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Exploring Perceived Factors Contributing to Poor Performance of Water Infrastructure Systems in Gauteng Province, South Africa

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Abstract.

Water infrastructure ensures public health, economic development, and social and environmental sustainability. However, various factors contribute to its poor performance, particularly in developing economies like South Africa. This review examines the factors that negatively impact water infrastructure effectiveness for achieving optimal performance. The study adopted a quantitative approach, using a structured questionnaire survey conducted among various water infrastructure management in Gauteng Province, South Africa. A descriptive survey research design was utilised to gather data. Non-random sampling was used to select 31% of the target population, resulting in a sample size of 201 respondents. The data was analysed using descriptive statistics, achieving a Cronbach's alpha of 0.775, indicating good reliability. The analysis revealed that the aging of water infrastructure, inadequate maintenance, vandalism to water infrastructure, the illegal connection of water supply, population growth, water pollution, insufficient funding, long-term planning for water supply and political interference are the major factors contributing to poor water infrastructure performance. The primary factor contributing to poor water infrastructure performance is the aging of the infrastructure. This presents significant challenges, such as reduced system efficiency and frequent breakdowns and inefficiencies in water supply systems. The findings emphasised that the government of South Africa at all levels (local, provincial, and national) prioritises investments in infrastructure maintenance, improving financial planning and resource allocation, building capacity and providing personnel training, implementing policy and regulatory reforms, and enhancing community engagement. The study recommends addressing the gap within the current water infrastructure administration challenges, policies, and applications over technological advancements.

Keywords: Water Infrastructure, Performance, Challenges, South Africa

1. Introduction

The success of infrastructure development and urban economic growth management are crucial for the future of growing economies (Kookana et al., 2020). Moreover, Aiyetan and Das (2021) enunciated that infrastructure development aims to increase economic growth and give social advantages by building roads, airports, seaports, trains, water systems, electricity, housing, and information and communication technologies. For this study water infrastructure, as a significant physical asset, was thoroughly evaluated among other types of infrastructure. Accessing safe and inexpensive drinking water is a basic human right and a pillar of sustainable development (Adeoti et al., 2023). Moreover, building sustainable water infrastructure involves designing and managing systems to guarantee that water resources are readily available of good quality, and inexpensive notwithstanding social, environmental, and economic turmoil (Henrietta et al., 2024). However, access to safe drinking water remains a concern in emerging economies. Several initiatives have been undertaken to ensure an adequate supply of potable and non-potable water and improve water infrastructure systems' overall sustainability (Asian Development Bank, 2018). Notwithstanding these efforts, numerous issues persist, such as unsustainable water infrastructure systems and distribution and poor water management. In addition, Laolang et al. (2022) pointed out that insufficient government support in financing water infrastructure remains a challenge in developing economies. Moreover, Dangui and Jia (2022) further explained water and water infrastructure are crucial for the economic growth of Sub-Saharan African countries, as evidenced by the Sustainable Development Goals (SDGs) that prioritise enhancing energy access, sanitation, health, and poverty eradication. However, Adeoti et al. (2023) and Angoua et al. (2018) indicated that despite significant efforts by developing economies in the water sector, insufficient water supply persists throughout Sub-Saharan Africa. Tseole et al. (2022) stressed that communities in Southern Africa continue to lack access to safe drinking water and adequate sanitary services. Furthermore, the high failure rates of water infrastructure exacerbate these issues, with estimates suggesting that up to 40% of water points in the region are not working. In addition, Salman-Abdou and Rajab (2023) asserted that population density in Sub-Saharan Africa significantly impacts the poor performance of water infrastructure. Also, Kaur et al. (2022) enunciated that high population density limits water infrastructure performance. Furthermore, Tadesse and Yutura (2023) pointed out that the water supply system's design and management are not effectively integrated with climate-resilient. Onyango et al. (2022) pointed out that water loss from distribution systems is a significant challenge for all water utilities, especially in emerging economies where illegal connections, meter tampering, and inaccuracies in metering contribute to higher losses. Vyas-Doorgapersad (2023) found that water infrastructure development in African countries faces challenges from migration, climate change, population growth, urbanisation, deteriorating infrastructure, insufficient water supply, poverty, inadequate financial and human resources, and inadequate maintenance. Zvobgo (2020) discovered in Zimbabwe that significant non-revenue water, inadequate maintenance, and insufficient investment resulted in widespread distribution system leaks, low water quality, and unreliable service delivery. Similarly, in Kenya, Onyango (2021) found that illegal water connections lead to non-revenue water and increased water loss in utilities. Also, Getachew et al. (2021) found that in Ethiopia, water pollution pressures arise from fast urban growth and industrialisation deprived of sufficient wastewater treatment facilities and solid waste management, coupled with agricultural activities.

Evaristo et al. (2023) asserted that as the deadlines for achieving Sustainable Development Goals (SDGs) 6 and 9 approaches set by the United Nations, the complexity of these targets becomes clear, with challenges extending far beyond basic water infrastructure and utility issues. Bulti and Yutura (2023) enunciated that rapid population growth, climate change, urbanisation, and industrialisation increase the demand for water for various purposes. However, high capital costs and inefficient project delivery have slowed planned progress. In addition, Bishoge (2021) added that water loss, corruption in infrastructure development, and a lack of expertise and technology in water utility administration pose challenges to the efficiency of the existing water system. Additionally, climate change leads to decreased water supply, while future population growth and water use increase water demand (Heidari et al., 2021). In support, Adome and Simatele (2021) highlighted that many countries, including parts of India, China, the Middle East, Mexico, the United States, Poland, Russia, and most African countries, face increased water infrastructure insufficiency. In Pakistan, Saleem et al. (2021) found that on account of climate change, rapid urbanisation, and poor water resource management hinder coping with increasing water demand, with non-resilient infrastructures being a major barrier. In New Zealand, Kirk et al. (2020) found that barriers to implementing freshwater policies stem from inadequate institutional, and social capacity and the barriers to coordinating local and national policies.

Accounting for these scenarios requires assessing the present state of the art in water infrastructure performance in South Africa, particularly in the Gauteng Province. Maphangwa and van der Waldt (2023) enunciated that Gauteng Province of South Africa is the principal commercial centre of the Republic of South Africa, consisting of three metropolitan municipalities namely the City of Johannesburg, Tshwane and Ekurhuleni with approximately 15 million of the population. However, the province faces water stress due to average annual rainfall below the global average of 363 mm, and insufficient water resources driven by economic expansion (Zubaidi et al., 2020). Moreover, Edokpayi et al. (2018) emphasised that the country's semi-arid nature and limited water resources pose significant challenges in establishing adequate water supply systems. Ruiters and Amadi-Echendu (2022) noted that South Africa faces significant investment challenges in its water infrastructure value chain, affecting resources and service provision. Also, Dithebe et al. (2019) shared that private finance is not commonly utilised in South Africa's water sector. Furthermore, Ndeketeya and Dundu (2022) highlighted that rapid urbanisation in emerging economies such as South Africa puts tremendous strain on cities to meet rising water service demands. In addition, poor quality service is exacerbated by inadequate staffing and overworked and demotivated staff which is prevalent in South African public service departments (Modise and Roberson, 2023). Similarly, Malima et al. (2022) emphasised that most South African municipalities face unsatisfactory management plans, inadequate water use planning, and insufficient conservation efforts contributing to potable water shortages. Furthermore, Kwati et al. (2022) added that ineffective management and leadership, combined with inadequate maintenance and deteriorating infrastructure, result in the inefficient operation of the potable water supply system. Munyai et al. (2023) found that municipalities struggle with proper planning for informal settlements, visibility of water and sanitation officials, public awareness, participation, overpopulation, monitoring, and insufficient budgets for operations and maintenance. Similar to Hofstetter et al.

(2020) found that practices regularly strayed from set policies within the four aspects of public water service delivery (identification, planning, construction, and operation). Gatekeeping and patronage also impair the accountability link between service delivery entities and end users.

The study aims to identify and rank water infrastructure-related indicators contributing to poor performance in Gauteng Province, South Africa. Addressing these challenges and bridging knowledge gaps in water infrastructure research requires collaborative efforts from governments, communities, and international organisations. Moreover, the study offers a unique perspective, particularly for developing countries seeking guidance on achieving optimal performance in sustainable water infrastructure development. This involves identifying and evaluating factors negatively influencing water infrastructure and prioritising them based on survey results from water experts and professionals in the field. To achieve this, a comprehensive review and descriptive analysis were conducted, focusing only on factors influencing the poor performance of water infrastructure in South Africa.

2. Methodology

The research methodology describes a descriptive study focused on identifying key factors influencing the poor performance of water infrastructure systems. The study utilised descriptive analysis to gain a thorough understanding of these factors. This design is suitable as it enables a detailed description of the current state of water infrastructure and its influencing factors. Alabi and Bukola (2023) assert that descriptive statistics organise data by depicting the relationships between variables within a sample or population. Kotronoulas et al. (2023) shared that descriptive statistics describe variables in a data set to demonstrate what is typical for a sample. This includes calculating the mean, median, mode, and standard deviation (Cooksey, 2020). Furthermore, the study employed a survey approach, sampling water infrastructure asset managers. The compilation of water infrastructure asset managers was conducted based on criteria such as professional engagement, field of work (e.g., municipalities), years of experience, and involvement in water infrastructure development. Water infrastructure asset managers, including project and construction managers, and civil, electrical, and mechanical engineers, participated in water infrastructure development and management and were considered study respondents. These respondents are professionals from all levels of management, with varying degrees of experience and who are either aware of or directly involved in sustainable water infrastructure development. They are responsible for the planning, execution, operations, and maintenance of water infrastructure assets. Le Gat et al. (2023) state that effective asset management is essential for the long-term maintenance of infrastructure. Respondents included representatives from the Department of Water and Sanitation (DWS), municipalities, the Trans-Caledon Authority, and various water stakeholders in Gauteng Province, such as water boards (Rand Water and the Water Research Commission). According to the participant rankings in (Table 1), the individuals interviewed are regarded as experts in water infrastructure. Furthermore, participants are from the Gauteng Province of South Africa as a study area. Also, this is where the national, provincial, and local authorities construct, rehabilitate, resurface, and maintain municipal, and regional water infrastructure.

The study adopted a structured questionnaire as a part of a quantitative data collection technique. Mohajan (2020) explained that quantitative research provides accurate data and enables statistical inferences about a representative sample. Quantitative research is crucial for evaluating and measuring through statistical analysis, analysing organised data that can be quantified numerically (Kotronoulas et al., 2023 & Ahmad et al., 2019). Furthermore, Ding et al. (2018) noted that this approach tests objective theories by examining the relationships between variables. Additionally, Polater (2018) enunciated that quantitative research uses precise statistical techniques and data is quantified or expressed numerically. The study chose this approach because it's ideal for gathering data through structured questions and conducting statistical analysis. Furthermore, the study used convenience sampling, a non-random sampling method. Lohr (2021) and Latpate et al. (2021) shared that convenience sampling is straightforward, cost-effective, and useful for pilot studies. As a result, convenience sampling was appropriate due to limited resources and restricted access to certain water infrastructure stakeholders. The study aimed to ensure that all participating stakeholders were knowledgeable and capable of providing crucial information about the performance of water infrastructure. The questionnaire was presented via online Google Form, which provided a quick and efficient means of data collection for the study. Moreover, primary data was gathered using a close-ended questionnaire. An online structured questionnaire using a Google link Form was distributed to accessible respondents via email, personal contacts, or phone numbers obtained from the Human Resource Management (HR) database to invite their participation in the survey. Oliveri et al. (2021) supported this approach and highlighted that conducting online surveys has several advantages, such as reaching large and geographically diverse populations. Two hundred and one (201) of the six hundred and forty (640) questionnaires issued to participants were returned and usable, as presented in (Table 1). This represents a 31% response rate. A five-point Likert scale was used to determine the factors contributing to poor performance of water infrastructure. The adopted Likert scale was as follows: 1 – Strongly disagree, 2 – Disagree, 3 – Not sure, 4 – Agree and, 5 – Strongly agree. Statistical Package for Social Sciences (SPSS) computer software was utilised to conduct the data analysis (Table 2). SPSS provided mean scores, standard deviations, frequencies, percentages, and a Cronbach's alpha of 0.775, indicating good reliability. Hair (2021) noted that a Cronbach's alpha of 0.70 or greater signifies suitable and consistent data.

3. Findings and Discussions

3.1. Demographic Information of the Respondents

The demographic findings (Table 1) show diverse professionals with various experiences in the water infrastructure sector.

Table 1. Demographic information of respondents

Response category	Frequency	Frequency (%)
Profession of Respondents		
Civil Engineer	78	38.8
Project Manager	55	27.4
Construction Manager	27	13.4
Electrical Engineer	22	10.9
Mechanical Engineer	19	19.5
Total	201	100
Work Organisations		
Municipality	62	30.8
Water Boards	55	27.4
Department of Water and Sanitation (DWS)	55	27.4
Trans Caledon Authority	29	14.4
Years of Experience in Water Infrastructure		
1-5 Years	68	33.8
6 -10 Years	68	33.8
11-15 Years	41	20.4
16-20 Years	10	7.0
More than 20 Years	51	5.0
Number of Water Infrastructure Projects		
1-5 Projects	71	35.3
6-10 Projects	54	26.9
11-15 Projects	15	7.5
16-20 Projects	10	5.0
More than 20 Projects	51	25.4

Source: Author's work

Professional respondents were civil engineers (38.8%), Project Managers (27.4%), Construction Managers (13.4%), Electrical Engineers (10.9%) and Mechanical Engineers (9.5%). Civil engineers are the most represented as the largest group, civil engineers are crucial for designing, maintaining, and improving water infrastructure. Their input highlights the technical challenges and needs for effective infrastructure solutions. For work organisation, Municipalities (30.8%), Water Boards (27.4%) & Department of Water and Sanitation (DWS) (27.4%) and lastly, Trans Caledon Authority (14.4%). Municipalities are the most represented (30.8%)**:** municipalities are often the primary entities responsible for local water supply and infrastructure. Municipalities' representation points to governance issues, funding constraints, and the need for better local government policies and management practices. Years of experience in water infrastructure, professionals with 1-5 years (33.8%) and 6-10 years (33.8%) are the most represented, highlighting a significant portion of respondents have relatively moderate experience, which indicates a need for enhanced training programs and knowledge transfer from more experienced professionals to maintain high standards of water infrastructure performance. Additionally, experienced water infrastructure professionals with more experience ranging from 16-20 years (7.0%) and more than 20 years (5.0%) are essential for strategic planning and addressing long-term infrastructure challenges. However, their lower numbers highlight a potential gap in leadership and mentorship within the water sector. For the number of water infrastructure projects involved, professionals with experience in 1-5 Projects (35.3%), 6-10 Projects (26.9%), 11-15 Projects (7.5%), 16-20 Projects (5.0%) and lastly, more than 20 Projects (25.4%). Professionals with fewer projects from 1-5 Projects (35.3%) are the most represented and might face challenges related to limited exposure to diverse issues, impacting their ability to handle complex infrastructure challenges effectively. Therefore, the demographic profile shows that the survey sample is diverse and suitable.

3.2. Descriptive Analysis of Factors Contributing to Poor Performance of Water Infrastructure

Table 1 below, presents the respondents' rankings of the factors influencing poor performance of water infrastructure in Gauteng Province of South Africa. The aging of water infrastructure, inadequate maintenance, vandalism to water infrastructure, illegal connection of water supply, population growth, water pollution and inadequate funding are the major factors with high occurrence in terms of contributing to poor performance of water infrastructure. Moreover, long-term planning for water supply and political interference also negatively influence the optimal performance of water infrastructure. Additionally, appropriate technology and climate change are recognised as challenges, their direct impact may not be as immediately perceived as other factors due to their low mean rankings.

Table 2. Factors influencing the poor performance of water infrastructure

Factors	**$\bar{x}$**	**σX**	**R**
Aging of water infrastructure	4.64	0.549	1
Inadequate maintenance	4.53	0.641	2
Vandalism to water infrastructure	4.41	0.795	3
Illegal connection of water supply	4.41	0.744	4
Population growth	4.37	0.777	5
Water pollution	4.32	0.707	6
Inadequate funding	4.28	0.796	7
Long-term planning for water supply	4.18	0.786	8
Political interference	4.18	0.715	9
Appropriate technology	3.99	0.869	10
Climate change	3.60	1.158	11

Notes: $\bar{x}$ = Mean item score; σX = Standard deviation; R = Rank

The findings revealed that the aging of water infrastructure ranked as the most significant factor contributing to the poor performance of water infrastructure in South Africa. The aging of water infrastructure leads to increased maintenance costs, reduced water quality, and decreased service reliability, necessitating substantial capital investment for upgrades (Leigh & Lee, 2019). The findings align with those of Pamidimukkala et al. (2021) and Mnguni (2018) indicating that the current water infrastructure systems are nearing the end of their functional lifespan, requiring significant financial investments to restore and maintain them in optimal condition. Leeuwen et al. (2019) accord with the findings that ageing water infrastructure presents significant financial challenges for cities and is a critical issue to address in the pursuit of Sustainable Development Goal (SDG) 6: Clean Water and Sanitation, SDG 11: sustainable cities and communities, and SDG 13: climate action. Ruiters and Amadi-Echendu (2022) coincide with the findings that water infrastructure management in South African municipalities is fraught with significant challenges. Also, added that the combination of deteriorating service quality, crisis-driven maintenance, escalating costs, and strategic management gaps severely hampers the effectiveness and sustainability of water supply systems. More so, long-term planning for water supply and political interference negatively influence the optimal performance of water infrastructure. Ngaka (2023) and Munzhedzi (2020) highlighted that political interference disrupts long-term planning for infrastructure development by instigating policy instability, encouraging corruption, and reducing accountability. More so, McCallum and Viviers (2020) accord that poor planning and budget adherence, inconsistent policies, lack of legislative protection, and a politically volatile appropriation process undermine effective water infrastructure development. Mokgobu et al. (2023), Agbor and Akpan (2019) concurred that political interference is a concern that negatively impacts the management and decision-making processes related to water infrastructure development and maintenance.

3.3. Implications

The study identifies several factors contributing to the poor performance of water infrastructure in Gauteng Province of South Africa. The findings reveal a significant gap in the resources available to stakeholders responsible for ensuring the optimal performance of water infrastructure. Local and metro municipalities in Gauteng Province play a critical role in water infrastructure development. However, their effectiveness is currently compromised by poor administrative capacity, resulting in inadequate service delivery. The study highlights the significance of collaborating with the private sector and enhancing governance through improving transparency, accountability and institutional capacities in water management. Moreover, the findings suggest that prioritising investments in infrastructure maintenance, enhancing financial planning and resource allocation, capacity building and personnel training, policy and regulatory reforms, and community engagement efforts, collectively aiming to improve the resilience, reliability, and sustainability of water infrastructure performance in Gauteng Province, South Africa.

4. Conclusion and recommendations

The study employed a survey method to identify perceived factors that hinder the optimal performance of water infrastructure. Based on the analysis, several factors contribute to the poor performance of water infrastructure in Gauteng Province, South Africa. These include aging infrastructure, insufficient maintenance, vandalism, illegal water connections, population growth, water pollution, inadequate funding, insufficient long-term planning for water supply, and political interference. Among these factors, aging infrastructure stands out as the primary contributor to the poor performance of water infrastructure. It is pertinent to conclude that the aging of water infrastructure compromises the reliability and quality of water services while leading to higher maintenance costs and reduced infrastructure lifespan. Ongoing challenges have hampered the provision of safe reliable, and accessible water supply services. It is, therefore, recommended that stakeholders collaborate with allocating sufficient resources and funding towards water infrastructure renewal and modernisation projects. The study recommends proactive maintenance strategies to extend the lifespan of existing infrastructure and enhance its reliability. Furthermore, fostering long-term planning frameworks with clear timelines and budget allocations to ensure sustainable water supply management. Emphasis should be placed on the overall factors contributing to poor performance of water infrastructure to attain sustainable development goals, specifically sustainable development goals (SDGs) 6 (clean water and sanitation) & 9 (industry, innovation and infrastructure) as highlighted by the United Nations (UN). Addressing SDG 6 (improving water infrastructure management to ensure reliable water supply, combat water pollution, and promote efficient water use) and SDG 9 (upgrading aging infrastructure, enhancing technological innovation in water management, and fostering sustainable industrial practices to support economic growth while safeguarding natural resources). As a result, aligning efforts with these SDGs can guide stakeholders and policymakers in addressing challenges related to water infrastructure holistically and sustainably.

5. Recommendations for further research

The study examined the perceived factors associated with the poor performance of water infrastructure at the local, regional, and provincial levels in the Gauteng Province of South Africa. Future studies can focus on providing necessary solutions for managing water infrastructure through stakeholder engagement and investment mechanisms, addressing challenges and opportunities at the national level in South Africa. The study also recommends adopting Fourth Industrial Revolution (4IR) technologies to improve the management of water infrastructure systems. Consequently, further research should explore the importance of Artificial Intelligence (AI) tools, their applications, and the readiness of water managers in developing nations, particularly in South Africa, to implement 4IR technologies in water utilities.

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