Feasibility, Stakeholder Perception, Technical Design and Infrastructure, and Environmental Sustainability—explain 66.2% of the variance in Urban Water Management Efficiency, with $R^2 = 0.662$. The corrected R^2 (0.648) indicates a strong match, influenced by the model's complexity and the sample size employed. The coefficient of determination (R-squared value, 0.813) indicates a strong positive correlation between the predictors and the dependent variable. The standard error of the estimate (0.5255) indicates a substantial diversity in forecast mistakes. The model demonstrates significant explanatory value, indicating that these parameters substantially influence the efficiency of water systems in urban settings.

Table 7. Model Summary.

Model Summary				
Model	***R***	***R Square***	***Adjusted R Square***	***Std. Error of the Estimate***
1	.813a	.662	.648	.5255
a. Predictors: (Constant), Economic Feasibility, Stakeholder Perception, Technical Design and Infrastructure, Environmental Sustainability				

Table 8. ANOVA table.

ANOVAa						
Model		***Sum of Squares***	***df***	***Mean Square***	***F***	***Sig.***
1	Regression	51.848	4	12.962	46.936	<.001b
	Residual	26.512	96	.276		
	Total	78.360	100			
a. Dependent Variable: Efficiency of Urban Water Management						
b. Predictors: (Constant), Economic Feasibility, Stakeholder Perception, Technical Design and Infrastructure, Environmental Sustainability						

The computed analysis of variance indicates that the regression model is statistically significant; F = 46.936, p < 0.001, signifying that the predictors—Economic Feasibility, Stakeholder Perception, Technical Design and Infrastructure, and Environmental Sustainability—substantially influence the Efficiency of Urban Water Management. The regression sum of squares was 51.848, suggesting that a significant portion of the total variation of 78.360 in the dependent variable is explained by the model. The residual variance (26.512) indicates that certain variability remains unexplained by the predictors. Consequently, the findings obtained validate the model and the selection of predictors as pertinent and robust.

Table 9. Coefficient Table.

Coefficients						
Model		*Unstandardized Coefficients*		*Standardized Coefficients*	t	Sig.
		B	*Std. Error*	*Beta*		
1	(Constant)	.255	.144		1.763	.081
	Technical Design and Infrastructure	.639	.113	.605	5.635	<.001
	Environmental Sustainability	.380	.144	.332	2.633	.010
	Stakeholder Perception	-.062	.115	-.057	-.538	.592
	Economic Feasibility	-.051	.113	-.047	-.450	.654
a. Dependent Variable: Efficiency of Urban Water Management						

The coefficients table indicates that Technical Design and Infrastructure more effectively predetermine and predict the Efficiency of Urban Water Management compared to other factors (B = 0.639, β = 0.605, p < 0.001). Environmental sustainability considerably enhances efficiency (B = 0.380, β = 0.332, p = 0.010). Nonetheless, the findings demonstrate that Stakeholder Perception has no significant influence in this model (Estimate = -0.062, t = -0.057, p = 0.592), nor does Economic Feasibility (Estimate = -0.051, t = -0.047, p = 0.654). This paper advocates for prioritizing technical and environmental issues to improve urban water management while reevaluating stakeholder and economic viewpoints.

DISCUSSION

The study shows that the proposed solution of designing underground reservoirs indeed works well for the purpose of water storage and flood management with 76.2 percent respondents' agreement; however, the issue of the technical difficulties cannot be regarded as solved. Furthermore, majorities of the respondents (78. 2%) admitted that technical problems affected reliability over the long-run and for this reason, there is need to address the problem. A correlation analysis also helps to substantiate the significance of technical design in attaining the efficiency of the urban water management (r = 0.796, p < 0.001). These findings support the work of Ansari et al. (2024), who revealed that engineering, excavation, and the usage of resources are difficulty in underwater reservoir development. The authors mentioned that due to high cost of constructing and maintaining this kind of system and technical complexities, these facilitate were also mentioned by Sadkhan and Al-Mudhafar (2024). To overcome them, stakeholders are required to put a lot of effort into high engineering standards that affect the creation of better and more long-lasting reservoirs that are applied underground. Measures like advanced manufacturing like use of modular structures and incorporation of nanotechnology coatings, described by Sinha et al., (2023) can deal with such technical challenges and enhance durability performance.

The results also shows that current underground reservoir designs in use meet or address the water scarcity issue with 79.3% of the participants agreeing with the statement that the urban water systems meet the stock. Also, 80.2% said that they are confident that the infrastructure is adequate to protect the area during a flood occasioned by a heavy rain. These observations are consistent with the ability of the reservoirs in water resources management in the urban areas under the two climatic events.

Real life examples drawn from literature include the Metro Area Outer Underground Discharge Channel in Tokyo and the Marina Barrage in Singapore where underground reservoirs have been implemented to good effect to both drought problems and flooding (He et al., 2024; Capodaglio, 2024). The relationship between technical design and efficiency of water management strengths the aspect of infrastructure in an urban setting (r = 0.796). However, there were some weaknesses noted by 14.9% of the respondents indicating that adequacy of designs in handling local environment condition was inadequate. That is why, further development of the strategies requires attention to specific urban issues and local environment conditions. There is need to use adaptive approaches including Integrated Water Resource Management (IWRM) which could build the capability of the water management systems [38].

It is acknowledged that the application of new materials and technologies is regarded as one of the key activities towards increasing the effectiveness of underground reservoirs. When it comes to pressures to use smart technologies in managing operations, there is significant endorsement of smart technologies with, 76.3% supporting the view that they enhance operations efficiency. High technologies, including intelligent sensors and automated techniques, facilitate monitoring and efficient usage of water resources, stated by Krishnan et al. (2022). Furthermore, there was great support for the utilization of sustainable materials which 83.2% opined reduced undesired effects on the environment. Used of new products include high strength concrete and corrosion resistant metals to increase the structure strength and durability, as well as decrease lifespan maintenance call for (Sinha et al., 2023). These advancements are supported by the concept discussed by Gholami-Shabani and Nematpour (2024) that manage to explain the necessity of approaching material for effective decisions about cost-efficient and sustainable water management [15]. The cost effectiveness analysis of these technologies is evident by the fact that overwhelming majority (82.2%) of the respondents agreed with the statement that advanced technologies are economical in the long run. However, 11.9% were unsure, meaning more discussion and studies need to be done to explain how initial setup costs can be Gela's initial cash outlay and how ROI will be achieved.

The perception that the stakeholders have for the underground reservoirs is of essence when it comes to implementation. The survey establishes that 77.2% of the participants share the view that stakeholder engagement has a strong impact on the uptake of these systems. The perception to the public is also important and 31 of them agreed that it contributes to the success of implementation by 79.2%. The high positive correlation between perceived environmental stewardship and actual level of environmental sustainability as measured by the coefficient of correlation (r = 0.806) supports the argument that water management policies should reflect the impression created by water. According to Nygaard et al. (2021), when those stakeholders are engaged in the design and decision-making processes more implementation occurs and combined solutions are more likely to meet the local requirements. The result showed that the natives' participation received a lot approval since 83.1% of the participant SI: The locals' participation cited on its contribution towards improving the projects outcomes. This supports the work done on the Marina Barrage project in Singapore, where stakeholder management was cited as one of the project success factors (Mahmud et al., 2024). 10% of respondents could not express a positive attitude and professors should improve their informative work and cooperation with students. Reasonable conversation on some of the advantages, disadvantages, and consequences of underground reservoirs to the environment would go a long way in addressing resentment from stakeholders.

The study has some important managerial implications for the management of water resources in cities. First, it is necessary to focus on technical problems and improvement of the underground reservoirs' stability. It builds on smart technologies and advanced materials that can demonstrate huge potential and bring more efficiency and sustainability in a business. Second, optimization of reservoir designs requires consideration of local environment conditions in the area. As suggested in the article by Huang et al. (2024), implementing adaptive and site-specific solutions improve the ability of the society to cope with climate change and effects of urbanization. Third, sustainable engagement of stakeholders and increased public awareness is vital to the effective of the water management systems [19]. The results reveal that transparency and engagement with local communities can foster trust with, and relevance to, society. Lastly, the identification of the economic advantage of underground reservoirs and enhanced technologies helps in improving acceptance. Addressing cost concerns and concerns of the financial feasibility of the innovation can be done by sharing references and pilot and case studies of other organizations researching and implementing sustainable procurement. This paper's conclusions suggest the need for a multidisciplinary approach toward technical, environmental, and social aspects of managing water in cities. Current designs and technologies show advances over previous technologies but four key areas must still be addressed: technical issues, stakeholder involvement, and adaptation of the solution to the prevailing local situation for achieving the maximum efficiency with the least negative impact on the environment of underground reservoirs. It is argued that these insights raise the knowledge base on sustainable urban water management and offer relevant advice to policy-makers and urban designers.

CONCLUSION

The purpose of this paper was to assess the feasibility of subterranean reservoirs in improving efficiency in Urban Water Management; Technical issues, Environmental Effects, Attitudes towards the concept and Economic viability. The objectives of the study were to establish the barriers to implementation of reservoirs, to examine the effectiveness of the currently used reservoir designs, to investigate potential new technologies, and to analyze the acceptance from the public. The results of this paper are significant as they contribute to the understanding of substance use disorders (SUDs) in urban water management, particularly as cities confront emerging climate-related challenges. This underscores the necessity to tackle diverse technical, environmental, and social issues in both pragmatic and theoretical frameworks for urban water resource management.

The following are some of the challenges that the study revealed about the underground reservoir design and implementation; Technical problems that affect the lasting reliability of underground reservoirs. Quite a number of the respondents (78.2%) for the fact that these are some of the challenges, thereby signifying the need to implement enhanced engineering to enhance structural strength and functionality. These findings are supported by the study by Ansari et al., (2024) who underlined that constructing reservoirs in an urban environment is a challenging task. The current designs were well defended and 79.3% strongly agreed on usability of urban water system in dealing with water shortage and 80.2% strongly agreed with their contribution to prevention of floods. However, 14.9% answered the problem of local adaptation, which is crucial due to the necessity of a more fit solution. These attest to Capodaglio's (2024) findings where site adaptations improve on endurance and efficiency among architectural designs.

Smart technologies were strongly supported with 76.3% agreeing that it enhances operational efficiency and 83.2% in favor of using sustainable materials in future. These results indicate innovative possibilities in the management of urban water resources, similar to what Gholami-Shabani and Nematpour predicted in 2024. Peculiarities of stakeholders were also greatly elicited with 77.2% concurring with the views that the perceptions of stakeholders affect acceptance, and 83.1% deemed that anybody from the community can contribute to the improvement of the success of projects [15]. This aligns with Nygaard et al. (2021) call for participation to ensure that the relevant organizational initiatives reflect the local needs and wants. These results respond to the research questions by showing technical, environmental, and social obstacles should and must be dealt to better manage urban water, as well as to support the generalizability of the study by comparing it to literature works.

This study's findings may benefit urban planners and politicians. It also emphasizes the necessity for advancing next-generation designed solutions, such as modular reservoir constructions and nanotechnology coatings, to enhance the stability of subsurface reservoirs in the future (Asamoah et al., 2024). Government officials should oversee the integration of advanced technology, such as smart sensors and automated control systems, inside the water management organization to improve operational efficiency in resource management. Site-specific designs that adapt to environmental and climatic conditions are crucial for achieving efficiency. Consequently, community interaction must be incorporated from the design phase to ensure that individuals embrace innovative solutions aligned with societal needs (Bartoloni et al., 2022). The aforementioned solutions can significantly enhance urban water management, mitigate adverse consequences associated with urbanization and climate change, and address the pertinent issues.

This study contributes to the existing body of knowledge by elucidating the interdependencies across technical, environmental, and social frameworks in urban water management. Empirical evidence demonstrates the correlation between the proposed design and system performance concerning environmentally sustainable technological design, hence advancing understanding of how materials and technology improve efficient water resource utilization (Zhang et al., 2021). The findings further enrich the current paper by deepening the comprehension of stakeholder perspectives regarding project success and the integration of sustainability.

Future studies should thus investigate more advanced materials for the sustainable construction of reservoirs, including bio composites. Investigating the extensive impacts of smart technologies on operational productivity would provide enhanced utility. Furthermore, literature on effective community engagement strategies may enhance stakeholder participation, leading to improved acceptance and implementation of urban water projects (Sigalla et al., 2021). These strategies require further examination to refine water management systems.

The inquiry contains specific limitations that may influence the generalization of the results. The approach, both the quantity of respondents and the geographical breadth of the study, limits the diversity of urban environments. Although the study presents advantages, augmenting the sample size and varying the demographic and geographic distribution of participants might enhance its applicability across many contexts (Fan et al., 2022). The data acquired was limited to participant impressions; while this information is valuable for comprehending stakeholder viewpoints, it may be influenced by prejudice. Perhaps, more confident supporting the perception-based metrics, quantitative assessment or longitudinal research could greatly add to the conclusions. The study primarily focused on underground reservoirs and their impact on the facility's water supply management, whereas alternative possibilities such as surface reservoirs or independently managed minor reservoirs were excluded from the investigation (Polomski and Wiatkowski, 2023). The level of generalization and specifics outlined here implies that the outcomes of this study can be used confidently to extend theoretical constructs and advance research in urban water management systems; this process has also revealed numerous areas for future research that would underpin optimizing the usefulness of these findings for a range of urban, environmental, and socio-economic settings.

According to the findings of this paper, further study and development of subterranean water sources should be pursued to address emerging issues in urban water supply and demand, as urbanization progresses and climatic conditions change. The study's conclusions highlight critical elements regarding the technological, environmental, and social dimensions of enhancing the efficiency, sustainability, and societal acceptance of these systems. The results facilitate the progression of sustainable urban water management due to their focus on experiential. The targeted proposals for economic transformation, such as investing in infrastructure like composite materials and intelligent systems, provide a clear pathway for urban planners and policymakers to improve water resource efficiency [66]. Moreover, public engagement emphasizes community involvement and the improvement of strategies aligned with the environmental context to boost project efficacy and subsequent sustainability. This paper describes problems and offers implementable solutions to support future more sustainable and resource-resilient urban water systems. By adopting such strategies, urban water management and supply can see considerable enhancement, Water shortages and flooding can be drastically brought on reduction while conditions in the environment may elevate in the 21st century (Tzanakakis et al., 2020). In the future successful innovation and collaboration results will help cities satisfy the necessary water management standards and build further development model for the generations to come.

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