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ORIGINAL RESEARCH PAPER

Water Infrastructure Installation and Maintenance Challenges: Perceptions of Division Managers and Contractors

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ABSTRACT

The objectives of this paper were to identify the challenges experienced by the municipality of the City of Tshwane, South Africa, during and after the installation of water infrastructure, to explore the root causes of the identified challenges, and to rank their importance. The research strategy is exploratory and qualitative, applying purposive sampling to collect data via twenty semi-structured interviews with City of Tshwane water and sanitation division managers and staff, and from two focus groups from the water division contractors; one comprising seven managers and the other seven employees from these contractors. The collected data were analysed through NVivo, Excel graphs, and tables. The findings revealed that the City of Tshwane faces multiple challenges with regard to the sustainability of their water infrastructure, including old and dilapidated water infrastructure, political interference, community interference, lack of management intervention and technical skills, poor communication, poor record keeping, inadequate project management, staff shortages, tender nepotism, violation of service level agreements, poor security, vandalism, and corruption. In summary, the study showed a lack of project management and communication, especially inadequate planning and control policies and systems, which threaten the long-term sustainability of the City of Tshwane. Recommendations for improving the installation and maintenance procedures are provided.

KEYWORDS: *local government; management; project management; South Africa; vandalism; water reticulation.*

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Introduction

This paper discusses a qualitative study at the water division of the City of Tshwane (CoT), South Africa during 2020, investigating the challenges experienced by the municipality during and after the installation of water infrastructure (WI), exploring the root causes of the identified challenges, and ranking the importance of these challenges. The overall aim of the study was to identify the WI challenges faced by a South African municipality to find ways to resolve such challenges.

The specific research objectives to achieve the aim were to:

- identify the challenges as perceived by the municipal managers and contractors during and after the WI installation.
- explore the perceived root causes of the challenges experienced during and after installation of WI.
- rank the importance of the identified challenges as perceived by the municipal managers and contractors.

The research objectives to achieve the purpose of this study are justified by the literature, which identifies possible challenges to the installation and maintenance of WI, the root causes of the challenges and the ranking of these challenges according to their seriousness and/or frequency. The literature has revealed the following challenges: poor financial management, lack of communication, vandalism and theft (City of Tshwane, 2019; Mokgobu, 2023), budget shortfalls (Lawhon et al., 2018; Miller et al., 2018), and infrastructure not being upgraded. According to Tshimbalanga (2022)

the Tshwane WI is old and needs an efficient renewal plan. The challenges of corruption, unemployment, poverty, and poor governance and leadership has resulted in service delivery protests in various South African cities (Damoah, 2023), which justifies the need for this research.

The specific research questions to be answered, based on the objectives, were:

- What are the main challenges experienced by the municipality during and after installation of WI?
- What are the root causes of these challenges?
- What are the importance rankings of these challenges experienced by the municipality?

The study contributed to the knowledge of project management theories (Koskela & Howell, 2002), namely maintenance theory (Phogat & Gupta, 2017) and system theory (Kerzner, 2009), as applied to WI management. In addition, the study not only contributes knowledge about the WI practitioners' perceptions but also to municipal managers' knowledge, and provides information and suggestions for other academics (researchers) to continue this stream of research. Overall, the contribution of this study is that it should open opportunities for authorities to form new, or improve existing, policies and systems in the workplace.

LITERATURE REVIEW

South African municipalities are faced with backlogs in the maintenance of WI. Some of these maintenance backlogs range from leaking water pipes which trigger non-revenue generating water, to water treatment plants that are in poor condition. These leaks cost approximately R9.9 billion annually from 44% of unattended water treatment plants (Schoeman & Chakwizira, 2023). For example, the estimated annual expenditure of the eThekwini Municipality on non-revenue generating water is R163.6 million, increasing by 2.3% each year (Samuels, 2022).

Mokgobu (2023) outlined that service delivery at the CoT is delayed by slow tendering and service level agreement processes, dilapidated WI, overdue payments, improper record filing and inadequate attention to complaints. Other identified issues are overworked WI without regular maintenance or overhaul, procedures are disregarded, a lack of experienced and qualified plant operating staff, no security on site, and corrupt practices. According to Mokebe (2018) staff operating without the necessary qualifications is common. According to Mokgobu (2023) and Mokgobu and Mason (2022), vandalism and theft, infrastructure needing upgrading, insufficient budget and corruption are also common problems.

These challenges according to Mokgobu et al. (2023) develop health and social hazards for the communities. Vandalism of infrastructure is not a recent phenomenon in the CoT (Mokebe, 2018). Since Khale (2015) reported a residents' service delivery satisfaction level of 84.4%, the current customers' satisfaction level has declined to 59% (Mandiriza, 2022). Some of the issues that CoT face emanate from the governance challenges of having to plan for mixed urban and rural geographies - CoT has almost 35% of land zoned as rural settlements (Rogerson, 2023). Worku (2021) suggests that the decline in service delivery could also be due to the failure to execute activities according to the Integrated Development Plan (IDP).

Most metropolitan municipalities are provided with insufficient funds (Rogerson, 2023), which leaves them with unmanageable and continually-breaking infrastructure and endless maintenance, eventually resulting in a need for new infrastructure. According to Makole et al. (2022), planning bottlenecks and poor service execution in CoT emanated from misalignment between the city's Integrated Development Plan and the National Development Plan. Mokebe (2018) described the misaligned processes of the CoT as cumbersome, bureaucratic, and political.

Municipalities in South Africa are almost all faced with the challenges of corruption, poor leadership, and mismanagement of funds (Bischoff-Mattson et al., 2020; Mamokhere et al., 2022; Mokgobu, 2023). This also holds true for CoT, considering the financial challenges suffered over the past five years.

An example of CoT's water problems is the substandard quality of water supplied by CoT to the Hammanskraal community (Mathane & Gumbo, 2022). Kotzé (2023) reports that waterborne diseases, including cholera which claimed the lives of 22 people, have led to hospitalisations and deaths at Hammanskraal. The South African Human Rights Commission (SAHRC) warned the community not to consume water in Hammanskraal due to elevated levels of nitrate and phosphate concentrations in the drinking water. Another warning followed the Organisation Undoing Tax Abuse (OUTA) which discovered E. coli bacteria in Hammanskraal drinking water that signalled a health risk.

The quality of water supplied to the Hammanskraal community is unacceptable and not comparable to water in the central business district of the CoT. The situation was exacerbated by the extended time to receive water test results. Mthimunye (2020) found that systems and

infrastructure failures of the Rooiwal Wastewater Treatment Plant caused the water contamination at Hammanskraal, eventually leading CoT to introduce water restrictions that triggered intermittent water supply. These water contamination issues at Hammanskraal required inventions by the CoT to curb cholera-based health risks. New state-of-the-art drone-based water quality testing technology, developed at University of Johannesburg's Water and Health Research Centre and funded by the Water Research Commission, is hoped to reduce the three weeks to six months backlog of water quality testing (Kotzé, 2023).

A further technology used by CoT to manage their water infrastructure is the Infrastructure Management Query Software (IMQS). CoT uses the IMQS to locate the position of underground WI, but the system is not effectively used as a database to store information and extract data (Maluleke, 2021). For example, Maluleke found that the IMQS has few records on the tangible state of the sewer networks. The study further indicated that this shortfall would slow down the city's long-term planning and prevent the forecasting of structural forms of unevaluated portions of the sewer networks. Although Maluleke's study reported on the performance of the IMQS only on sewer networks, this may hold true for the water networks as well.

These issues indicate that the water infrastructure at CoT is not effectively managed. Furthermore, Mthimunye (2020) reported that the water supply challenges at Hammanskraal and Atteridgeville arise from mismanagement and lack of information sharing by the municipality. These inefficiencies created a lack of trust by residents and, in some cases, residents even resorted to illegal connections to cater for their daily needs (Dube, 2022). These illegal connections may be detrimental to the city's water infrastructure, for example, leaks, improper connections, damage to main lines, and defective materials.

Wall (2021) attributed the failure of infrastructure to poor operation, insufficient maintenance and inability to cater for demand, which results in poor socio-economic growth and lack of sustainable growth and spatial transformation. This inefficient operation and maintenance of infrastructures undermines the development of the economy and the citizens' quality of life.

Many of the challenges leading to service delivery decline at CoT are, according to Dube (2022), due to the spatial arrangements inherited from the old apartheid regime. Wall (2021) and Mthimunye (2020) argue that the WI is overloaded with the amount of water that must be supplied to the increasing number of people in urban settlements and the fast pace of development since the end of apartheid nearly 30 years ago. However, Tshimbalanga (2022) highlighted that half of the operating water mains in the CoT are over 20 years old, and 63% of these mains were manufactured from Poly Vinyl Chloride (PVC) which are experienced 37% material failure due to the stresses they must withstand. Clearly, water infrastructure maintenance has been problematic for many years. Quality operation and maintenance of the infrastructure is essential for good service delivery results. As stated by the American Society of Civil Engineers (2021).

Methodology

Research design

This study applied a mixed methods two-phase approach, i.e., interviews and focus groups, to collect data from participants. Data were collected in the form of a convergent parallel design methodology (Schoonenboom & Johnson, 2017).

Participants and sampling

For the interviews, non-probability purposive sampling was used to recruit CoT Water and Sanitation Division managers and staff. The various designations covered by the sample were director, functional head, engineering technician, supervisor, senior process controller, and artisan. The reasons for sampling this number and type of participant was that they have a specific understanding of the research problem and the internal challenges of the city's WI. The sample size was adequate to obtain coverage of various managerial and staff positions and genders.

Participants for the focus groups were recruited with the help of the CoT employees responsible for managing the water division contractors (Muijeen et al., 2020). Two focus groups, with seven members each, were sampled through non-probability purposive sampling to obtain the contractors' point of view on the challenges faced by the city and the contractors. Managers and employees were allocated to separate focus groups to ensure that employees were free to deliberate and discuss issues without being inhibited by the presence of managers.

Administration of data collection

Interviews were conducted over four days in venues and dates convenient for the interviewees, such as workplaces, homes and other convenient places. Data were collected through a semi-structured interview schedule developed from

the literature, with digital audio recordings and field-note taking. Interviews were recorded with the participants consent. Participation was voluntary and there was no stipend or remuneration for participants. Data were collected until saturation was reached, when it became apparent that no new responses were being generated, i.e., the answers became repetitive (Kyngäs, 2020).

The contractor focus groups were conducted in the CoT Water Division boardroom. Each focus group discussion lasted for just over one hour, which met the recommendations of Dawson (2009), Muijeen et al. (2020) and Wangsom et al. (2018). One researcher moderated the focus group proceedings using a topic discussion guide developed from the literature, while the other took notes during the discussions and asked follow-up questions. The discussions were recorded on a digital audio recorder (Dawson, 2009; Maree, 2007).

Analysis of data

The audio recordings were professionally transcribed and then played back and cross-checked with the field notes and transcriptions. The transcriptions were edited and typographical errors and spelling mistakes were corrected. Data were refined and captured into a Microsoft (MS) Word document. The transcribed data were then read and assigned to significant analytical items that produced word clouds, word counts, word clusters, word tree map analyses, statement frequencies, charts, themes and tables. Data from both interviews and focus group datasets were analysed through NVivo and Excel graphs, pie charts, and tables.

Ethical Issues

Prior to data collection, Durban University of Technology's Management Faculty Research Ethics Committee (FREC) granted ethics approval. Then gatekeepers' approval was obtained from the CoT before any data collection began. The following principles governing the study were explained in person to participants: voluntary participation, confidentiality of information, anonymity, and voluntary withdrawal from the study without giving reasons. Participants signed a consent to participate form.

FINDINGS

The findings obtained from the interviews and the focus groups are discussed according to the relevant research objectives. The research findings from the CoT managers and the two contractor focus groups are summarised in Table 1.

Challenges experienced by municipality during and after installation of WI

The issues of insufficient budget, community-caused problems, tendering problems, security issues, general maintenance problems and delays, and poor project management were mentioned by all three groups of participants. This indicates that these six groups of issues are perceived as the most important and influential challenges experienced during the installation and maintenance of WI.

Issues perceived as problematic by only two groups of participants included poor communications, old infrastructure, staff lacking experience and skills, corruption, and violation of Service Level Agreements.

The impact of these issues on the WI installation and maintenance, as indicated by literature such as Boulos (2017), Dludla (2020), Lawhon et al. (2018), Miller et al. (2018), Portfolio Committee Human Settlement, Water and Sanitation (2019) and Schwartz et al. (2017), are confirmed by our study.

Although only mentioned by the contractors' employees, the challenges of vandalism and theft cannot be underestimated – they are seen as the most serious challenges by the employees involved with day-to-day implementation and maintenance of WI. Furthermore, this supports the findings from the Portfolio Committee Human Settlement, Water and Sanitation (2019).

Table 1 summarises the combined findings of the challenges experienced according to each category of participants.

Table 1: Summary of combined research findings

CoT managers (Interviews)	*Contractor's managers (Focus Group 1)*	*Contractor's employees (Focus Group 2)*
Insufficient budget.	Insufficient budget	Insufficient budget
Community challenges, leaks, no enforcement.	Community interference	Community interference Community strikes Coerced to hire locals
Inefficient tendering processes.	Long tender process	Tender nepotism
Lack of enforcement.	Insufficient security	Unsafe sites. No security. Vandalism/theft. Pressure to take shortcuts. Disregard for procedures.
Maintenance issues shutdowns, delays.	Poor maintenance, delays	Defective materials

Poor project management. Poor communication	Poor project management Inefficient/poor communication Community misinformation	No record-keeping
Old and dilapidated infrastructure. Lack of skills/experience. Lack of staff training. Staff shortage	Old infrastructure	Inexperienced municipal employees
	Corruption Violation of SLAs	Corruption Violation of SLAs
No integrated approach, financial challenges. Challenges related to communities, finance, and technology.		
	Inefficient decision making Lack of implementation	

Root causes of challenges during installation of WI

'Community challenges', 'compliance predicaments', 'finance shortfalls', and 'technology challenges' are the root causes affecting performance in CoT as shown in Figure 1. The aspects of 'skills shortage', 'ineffective tendering system', 'poor planning and management', and 'political interference' are part of the root causes of the challenges. These findings affect the management of key infrastructural operations such as installations and maintenance and are confirmation of the literature findings (Pooe et al., 2016; Ruiters & Matji, 2015, 2016). Our findings also support Tshimbalanga's, (2022) recommendation of proper maintenance to upgrade the infrastructure and improved training for technicians and plumbers who play a leading role in the maintenance of infrastructure.

Figure 1 indicates the frequency of mention during the discussions of each of the root causes. The community challenges appeared eight times, and compliance challenges seven times, indicating their dominance in the interviews and focus groups.

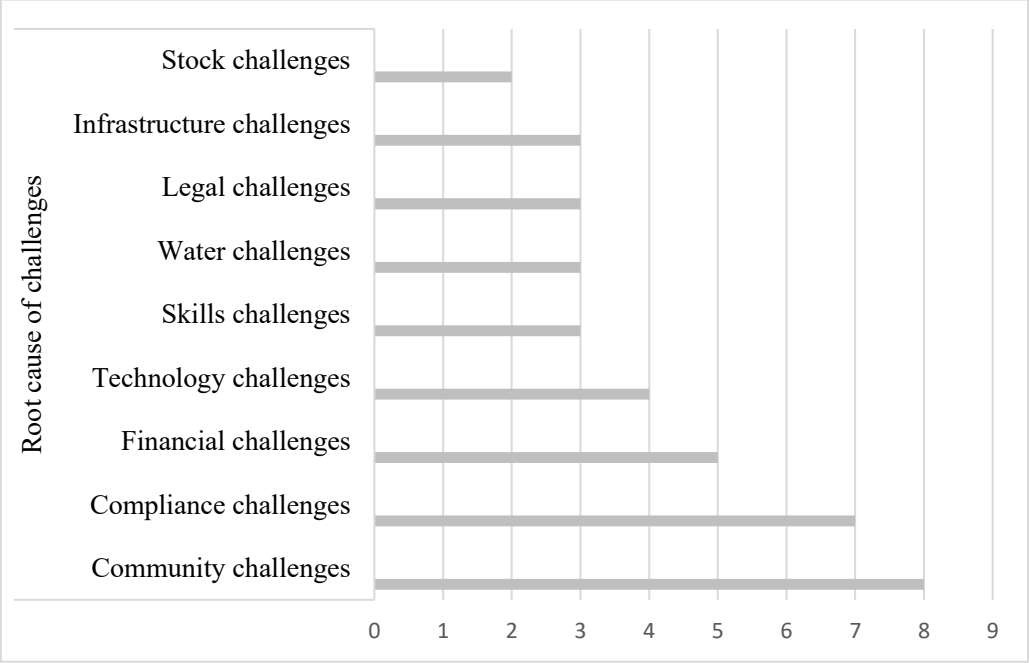

Figure 1. Frequencies of root causes of challenges of according to CoT managers

Ranking the challenges experienced by contractors

Figure 2 illustrates the rating of the perceived challenges of the contractor manager and employee focus groups. 'Vandalism and theft' ranked as the greatest challenge by employees, with five mentions, with 'infrastructure needing upgrading' ranking second with four mentions. According to managers, 'budget and finance' matters, 'inefficient purchasing/tenders', 'poor communication' and 'high prices' were ranked equally highly. This indicates that employees' perceptions were more to do with operational matters, whereas managers' perceptions were more to do with management or administrative matters, which is to be expected considering their different focus areas.

Combining the findings from both focus groups shows that 'insufficient budget' and 'inefficient procurement' ('corruption' applies to 'procurement') ranked the overall greatest

challenges with six occurrences each. 'Poor maintenance and infrastructure upgrading' and 'vandalism and theft' were the next highest ranked, with five occurrences each. Thereafter, 'community interference' and 'insufficient security' were next with four mentions. The ranking of these challenges according to the perceptions discussed in the contractors' focus groups are more or less in line with the literature of Miya and Grobbelaar (2015), Mokgobu et al. (2023) and Sershen et al. (2016). Our findings especially support Birkett (2017), Chauke (2017) and Mokgobu (2017) in terms of the high rate of vandalism and theft as shown in Figure 2.

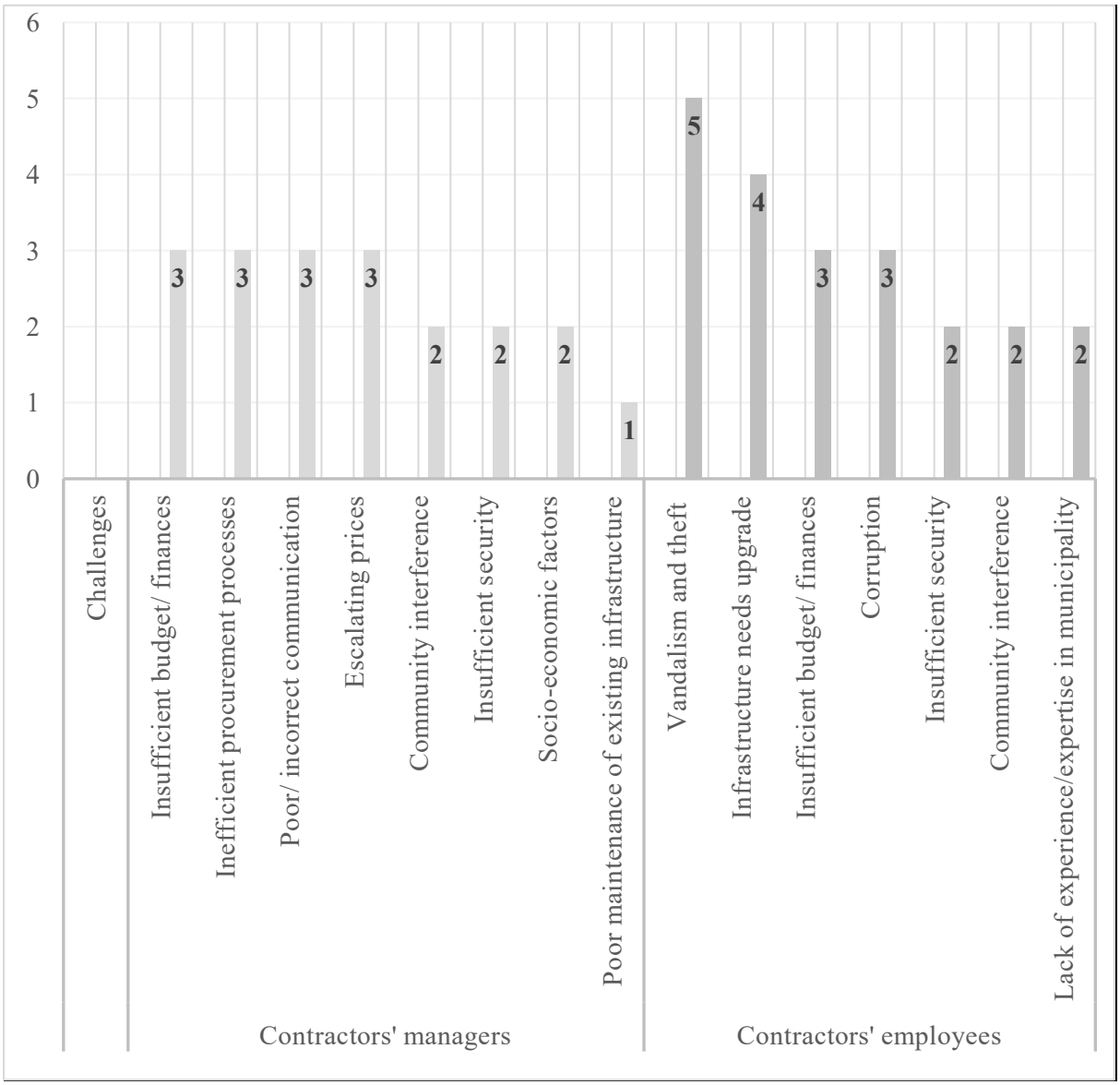

Figure 2: Combined contractors' ranking of challenges

Discussion

Significant challenges are experienced by CoT during and after the installation of WI. Various issues such as budget constraints and tender irregularities cause underperformance in the maintenance and upkeep of the WI, supporting the findings of Dludla (2020), Lawhon *et al*. (2018) and Portfolio Committee Human Settlement, Water and Sanitation (2019).

The challenges of security and safety issues, including vandalism and theft, ineffective security, and unsafe sites appeared multiple times across all the objectives. In addition to working under unsafe conditions, long processes to finalise tenders, inefficient decision making, poor project management, and lack of training were also challenges mentioned by CoT employees and contractors. These findings supported the literature on these challenges, for example, Makgopela and Radikonyana (2023), Mokgobu (2023) and Mokgobu and Mason (2021). The use of inexperienced staff and defective materials to install and maintain the infrastructure beyond its planned useful life added

to the challenges of breakdowns and poor service levels.

CoT managers and contractors explored the root causes of the challenges in the interviews and focus groups. The highest frequencies of the root causes were community challenges and compliance challenges. However, it can be assumed that if installation and maintenance were carried out efficiently and effectively there would be significantly fewer community complaints. Thus, the main root cause is probably a lack of compliance which ultimately means inadequate management. More effective management would reduce challenges like budget constraints (budget would be more effectively used), lack of experienced workers (effective training programmes implemented), ineffective planning and poor project management, all of which would give management the power and strength to resist, or minimise the effect of, political interference and the ineffective tender processes. These findings support the conclusions of Pooe et al. (2016) and Ruiters and Matji (2015, 2016).

Challenges experienced by contractors were ranked according to the frequency of occurrence in order to identify the severity of the challenges. The highest frequencies from the contractor's managers were escalating prices, tight budgets, communication breakdown, and procurement processes (all three mentions each). From the contractors' employees' perception, vandalism and theft (five mentions each), upgrading of the infrastructure (four) and budget deficits and corruption (three) were the most important challenges. These findings support the observations of Birkett (2017), Chauke (2017), Miya and Grobbelaar (2015), Mokgobu (2017) and Sershen et al. (2016).

The implications for academia and business cover knowledge about the application of project management (Koskela & Howell, 2002), and maintenance (Phogat & Gupta, 2017) and systems (Kerzner, 2009) theories to the installation and maintenance of WI in CoT. The study revealed inadequate project management in the CoT's water division. The contractors were not fully provided with the necessary materials and equipment to do the work. In other words, project management theory was not properly executed by those responsible for CoT WI. The project management activity of dividing tasks into smaller, more affordable, manageable and independent tasks was not implemented. Similarly, management sub-theories of planning, execution, and control were not executed.

The study has confirmed the importance of various aspects of project management, for example, monitoring and enforcement that were lacking in CoT's WI system. The study confirmed that, for a project to realise successful completion, the knowledge areas of project management must be applied. The important aspects of improved project management, efficient communication, and staff training are supported by this study.

Secondly, the study found that, in the CoT WI system, there is haphazard execution of maintenance without planning (unplanned maintenance), lack of implementation, and insufficient resources. The principles of maintenance theory are confirmed as the study found that there is a lack of maintenance planning. This theory includes the activities to perform, the processes to follow, the assets to maintain, and the time allocated to complete the maintenance. These then give rise to implementing maintenance, control, and observation of the production systems. Thesa findings support maintenance theory by showing that planned maintenance, compliance with the set processes, and employment of qualified personnel is essential for effective WI maintenance.

Thirdly, the study found that adequate policies and systems are not in place. The lack of communication resulted in a broken chain of communication that conveyed insufficient or distorted information. Systems theory stresses that it is necessary to first get the systems right for a project to be successful. Our findings support this systems theory principle resulting in the proposed solutions that policies and systems must first be improved before significant improvements in installation and maintenance can be achieved.

CONCLUSION

The study has demonstrated the shortfalls created between the various divisions that operate like silos, for example, staff shortage and lack of training is a human resources prerogative that has not been effectively executed, resulting in a lack of technical and management skills and expertise to do the work. The time taken to finalise the tender documents for the appointment of contractors is excessive resulting in delayed installation and maintenance. The lack of records and poor communication create a broken chain between the sections. The community lacks information and so perceives a lack of service delivery. In other words, there is a lack of proper project management in the WI division.

The infrastructure performs poorly because of poor maintenance. There is poor service to the community because of the water leaks resulting from old and dilapidated infrastructure. Some installations of WI obstruct the communities

from accessing their homes because of the deep and unprotected trenches. These aspects result in dissatisfaction with service delivery and community protest marches that sometimes destroy valuable assets of both the state and private owners.

The budget is not properly distributed and leads to a financial deficit that results in contractors having to do patch-work repairs with substandard materials. Politicians interfere with the operations and do not support the projects, while the community compels the contractors to hire local people or contractors regardless of the required minimum qualifications and skills. The municipality disregards the Service Level Agreements and there is a lack of enforcement of these agreements. The lack of security makes it possible for thieves to operate with impunity and for vandalism to go unpunished. These problems are further aggravated by corruption taking place in the CoT water division.

Regarding the study objectives, it is concluded that there are indeed challenges experienced during and after the water infrastructure installation. These challenges were ranked according to their urgency - those with higher ranking require urgent attention (see Figure 1). The challenges were not only listed, but the triggers, or root causes, have also been discussed. Most of the challenges' root causes arise from poor management, the community and the compliance challenges as illustrated in Figure 1.

The main limitation of this study was the effect of the Covid-19 pandemic that caused movement and contact restrictions that affected gatherings. Data gathering processes needed regular adjustments as some of the participants had to isolate due to contact with Covid-19 patients. Some offices were closed as a result. In addition to these difficulties, some participants cancelled appointments due to other reasons, such as work commitments and pressure, resulting in rescheduling of appointments with new participants.

This was essentially a case study in a single municipality using a qualitative methodology. Thus, the study suffers the limitation of a lack of generalisability to other municipalities and so these results should be extrapolated to other municipalities with care.

This study has highlighted numerous aspects and causes of WI installation and maintenance challenges. However, since the study was essentially exploratory, further research is needed to delve deeper into some of the key aspects identified by this research. For example:

- The process of the allocation and proper use of funds in CoT's WI.
- The triggers of violence that occur between the community and CoT's maintenance contractors.
- Exploration of the WI asset register to identify assets that have exceeded their useful life and which are due for replacement.
- Investigation of more modern technologies that could help CoT and contractors to monitor the WI and so increase the efficiency of maintenance processes, e.g., space technology.

Author Contributions

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Project administration: M.L. Mokgobu.
Resources: M.L. Mokgobu; R.B. Mason.
Supervision: R.B. Mason.
Validation: M.L. Mokgobu; R.B. Mason.
Visualization: R.B. Mason.
Writing – original draft: M.L. Mokgobu; R.B. Mason.
Writing – review and editing: R.B. Mason.

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Conflict Of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

Declaration of Competing Interest

With regard to this study, the authors have declared that no financial or any other personal interest exists between them.

Availability of Data and Materials

All necessary data are incorporated and supplementary data can be accessed through the corresponding author.

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