The application of space technology and the challenges of managing water infrastructure in a selected South African municipality

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ABSTRACT

The installation of water infrastructure in cities poses a challenge to communities, municipalities, and installation contractors. These challenges range from the inaccessibility of streets, the community's limited access to homes, traffic jams, deep trenches with few or no barricades, leaking water pipes, water supply cut-offs, electricity supply cut-offs, vandalism, and theft of water pipes and accessories. The research problem, therefore, revolves around a better understanding of these water infrastructural problems, how to mitigate such problems caused by inadequate planning, leading, organising, controlling, and coordination by management, arising from various technical aspects of water infrastructure.

The need for this study arises from the inconvenience and dangers experienced by communities with heaps of materials lying around causing disturbances to traffic flow, open hazardous trenches becoming dangerous to children playing in their vicinity, vehicle accidents because of the trenches, and damaged kerbs. The study aimed to investigate the challenges of managing water infrastructure in a selected South African municipality to find possible ways to resolve such challenges with the help of space technology.

The study achieved the objectives, namely, to identify the challenges experienced by the municipality during and after the installation of water infrastructure; to rank the importance of the experienced challenges; to explore the root causes of the challenges experienced during the installation of water infrastructure; to identify how space technology can help with the management of water infrastructure; to develop a framework of the challenges and the causes; and, to explore water management strategies with the effort of finding possible ways to resolve the challenges.

The study was exploratory and applied mixed methods research methodology. Data was collected via a survey (402 City of Tshwane residents), in-depth interviews (20 City of Tshwane managers of the Water Division), and two focus groups (7 participants per group of City of Tshwane contractor managers and contractor employees) through the convergent parallel design method.

The quantitative data was analysed using the Statistical Package for Social Sciences (SPSS Version 27), and the qualitative data was analysed using NVivo version 27, charts, tables, and themes. The results from the three sets of participants indicated multiple challenges related to skills deficits, management deficits, political interference, and inexperienced staff in the water infrastructure division. The findings indicated knowledge, ability and performance gaps in human resources, management, technical skills, financial management, socio-politics, and legal frameworks. The study contributed new knowledge to systems theory regarding the policies, systems, installation and maintenance of water infrastructure, and communication, and these aspects are supported by the findings.

The application of space technology on a large scale can help the City of Tshwane fight criminal acts of vandalism and theft of infrastructure. This study found that space technology is still in its infancy in the city, and that the application of this technology requires an elevated level of education, experience and specialised technical skills to operate. This study recommended extensive investment in space technology.

The study further recommended that the City of Tshwane improve human resources, training, culture, finance, operations, and control measures. The study recommended further research on the proper use of funds, the causes of community violence against the contractors doing maintenance, investigation of the delays in the procurement of services, turnaround time for the various water infrastructure activities, relationship management between the city employees and the contractors, the impact of lack of reporting by the managers and employees to the superiors in the water infrastructure division, and clearer definition of roles between municipal employees and politicians. More academic research into water infrastructure, based on the use of and relationship between water infrastructure and space technology, is warranted.

DECLARATION

I hereby declare that the work in this thesis is my work, except where indicated, and that the references herein are reported accurately.

.... …25 September 2022.

Matlou Lesley Mokgobu Date

DEDICATION

This doctoral thesis is dedicated to the Mokgobu extended family, all fellow scholars and teachers from my primary school (Tibanefontein), and the people of Tibanefontein village. The lifetime experiences I went through amongst these people made me the person I am today. These people have contributed meaningfully to my growth, and for this reason, they deserve this dedication.

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I thank the City of Tshwane for showing interest by allowing me to conduct this study in their organisation during the deadly Covid-19 pandemic. I am extremely proud of the City of Tshwane's employees and the contractors in the Water Division, and the citizens of Tshwane for their meaningful contribution to this study, and without whom the study would have failed.

This thesis is one of the greatest milestones I have ever achieved in the course of enduring many different situations. After this research, I don't think there will ever be any project that is too complex to cause me to give up, no matter how challenging it might be. I have learned that people view issues differently, but there is not a vast difference in how people express themselves about the particular matter on the table.

Most importantly, I would finally like to acknowledge the financial assistance from the Department of Science and Technology (Space Science Institute). The ideas,

conclusions, and recommendations expressed in this thesis are that of the author and not of the Department of Science and Technology.

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LIST OF ABBREVIATIONS AND ACRONYMS

4IR- Fourth industrial revolution

ANC- African National Congress

CoCT- City of Cape Town

CoE- City of Ekurhuleni

CoJ- City of Johannesburg

CoT- City of Tshwane

CSIR- Council for Scientific and Industrial Research

DA- Democratic Alliance

DST- Department of Science and Technology

DUT- Durban University of Technology

DWS- Department of Water and Sanitation

EFA- Exploratory factor analysis

EPA- Environmental Protection Agency

EO- Earth observation

et al.- and others (Latin phrase)

FREC- Faculty Research and Ethics Committees

GIS- Geographic information system

GPS- Global positioning system

IAM- Infrastructure Asset Management

IDP- Integrated Development Plan/ Planning

IoT- Internet of Things

ISS- International Space Station

ML/d- Megalitres per day

mm- millimetre

n- total number in a sample

NASA- National Aeronautics and Space Administration

NRW- non-revenue water

POPIA- Protection of Personal Information Act, 2013 [Act No. 4 of 2013]

R- rands

RS- remote sensing

RWWTP- Rooiwal Wastewater Treatment Plant

SA- South Africa

SACSA- South African Council for Space Affairs

SAHRC- South African Human Rights Commission

SANSA- South African National Space Agency

Sig- significant

SLA- Service level agreement

SPSS- Statistical Package for the Social Sciences

SSA- sub-Saharan Africa

US- United States

WDM- water demand management

WDN- water distribution network

WI- water infrastructure

WMDs- Water Management Devices

WMS- water management system

WSA- Water Services Authority

WSI- Water Services Institution

WSP- Water Services Provider

CHAPTER 1: INTRODUCTION

1.1 Introduction

In a modern world such as the one we currently live in, technology evolves at a very fast pace. This technology has become a global space to play in and requires governments and organisations that are ready and prepared for the game. Organisations must plan before they are challenged by this global evolution. This study took place in the City of Tshwane (CoT) which lies between the latitudes 25.5 and 26.5 °S, and longitudes 27.7- 28.4 °E (Fitchett and Raik 2021: 3; Shikwambana and Tsoeleng 2020: 211; Adeyemi 2015: 27). The CoT is in the province of Gauteng and shares boundaries with the City of Johannesburg (Peres, du Plessis and Landman 2017: 691). The CoT is a metropolitan municipality with executive and legislative powers within its jurisdiction (Molepo, Maleka and Khalo 2015: 346), and is home to 3.31 million people with a surface area of 6 345 square kilometres (km^2) (Ariyan 2020: 17; [CoT] 2019b: 22). It is the metropolitan settlement with the third-largest surface area in the world (Ariyan 2020: 17; [CoT] 2019b: 22).

The CoT is located at an altitude of 1339 metres above sea level at the foot of the Magaliesberg mountain range north of Gauteng and is well known for its thousands of Jacaranda trees. It is the capital city of South Africa and is the second-largest contributor to gross domestic product in the Gauteng province. The major languages spoken in the city are Afrikaans, English, Ndebele, Zulu, Northern Sotho, Tswana, and Tsonga (Ariyan 2020: 5, 7). The city experiences an average annual temperature of 25 ℃ (Dyson, van Heerden and Sumner 2015: 116), with hot and wet days in summer, and mild winter days with frosty nights (Shikwambana and Tsoeleng 2020: 211). The mean annual rainfall is 715 mm, with 122 mm in January (wettest month) and 6 mm rainfall in June (driest month) (Adeyemi 2015: 28).

The management of water infrastructure (WI) is a critical concern to the local authorities which have the challenge of delivering services to the communities they serve. In some cases, it has become a life-threatening matter with communities staging protests for days, seeking better service delivery (Ndlovu 2015: 16) While some successes regarding service delivery have previously been reported in the CoT, Ndlovu (2015: 1) asserted that protest actions about the delivery of services continue in the CoT. The CoT manages a vast range of WI networks that are spread within and across the seven regions within its boundaries. These networks are managed daily to ensure a reliable and uninterrupted supply of water to communities.

The remainder of this chapter will provide background to the WI problems experienced by CoT, a definition of the research problem, an explanation of the theories upon which the study is based, the rationale and justification for the study and a summary of the methodology used. The chapter ends with some definitions of concepts and an explanation of the remaining thesis chapters.

1.2 Background of the study

Ariyan (2020: 7, 9) reported that CoT has historically experienced an average of 3.4 percent annual population growth. The increase has been double that of the national average of 1.7 percent. The city started to experience even higher growth of 4.4 percent per annum since 2005. As a result, the city started experiencing pressure on roads, housing, water, electricity, and transport infrastructures. These circumstances led to a failure of the city to sustain the existing and to provide new, infrastructure, due to a lack of adequate finances. The city struggled to obtain adequate revenue even after the collection of rates and taxes and the sale of water and electricity utilities. According to Leburu (2017: 81), the CoT's water and sanitation division is ineffective in tracking the water management system (WMS) usage, so this failure consequently leads to accumulation of debts by clients. A study carried out in 2011 by the World Bank on the African continent found that urban water supply investments do not keep up with the pace of urban population growth (Van Ginneken, Netterstrom and Bennet 2011: viii). The study further revealed no correlation between stages of public expenditure and the levels of access to the supply of water and sanitation in different countries.

The aspects of lack of adequate finance, inappropriate installation, maintenance, and provision of new infrastructure may trigger a backlog. According to Leburu (2017: 14, 33), backlogs may trigger monetary challenges to municipalities and may bring service delivery to its knees. In the same vein, certain challenges suffocated the effective implementation of the City of Tshwane Metropolitan Municipality's indigent policy. These challenges are inoperable and dilapidated infrastructure, limited engineering skills, and insufficient funds. In terms of management, South African municipalities still prefer a top-down approach which provides little room for communication and public participation. For those reasons, in several instances, municipalities still lack proper service delivery, and functional and performing infrastructure due to a lack of adequate capacity to run it.

According to Snyman and Vorster (2011: 540), the CoT had been immune to service delivery protests. However, things took a turn for the worse when the city was ravaged by these protests (Ndlovu 2015: 1, 16); between the years 2007 and 2011, 20 percent of the service delivery protests that spread across Gauteng province occurred in the CoT (Ndlovu 2015: 7). The current situation is that the CoT owes the electricity supply utility Eskom R635m (*Ditlalemeso* 2022). The supply utility itself faces huge debts, electricity supply interruptions, and maintenance backlogs that leave the water supply at risk (Herold, van Dijk and Potgieter 2020: 29-30).

Several issues affect communities, cities, and towns when water pipes are being installed and maintained. These issues can affect the daily routines of communities and businesses negatively. Installation contractors often leave materials lying around causing traffic flow disturbances. Hazardous trenches are left open for undetermined periods which become dangerous, especially to children who play in their vicinity. Vehicles are often involved in accidents because of these trenches, heaps of materials, and damaged kerbs.

Maintenance becomes an issue when pipes are left leaking for a long time, with children playing in flowing and dammed water in the streets and nearby bushes. This exposes children to the risk of drowning and water-related diseases. The installation and maintenance of water mains requires strategic management so that businesses and communities are not left without water for long periods.

According to the organogram of the CoT, the WI sub-section operates with various units, such as: water distribution as a subsection or a directorate in each of the seven regions of the CoT. The sub-section has two units in each region, namely: infrastructure operations and maintenance services, and infrastructure operations and maintenance-technical support. Each of these units have sub units in all the seven regions of the CoT. Some of the CoT's maintenance or repair functions, for example maintenance of pumps and pressure reducing valves, are subcontracted.

This vast area, as Ariyan (2020: 17) and CoT (2019b: 22) alluded to, takes into account the geographical extent of 6 345 square kilometres and a population of 3.31 million people. The Portfolio Committee on Water and Sanitation (2022: 10) indicated that the city has to cope with community interferences and other complaints. According to Van Rooyen and Pooe (2016: 148-149) a strategic decision was adopted to subcontract certain functions of the city to augment service delivery, with a condition to monitor performance of the subcontractors.

1.3 Research problem

The installation of water infrastructure in cities poses a challenge to communities, municipalities, and installation contractors. The challenges range from inaccessibility of streets, limitation of access to homes, shops and offices, traffic jams, deep trenches with few or no barricades, leaking water pipes, water supply cut-offs, electricity supply cut-offs, vandalism, to theft of water pipes and accessories. The quality of material used for the infrastructure may be substandard and may also be outside the scope of specifications. The research problem for this study is therefore how to overcome inadequate planning, leadership, organising, controlling, and coordination by management, arising from various technical aspects of water infrastructure.

Vandalism and theft are damaging reservoirs, and communication in remote areas are interrupted due to the theft of required infrastructure such as electrical cables and solar panels (Portfolio Committee Human Settlement, Water and Sanitation: 2019; CoT 2019b: 128; Ikejemba and Schuur 2018: 15; Mokgobu 2017: 87; Loots *et al.* 2014: 4

& 8). The relevance of electrical cables and solar panels to the WI challenges presented is that solar panels power the batteries using electrical cables. The batteries supply power to the telemetry systems which provide a means of communication to office staff about the water levels, inflows, and outflows in the reservoirs. Tamper switches and alarm systems installed at pump stations/ chambers are also powered from these sources of power. According to Loots *et al*. (2014: 6), it is unreasonable to travel long distances every day to physically inspect installations and water levels in reservoirs when monitoring devices can perform these functions. To this end, space technology may be able to perform these functions through satellites or drones.

Considering that these problems affect the community negatively, all avenues should be explored to mitigate this, which could be assisted by application of space technology to augment service delivery. Space technology has already assisted other municipalities which have experienced similar challenges.

1.4 Aim and research objectives

The study aims to investigate the challenges of managing water infrastructure in a selected South African municipality and to find possible ways to resolve such challenges with the help of space technology. Research objectives should closely relate to the research questions and incorporate every element of the research problem (Doody and Bailey 2016: 22). The words used to construct the aim of the study are obtained from the research question. The aim of a study generalises the purpose and the goal to be accomplished (Tully 2014: 33). In the current study, the aim was achieved by addressing the following research objectives:

- To identify the challenges experienced by the municipality during and after installations of water infrastructure.
- To rank the importance of the identified challenges experienced by the municipality.
- To explore the root causes of the challenges experienced during the installation of water infrastructure.
- To identify how space technology can help with the management of water infrastructure.

- To develop a framework of the challenges and their causes.
- To explore water management strategies to find possible ways to resolve the challenges.

1.5 The research questions

The following research questions were developed based on the objectives of this study and the literature review to guide the research. According to Mertens, Pugliese and Recker (2017: 135), the research questions and analysis plan are the basis from which the data should be structured. The research questions in this study are:

- What is the cause of the challenges experienced by the municipality during and after installation of water infrastructure?
- How to rank the importance of the challenges experienced by the municipality?
- How can the root causes of the challenges experienced during the installation of water infrastructure be explored?
- How can space technology help in managing water infrastructure?
- What framework of the challenges and the causes can be developed?
- What water management strategies can be explored to find possible ways to resolve the challenges?

1.6 Theoretical underpinnings of the study

This study is underpinned by project management theory, systems theory, and maintenance theory to understand the topic under examination.

1.6.1 Project management theory

Project management theory is considered by the study as key and vital to water infrastructure. Project management phases play a pivotal role in the installation and maintenance of water mains, boreholes, water pumps, construction of towers and reservoirs, etc. which have a defined period from start to finish. Water infrastructure is underpinned by the four phases of project management; namely, initiation, planning, execution, and outcomes realisation (Zwikael and Smyrk 2019: 45). This theory eliminates haphazard work done by contractors by limiting them to project management techniques.

Theory should be specific and in line with the methodology to actively contribute to the set goals (Koskela and Howell 2002a: no page). To fulfil the goal of project management theory, this study considered three actions: systems design, systems control, and systems improvement. These actions eventually led to another theory of systems.

According to Koskela and Howell (2002b: 3), project management theory comprises two theories; namely, project theory and management theory. Project theory is viewed as changing how operations are interpreted by converting inputs to outputs. This is the theory in which tasks are divided into smaller cost-effective manageable independent tasks. The theory of management has three sub-theories; namely, theory of planning, theory of execution, and theory of control. The theory of management sets performance standards, measures performance output, and takes corrective action after realising the difference between the measured performance and the standard performance. The installation of water infrastructure can be executed according to these theories by converting big tasks to smaller manageable tasks to accelerate the transformation of inputs into outputs.

1.6.2 Systems theory

Kerzner (2009: 38) defines systems theory as a management style trying to incorporate and bring uniformity to scientific facts. The initial stage of getting anything accomplished is to first get the systems right. Systems theory approaches and solves problems collectively. This theory is relevant to the installation and maintenance of water infrastructure as a system rather than as a single component. A breakdown of one component of the infrastructure renders the entire system of infrastructure dysfunctional. Solving one breakdown of the entire system of infrastructure will collectively restore the community's satisfaction.

1.6.3 Maintenance theory

Phogat and Gupta (2017: 213) write that maintenance theory involves strategies that encompass activities, processes, assets, and time. This theory enables an organisation to accomplish its set targets. Activities can be accomplished through maintenance planning. The various characteristics of maintenance are mentioned and discussed in detail later in the study. Maintenance planning is followed by the strategic allocation of resources. The planning of maintenance prepares a solid base for the implementation of maintenance, control, and observation of the production systems.

1.7 Rationale of the study

The CoT is one of the biggest cities in South Africa with a wide range of water infrastructure. The CoT shares water supply and sanitation boundaries with other towns and cities and this makes the study challenging due to its several complexities. According to the CoT (2017: 8), these towns and cities are the City of Johannesburg (Midrand), Ekurhuleni Metropolitan Municipalities and the local municipalities of Bojanala, Moretele, Bela-Bela, Dr JS Moroka, Thembisile (Bronkhorstspruit), Emalahleni, and Delmas. The study is important since it will add to previous research in the management of the challenges, installation, and maintenance of WI. The researcher used to work for the CoT and for that reason it has been selected as the municipality for this study.

This study will add value to other government departments, researchers, managers, water infrastructure practitioners, and help to end community dissatisfaction. In addition, it will contribute towards addressing management, security, and technical challenges and identify ways to better manage community complaints, cost escalations, and introduce innovation. The main reasons for the study are:

- To contribute new knowledge on overcoming managerial challenges experienced during water infrastructure installations and maintenance.
- To diagnose the managerial challenges from the start of placing infrastructure to the ongoing treatment, which is later maintenance.
- The study adds value to the business fraternity, government, and communities since it will incorporate new ways to manage the installation and maintenance of WI.
- To identify ways to manage community complaints, cost escalations and to bring innovation.
- To align water infrastructure to space technology innovation.

Searching for innovative ways to reduce wastage, and the non-reinvention of work from previous studies, make this study highly beneficial.

1.8 Scope of the study

The scope discusses what the study will consist of and what it will not consist of, and any possible difficulties that the research will face. These are discussed in the delimitations and limitations sections.

1.8.1 Delimitations

This research did not study other municipalities in South Africa. The study was restricted to the City of Tshwane Metropolitan Municipality. As a result, the findings of this study cannot be generalised to other cities in South Africa. The emphasis of this study is on the application of space technology and the challenges of managing water infrastructure in a selected South African municipality.

1.8.2 Limitations

The focus of this study is on the challenges to the management of the WI of the City of Tshwane Metropolitan Municipality. All other infrastructure such as sewerage, stormwater, electrical, telephone, and roads were excluded from this study. The WI was selected for this study due to the challenges that are encountered daily that result in damages and violent protests. This study was conducted when South Africa and the rest of the world experienced the Covid-19 pandemic and lockdowns were imposed. The lockdowns started from the 26 March 2020 and had several extensions thereafter (Stiegler and Bouchard 2020: 695; Young 2020: 331). The movement restrictions amongst provinces worsened the negative impact to travel for data collection for this study.

The study of a single municipality is a limitation and any attempt to extrapolate these results to other municipalities should be done with extreme care. This does not undermine the importance of this research, as one of the main aims of the study was to use this as a case study to understand typical WI problems and how space technology could assist in their mitigation.

In addition, the typical weakness of qualitative research with small samples further added to the limitations of this study. The problem of choosing a sample size is always present in most qualitative researches and requires attention (Oppong 2013: 204). According to Simmons (2018: para. 1 line 4-7) sampling errors impact accuracy and can distort outcomes. These errors can be costly to organisations and may have detrimental effects on the phenomena under examination. According to Blaikie (2018: 636), the choice of a sample is a serious matter and requires focus on items such as research problem, the framework of the research, the research question, and the features of the items to be researched. The interviews and focus groups in this study could be subject to the potential problems outlined by Simmons (2018), but the likelihood was reduced by applying the principles outlined by Blaikie (2018) and by using methodological triangulation (survey, interviews and focus groups) and data triangulation (CoT employees, and contractors' managers and employees) (Maree 2007: 298).

1.9 Research methodology

Mixed method research methodology was used to obtain in-depth knowledge of the issues (qualitative), and to statistically measure responses (quantitative) (Austin and Sutton 2014: 438). Sampling included 20 CoT managers (interviews), 402 Tshwane citizens (survey), and 14 contractor experts split into two focus groups (contractor managers and contractor employees). Data was collected through questionnaires, interviews, and focus groups (three-phase approach).

The quantitative (survey) data were analysed through the Statistical Package for the Social Sciences (SPSS Version 27). The qualitative (interviews and focus groups) data were analysed through NVivo and Excel tables. The details of the methodology are discussed in the research methodology chapter.

1.10 Definition of concepts

Blue Drop Certification Programme - a programme introduced to certify that the water discharged from a tap conforms with the set South African National Standards for drinking water quality (Edokpayi *et al*. 2020: 188; Mashele 2017: ix).
Climate change - any major climatic variation in the form of temperature, precipitation or wind lasting for a prolonged period of a decade or longer (Zhang 2012: 2062).
Infrastructure asset management (IAM) **-** a sequence of logical and synchronised management applications to assist performance with the least costs and least possibility of asset breakdown (Boulenouar and Schweitzer 2015: 1-2).
Remote sensing (RS) - the collection of data utilising an instrument or sensors which are attached to a satellite, an aircraft, or unmanned aerial or unmanned ground vehicle that involves an object or a phenomenon that it is not in direct contact with (Weiss, Jacob and Duveiller 2020: 3, 39).
Space technology - spacecraft, satellites, space stations, backup infrastructure, tools, and processes established and utilised by the aerospace environment in

spaceflight, satellites, or space exploration (Ojoyi 2016: no page number).

Spatial resolution - the phenomenon or the degree to which details on an image are recognisable, and the possibility of detecting the smallest feature from an image (Weng 2012: 35).

Water infrastructure (WI) - a network of existing, scheduled, or works in progress, linked to water which involves large dams, irrigation schemes, and projects to convey water from one drainage area to another (Water Resources Coordination 2012: 29).

Water Services Authority (WSA) - a district or rural municipality authorised to oversee the guaranteed access to water services (South Africa, Department of Water Affairs and Forestry 1997: 10).

Water Services Institution (WSI) **-** a water service authority, water services provider, water board, or a committee (South Africa, Department of Water Affairs and Forestry 1997: 10).

Water Services Provider (WSP) **-** any person or entity entrusted with the provision of water services to clients or water services institutions but excludes a water services intermediary (South Africa, Department of Water Affairs and Forestry 1997: 10).

1.11 Structure of the thesis

This study consists of eight chapters with each briefly summarised as follows:

Chapter 1: Introduction

This chapter introduces the purpose of this study with an outline of the background to the context and geographic area in which the study is taking place. It also details the theoretical underpinnings of the study, the aim of the study, the objectives, the research questions, the reasons for the focus area, and the research problem.

Chapter 2: Literature review - introduction to management of water infrastructure

Chapter 2 provides section one of the literature review and outlines the introductory part of the management of water infrastructure (WI) in the international, South African, and the CoT contexts. The regulatory framework governing the WI in South Africa as well as the South African National Standards parameters for drinking water are presented in this chapter. Planning for the right strategies to improve the performance of the CoT as the Water Services Authority are incorporated in the discussions.

Chapter 3: Literature review - Challenges of managing water infrastructure

Chapter 3 covers section two of the literature review and presents the challenges of managing the WI in the CoT. The chapter further discusses the drought situation in SA, the WI installation approval process, the challenges experienced during and after installation of WI, the causes of challenges, and the ranking of such challenges. The managerial shortfalls of CoT are also incorporated into the discussions.

Chapter 4: Literature review - The application of space technology

Chapter 4 covers section three of the literature review and deals with the application of space technology for the improvement of the WI services in the CoT. The discussions covers the economic contribution of space technology to Africa, SA, and the CoT, and the impact of the fourth industrial revolution (4IR) and the legislative framework governing space technology in SA.

Chapter 5: Research methodology

This chapter discusses the research design and the methodological approach that was followed to conduct the entire research process. The chapter presents the tools to gather data, namely, survey, interviews, and focus groups. The chapter further discusses population, sampling, pilot testing, the data collection methods, and data analysis processes.

Chapter 6: Presentation and analysis of results

Chapter 6 presents and analyses the data generated from the respondents. The presentation and analysis of data starts with quantitative findings and proceeds to qualitative findings. The quantitative data analysis covers the results of the survey of the residents of the CoT, and the qualitative analysis addresses the findings from the interviews of the CoT managers and concludes with the findings from the contractor, manager, and employee focus groups.

Chapter 7: Discussion and interpretation of results

Chapter 7 presents the discussion and interpretation of the research findings. This chapter uses the responses of the respondents to arrive at the overall findings for this study. The chapter discusses the findings in relation to the research objectives and the research questions, as well as the solutions to the findings to each research objective.

Chapter 8: Conclusions and recommendations

Chapter 8 provides a conclusion, recommendations for both academics and practitioners, limitations of the study, and the areas that need further research on this topic, especially in the CoT. The recommendations arise from the findings of this study.

1.12 Chapter summary

This chapter has presented the background of the study, the research problem, the overall aim, the research questions, rationale, delimitations, and limitations. In a nutshell, the chapter has presented the overall geographical location of the study area, the altitude, the extent, the population, and the contribution of the city to the provincial gross domestic product. A brief overview of the challenges that the city is facing has been discussed. The theories that underpin this study have been discussed with references to support their relevance to the study.

The next chapter will discuss section one of the literature review, namely the introductory part of the management of WI in the international, South African, and CoT contexts.

1.13 Conclusion

The chapter has laid a foundation for this thesis which provides a basis for the structure of the thesis. Finally, this study has been conducted with the hope that the outcomes and the recommendations will be implemented to guide the policies and help to improve the service delivery for the CoT.

CHAPTER 2: MANAGEMENT OF WATER INFRASTRUCTURE

2.1 Introduction

The literature review consists of three chapters that are covered as follows: a) Chapter 2- introduction to management of water infrastructure; b) Chapter 3- challenges of managing water infrastructure; and c) Chapter 4- the application of space technology. All content surrounding the literature review will revolve around these issues.

Managing WI is a complex matter considering the network of pipes connected to supply villages, towns, and cities. Water infrastructure is an arrangement of water supply, treatment, storage, water asset management, prevention of flood and hydropower. Water pipes whether above or underground must cope with a range of factors such as human effects, animal effects, environmental effects, water pressures, ground pressures, tree root systems, etc. Managers expect all these factors to be taken care of by the networks regardless of their materials of manufacture. These networks must perform to their design life or even outperform their design life. Managers must make sure that pipes are laid properly, maintained properly, and that records are kept as to when and where pipes were laid. However, the unexpected does happen sometimes that pipes do not perform to their life expectancy. This then requires maintenance intervention.

Decisions taken by managers in the beginning must be effective enough to accommodate the drinking WI systems for the future. These decisions are necessary to accommodate the increase in the drinking water level of WI systems for the future. The systems, therefore, require a person/s well suited to understand these complexities (Kloosterman and van der Hoek 2020: 2). Managers must solve problems with optimisation practices with an emphasis on the reduction of costs to resolve a particular problem. Water distribution network management seeks to improve service delivery standards and improve client satisfaction (Bello *et al*. 2019: 2 & 3).

Water is a key commodity and the means to convey water to the communities is through pipes. It is vital therefore that means of conveyance (pipes) must be concealed from easy access by humans and animals. Cosgrove and Loucks (2015: 4824, 4834) explain that the global percentage use of water has increased twice as fast as the population itself. Water consumption patterns have changed, and managers must factor these into management planning. These demand patterns fluctuate and are not easy to predict what they will be in the future. Thus, urban water planning, improvement, and management require innovative approaches. However, water supply pattern changes are certain. Cosgrove and Loucks (2015: 4835) further predicted that two-thirds of the world's population may suffer water shortages in the forthcoming decades. Urich *et al.* (2013: 301) advise management to update their water management strategies to align with future urban requirements of water systems.

City of Tshwane (2019b: 7, 14; 15) notes that the City of Tshwane's (CoT's) vision 2030 as adopted on the 25 May 2017 is *"Tshwane: A prosperous capital city through fairness, freedom and opportunity"*. The values as outlined in the 2030 vision will drive the city to its vision if the following strategic pillars are upheld: economic growth, development, and creation of jobs; formation of a caring atmosphere and encouraging togetherness; outstanding service delivery and environmental protection; protection of residents; and honesty, openness, and approachability. In the 2019-2020 Integrated Development Plan (IDP) Review's preamble, a reference was made about the city aiming to create a city of opportunity, a maintainable city with care and comprehends equality access to service, safe, and clean city, open and reliable city. In November 2017, a mayoral committee strategic session resolved to adopt the continuation of the 2016-2021 IDP which was focused on "Stabilise, Revitalise, and Deliver".

City of Tshwane (2019b: 15-16) further noted that the three aspects of focus are: that the city's administration will be stable, the economy will be revitalised, and services will be rendered to all communities. Palmer *et al*. (2016: 3) posit that South Africa (SA) faces a significant degree of economic, social, and environmental challenges clustered in cities. The country must devise means to strategise nationally to guide urban infrastructure investments. This will ensure that tax revenues are spent appropriately for the benefit of present and future generations. However, the demands of service delivery for the city place its budget under severe strain resulting in poor services (Masolane 2019: 54). As a result, in 2019 CoT placed in position four from a total of eight metros according to the South African Citizen Satisfaction Index (steered by Consulta) (Head 2019).

The unprecedented socio-economic issues facing SA and CoT make it difficult for the city's economy to rise. Masolane (2019: 53-55) posits that firstly, cities must deal with large immigration numbers which are overwhelming service delivery. The burden has become too huge for land, housing, education, and health care facilities to handle with the allocated budget. Secondly, many of the population are unable to pay for services but are still accommodated under the qualifying criteria. In terms of the constitutional requirements, the city is obliged to render basic services to the residents. However, the city experiences revenue collection difficulties due to a culture of reluctance to pay even by those who can pay. This applies to CoT as well (Dludla 2020).

Municipalities are overseers of community resources and are therefore duty-bound to ensure the fruitful usage thereof. The use of resources is directed to basic services such as infrastructure, water, electricity, waste removal, and spatial development for communities. Basic service delivery is a fundamental role of local government and controls local growth. Several government attempts to restore service delivery failures to struggling municipalities have not been successful to date (Reddy 2016: 3-4 & 8). In terms of introspection for municipal functionaries and politicians regarding service delivery, there is a need for a total overhaul.

Managers have various functions that they must undertake daily as far as water utilities are concerned. According to Bello *et al.* (2019: 5), utility managers must keep losses to a minimum by sustaining water assets, protecting the environment, growing revenue, and delivering outstanding client service levels. This is a challenging exercise for water utility managers. However, they must be equal to the tasks assigned to them as strategists and experts. The whole team of employees rely on the management team to make good decisions and execute duties diligently. Laitinen *et al*. (2020: 10) are adamant that to maintain a good service level, water utilities must adhere to the following aspects: maintain asset management; good control; stick to the allocated budget and recover the costs; strive for uninterrupted improvement; adhere to the set organisational arrangement; increase capacity; and stick to the policies.

Figure 2.1 is a framework describing the various aspects of WI management in various African cities and SA and the CoT as the focal point of the study. The legislative framework that governs WI in SA is outlined in detail in the figure. The rest of the discussions in this chapter are underpinned by this framework in Figure 2.1.

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- The ownership hierarchy of water infrastructure (WI) in SA
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- South Africa struggles to make WI ends meet

The regulatory framework governing infrastructure in SA

- Infrastructure Development Act of 2014
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- The estimated funds to install and repair infrastructure
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Conclusion

Figure 2.1: **Water infrastructure management framework**
Source: researcher's creation

2.2 The international context of infrastructure management

Currently 40 percent of the global community share rivers, lakes, and aquifers. These communities reside in 153 countries around the world (Makarigakis and Jimenez-Cisneros 2019: 1). Benchmarking with world countries can set a tone for improvement for SA to check if they are declining, on the same footing, or advancing. The SA context has been outlined and the study compared this with how other countries do things. Management of infrastructure differs from country to country, but there may be similarities in selected activities. In that light, Muller (1999: 9) anticipated SA's collaboration with Southern African countries to address the water challenges. The Deputy Director-General of DWS, Anil Singh, has commented on the importance of quality water and WI (Smith 2019).

Africa, compared to the rest of the world, remains behind schedule regarding sustainable access to safe drinking water and improved sanitation. This is non-compliant with the target set for Millennium Development Goal 7. This goal calls for the number of people without sustainable access to safe drinking water and improved sanitation to be reduced by half. The African continent's rates are the highest compared to the rest of the developing regions. The continent is unable to finance its capital expenses and maintenance. They must focus on operation and maintenance. Governments themselves must start introducing strict rules not to default on payment of services (Bond 2016: 324, 330, 331). Failure of governments and government institutions for payment of services rendered demonstrates an elevated level of managerial irresponsibility.

According to Bond (2016: 309, 311), Africa is characterised by its low-quality performance in infrastructure service delivery resulting in weak finances, less payment of services, and weak management of finances and operations. The continent's expense necessities are not met, there is no maintenance of properties, and there is a shortage of managerial skills at all levels. Africa is rated the lowest in terms of infrastructure in the rest of the developing world. An example of low-quality infrastructure is Eritrea, which has experienced various water supply issues such as quality, inadequate supply, consumer supply imbalances, water-shedding, service delivery hiccups, distribution networks, treatment plants, pumping stations, and poor management of utilities (Zeraebruk *et al*. 2014: 93-94). Furthermore, sub-Saharan Africa's (SSA's) income is the worlds' lowest with its 48 low-income countries being considered the lowest region. SSA has 25 of its countries in the World Bank-classified low-income countries from a total of 30 in the world. This is a further expression of the performance of poor infrastructure in Africa as costly, inconsistent, and unpredictable.

Like SA, local authorities are at the heart of service delivery in Botswana (Madala and Phirinyane 2016: 1). Botswana experiences water scarcity with centralised management of water and regularly sidelines the participation of interested parties. Existing infrastructure maintenance is a major problem and new installations are a challenge. This saw Botswana struggle to serve their supply areas and frequent water shortages were experienced. They require a quick renovation of their water governance division to maintain their existence (Setlhogile and Harvey 2015: 1, 2 & 4). Water distribution networks with the best possible means of water supply from the source to consumers is an ideal design (Banos *et al*. 2010: 1).

Southern African cities are faced with multifaceted issues that are similarly experienced by SA. These issues are insufficient water supply, mismanagement, weak governance, infrastructure challenges, and inadequate capital. Additional issues are swift urbanisation, increasing populations, growing informal settlements, and climatic variations which cities find challenging to manage (Ndebele-Murisa *et al.* 2020: 1-2). Similar issues exist in Zimbabwe where Chigonda and Chazireni (2018: 139) reported poor service delivery and deteriorated water and sanitation infrastructure. The same report noted that Zimbabwe depends on external donor funding for water and sanitation infrastructure. Manzungu *et al*. (2016: 57) presented a similar picture of the inadequate supply of water and sanitation services in Zimbabwe.

Manzungu *et al*. (2016: 62) recorded the failure of the Zimbabwean local and central government to provide funding for new, maintenance of, and aging, WI. This urban infrastructure was inherited from the colonial system in good working order. Over two million residents in Harare are without municipal drinking water due to drought and high levels of water contamination. Half of the 4.5 million residents were reported by the city authority of Harare and neighbouring towns to be presently receiving municipal water. The city experienced a severe drought that ran two dams dry leading to supply being necessary from the other two dams which were, however, severely contaminated. Mayor Herbert Gomba reported that the city's daily supply of 450 million litres was less than half of the daily demand (Goodman 2019). This indeed confirms the dire situation that the country is in.

Zimbabwe is confronted by severe water shortages resulting from climatic variation. Aging infrastructure which last experienced an upgrade in 1994, designed to cater for a population of 350 000, escalates the challenges the country faces. These network segments are reported to have outperformed their projected economic life four times. A $144 million loan from China Export-Import Bank for the Zimbabwean government to develop WI in 2011 was overwhelmed by corruption and economic disaster (Goodman 2019).

2.3 The politico-social problems faced by South Africa (SA)

South Africa is still experiencing inequalities within society, many of which are perpetuated by the political situation. Standards of living are still declining with employment dropping to an all-time low. The cost of living, poverty, social expenses, escalating skills shortage resulting from deficiency of suitable education, rising housing, infrastructure and service delivery bottlenecks, rising health challenges and aids diffusion, increasing crime statistics, political volatility, and corruption are social problems experienced that create unpleasant living conditions in SA (Chikowore and Willemse 2017: 87).

The social challenges that SA faces are causing an increase in community dissatisfaction. Protests have spread all over the country as communities express their unhappiness with the leaders. These protest actions occur because of the unpopular decisions taken by municipal officials.

A study by Pooe, Worku and Van Rooyen (2016: 24) reported extensive service delivery protests prevailing in SA municipalities due to the rendering of an inferior quality of service. Such protests place municipalities under public scrutiny. Khale (2015) praised the CoT's efforts to intensify service delivery, but the residents were still not satisfied and did not stop their protests. The local government's plan to amalgamate the district municipalities into CoT came as a positive move to monitor and evaluate the performance for the betterment of the service delivery (Pooe, Worku and Van Rooyen 2016: 25).

The protests that have surfaced all over the country are discussed by Hamer *et al*. (2018: 1) and Alexander *et al.* (2018: 27). A study by Sershen *et al*. (2016: 458) revealed that the service delivery inequalities and the challenges faced by the municipalities triggered the SA countrywide service delivery protests. Amongst the issues pointed out were incapability of decision-makers; skills shortage in the water sector; unreliable political undertakings; and deteriorating infrastructure. Galaitsi *et al*. (2016: 18) note that the issue of discontinuous water supply involves one or all of the following: politics, engineering, human health, and social rules.

According to Mofolo (2016: 230-232), the highest peak of SA's protests was experienced in 2014 with 218 service delivery protests. Turok (2016: 220) noted the the rising turbulence in big cities. The protesters complained that they were side-lined by decision-makers who were not inviting them to participate in meetings. Mofolo (2016: 230) further pointed out that the intergovernmental relations in SA municipalities were a cause for concern. The protests were caused by communities being side-lined from the decision-making process, and ward committees lacked accountability and were dysfunctional. This is viewed by Van Leeuwen *et al*. (2019: 5) and Tacoli, McGranahan and Satterthwaite (2015: 5) as a setup for failure because successful, good leadership rests on collaboration between civil society and local government. Turok (2016: 221) observed that the subject of escalating unrest is ill-understood, and unattractive to researchers.

Institutions face escalating failures due to the exclusion of locals from the meetings or decision-making structures. The exclusion narrows the discussions of the decision-makers to only what they want to hear. The locals are then barred from airing their challenges about unreliable water supply. It is important to include local experiences into the decision-making process and any other arrangements for sustainable water supply. Locals will have a feeling of ownership, their voices will be heard and understood, and discrepancies will be settled, with the roles being clearly defined (Hamer *et al*. 2018: 2).

Mofolo (2016: 243) argued that the exclusion of communities from provincial-local intergovernmental relations is a serious weakness. This exclusion limits the democratic rights of communities to air their views which may be helpful to the authorities. The findings pointed out that the provincial government should ensure the smooth running of the IDP forums within the local authorities. The remaining work is for the provincial government to continuously observe the efficiency and effectiveness of the IDP representative forums within the municipalities.

The water utilities have exhibited inferior performance even after receiving multiple resuscitations. The fault is always placed on the political economy. Unworkable political economies place the focus of water utilities outside the interests of clients, focusing rather on maximising votes, awarding of job offers, and providing water services at low rates to clients. Politicians sometimes ‘fiddle’ in order to benefit themselves through interfering with the work of water utilities. Managers, as a result, are left with having to rescue the utilities from the damage caused by the politicians and this affects the employees (Soppe, Janson and Piantini 2018: xii-xiii).

Mello (2020: 83-84) condemned the employees of the CoT for turning back the clients from other regions of the city as improper and confusing. The clients from other regions of the CoT who request service, are being referred by the CoT employees to enquire about the state of their accounts at the city’s head office in Pretoria. As a result, the residents expressed the view that the city should be placed under administration due to endemic political factional battles that deny them access to water. Another dissatisfaction by residents was that councillors only make themselves available in emergency situations related to service delivery.

Spending on infrastructure is in decline because of the general economic downward spiral. The inherited low spending on WI persists and deficiency of critical skills is growing. Public-private partnerships (PPPs) have confirmed their functionality globally and in SA in other business sectors. The PPPs were introduced to assist emerging economies to boost the infrastructure backlogs through partnership between state and private companies. Despite the guidelines set for PPPs by the National Treasury in 2004, their performance in the water sector is still exceptionally low (Viljoen 2019: i).

Soppe, Janson and Piantini (2018: xi) acknowledge that some public water and sanitation utilities perform outstanding quality of work, but others still find this too hard. Several factors hinder the performances of public utilities, but the two aspects which are most common are weak operations and investment inefficiency. The problems that public utilities such as municipalities encounter are complex and multifaceted, including unworkable political landscapes and ever-increasing backlogs exacerbated by unproductive activities that do not require technical or managerial techniques to resolve. However, it takes a competent manager to solve unpredictable events that arise. This is possible by creating integrity with customers and building confidence in employees.

2.3.1 The ownership hierarchy of water infrastructure (WI) in SA

According to the Department of Water Affairs (2013: 28), the ownership hierarchy of WI in SA is as follows: any infrastructure funded by the state or water resource infrastructure built for the purpose of serving the public is always owned by a state organ. A state organ may be in the form of a National Government, a municipality, a water board, a water user association, or a catchment management agency. However, there may be other sources of finance used to construct and manage the infrastructure but this should not diminish the ownership position of the state. However, privately funded, owned, and managed dams are not bound by the regulations governing state infrastructure.

The Department of Water Affairs further insists that any infrastructure of national water resources and the components of a system, and that are of strategic significance, are directly owned and controlled by the Minister. The bulk and regional WI are controlled by a regional water utility and the irrigation schemes are controlled by a water user association. The municipality can control the local water resource infrastructure, provided there is enough capacity to execute the asset maintenance and to guarantee the safeguarding of dams. If there is no capacity from the municipality it will then be the function of a water board. Consequently, it is through the proper management of cities that appropriate skills are recruited to properly execute their obligations.

2.3.2 South African context of managing WI

There are several reasons why communities, towns and cities require water. These reasons include: the conditions of the climate; service level; socio-economic conditions; wet industries; organisational capability; and consumer conduct (Hay *et al*. 2012: 437-438). Despite various local authorities knowing that groundwater is an unreliable resource, there is a problem of ineffective management of this resource by insufficient staff.

The issue of lack of proper management skills is common within SA municipalities. Hay *et al*. (2012: 442) reported that the Eastern Cape and Western Cape province municipalities have experienced a lack of technical skills and management shortfalls in the running of WI and water resources. The shortfalls resulted in the following service delivery disruptions: ignorance of operation and maintenance of existing schemes; WI decline; drop in quality of drinking water and wastewater; and, increased loss of water. Indeed, these shortfalls expose the leaders in the country and the municipalities.

There have been some interventions to address the water supply hiccups faced by towns and rural villages of the aforesaid provinces. These include requests by the authorities to apply water conservation and demand management to reduce loss and wastage of water; improve the infrastructure to guarantee the supply; upgrade groundwater; recycle water; sell water; collect rainwater and desalinate sea or brackish water. According to McKenzie and Wegelin (2009: 173), SA experiences a consumer support dilemma about the use of water. However, there has been considerable progress which is noticeable in the behavioural changes regarding the use of this resource.

Other measures which have been implemented by compliant consumers to manage the excessive loss of the resource as mentioned in the study conducted by the Water Research Commission (2016: 30) are:

- Draw-off points are not left running unattended.
- Repair leaking taps.
- Apply water use limits.
- Water gardens less.
- Use shower instead of bath.
- Fully load a washing machine or dishwasher before running it.
- Recycle greywater.
- Collect rainwater.

South Africa shares common water resources with the following SSA countries: Botswana, Lesotho, Mozambique, Namibia, Swaziland, and Zimbabwe. All these countries except Lesotho fall within the category of water-scarce countries. As a result, any one of these vulnerable countries that misuse the resource will negatively impact the others. Collaboration on the conservation, management, and effective use of the resource is beneficial to others (Muller 1999: 9). Viljoen (2019: i) and Sershen *et al*. (2016: 456) have reiterated that SA is a water-scarce country, and Viljoen added that the situation is worsened by climate change. As a result, water must be used sparingly.

Considering the rapid global changes, Van Leeuwen *et al*. (2019: 1, 3) view water governance as needing to be more stringent in the future than it ever was in the history of humanity. It is expected that water governance and water management will escalate in the next 20 years more at a faster rate than for the past 100 years. An approach to policy adjustment has already occured at one of the SA cities – the City of Cape Town. The city has started to align its drought policies to fit the present drought situation.

2.3.3 South Africa struggles to make WI ends meet

There was very little infrastructure investment in SA before the years of democracy. At the present time, a joint effort between government and state-owned entities has plans for R845bn expenditure on infrastructure. Together they are targeting to meet five million jobs in the 2020 New Growth Path or 11 million jobs in the 2030 National Development Plan. These developments aim to reduce poverty imbalances and joblessness, and grow the economy by spending on infrastructure (Maisonnave *et al*. 2019: 2). The government has dedicated huge sums of money to infrastructure after realising that there was such a slow pace after assessing development.

Masindi and Duncker (2016: 37) outlined SA's weaknesses in response to issues of water as being neglect of maintenance and sustainability, ignorance of sanitation, failure of government's maintenance and funding levels in the water sector, insufficient skills in all ranks, and inadequate planning. Considering the above, studies have shown that effectively managed utilities produce satisfactory results for the poor in terms of access to water (Heymans *et al*. 2016: 7).

Hamer *et al*. (2018: 1) and Galaitsi *et al*. (2016: 1) have a collective understanding of the difficulties encountered by South Africans regarding access to water. Galaitsi *et al*. highlighted that the main problem articulated by authorities is the scarcity of water. However, there is another part which is environmental. Hamer *et al*. (2018: 1) observe that South Africans suffer frequent water interruptions which are likely to occur several times a week.

Galaitsi *et al*. (2016: 8-9) characterised the causes of intermittent water as follows:

- "Large-scale trends" - extensive scale forces that operate above the political scope at the scale of the water network.
- "Local governance" - conclusions are drawn at a local level within the water supply locality.
- "Capacity constraints" - the restrictions of the network capacity or management of the network.
- "Consumer response" - reactions by individual consumers that are not influenced by the policies.
- "Health" - negative effects on the health of humans (debris is collected into the pipes).

According to Jacobsen, Webster and Vairavamoorthy (2012: 33-34, xxi), alternative methodologies such as innovative technologies to reuse water and address the challenges of water supply and wastewater services can enhance the process. These technologies properly align with the low-energy consumption requirements of developing countries. In addition, the literature highlights the strategic water effort introduced by the City of Polokwane in Limpopo Province of SA. The strategy aimed to reinforce the ability to manage the use and supply of water, safety plans of water in the catchment areas, a plan to manage drought and encourage the use of recycled wastewater, manage the demand, and reduce pressure to lessen the leaks.

The first SA town to enjoy the benefits of 30 percent wastewater recycled to direct potable water is Beaufort West (Mnguni 2020: 204-205). According to Tortajada (2020: 1, 2), Sustainable Development Goal 6 (SDG6) requires that wastewater should be recycled, and half of it should not be disposed of untreated. This goal is intended to improve recycled water quality.

Water reuse is not a new phenomenon as it is currently being introduced in developing countries. The phenomenon of water reuse and recycling have been occurring across the globe (Angelakis *et al*. 2018: 1 and Paranychianakis *et al*. 2015: 1410), from ancient history to the contemporary era as confirmed by Angelakis *et al*. (2018: 1). The current trend is that water is being reused and recycled for most functions including potable purposes (Angelakis *et al*. 2018: 1). For example, Shibam in Yemen and Mexico City in Mexico use wastewater for irrigation and crop fertilisation (Angelakis *et al*. 2018: 4, 5). Ethiopia, Ghana, and Tunisia reuse their wastewater for numerous other functions (Swana *et al*. 2020: 229), whereas in Mossel Bay and Durban it is only for industrial use (Mnguni 2020: 205). The process was initiated in Namibia in 1969 which has seen five decades of recycled water consumption. Singapore followed suit in 2003 with its recycled water undergoing 65,000 scientific experiments and which outperformed the standards for drinking water as set out by WHO (Ghernaout 2018: 2).

2.4 The regulatory framework governing infrastructure in SA

The constitution of SA is the supreme law of the country, and all other laws conform to the constitutional requirements. SA has legislation governing the management, coordination, implementation, monitoring, installation, service, and maintenance of the infrastructure. There are many legislations governing infrastructure, but the ones discussed below are most pertinent for this study. The role of legislation is to give guidance on how things should be done within the ambit of the law.

2.4.1 Infrastructure Development Act of 2014

The object of the Infrastructure Development Act of 2014 [Act No. 23, 2014] is to empower the Economic Development Department with the duty of facilitating and coordinating the development of public infrastructure. The Act provides a guarantee that the pillars of planning, approval, and implementation of infrastructure development are given a preference. The development of infrastructure will affirm the progress in the goals the state has set for itself. Furthermore, the Act aims to improve infrastructure project life cycles such as planning, approval, implementation, and operations (South Africa, Economic Development Department 2014: 2). The custodian of this legislation is the Economic Development Department.

2.4.2 The National Water Act of 1998

The National Water Act of 1998 [Act No. 36, 1998] provides a guarantee regarding the security, usage, development, preservation, supervision, and control of water resources. Factors catered for by the Act are: meeting the human needs for generations to come; supporting equal access to water; reparation of historical racial and gender discrimination; support for the proper and sustainable use of water for the public benefit; expedite socio-economic development; perform according to the growing need of water; decrease and prevent contamination and dilapidation of water resources; conformance to international requirements (South Africa, Department of Water Affairs and Forestry 1998: 18).

2.4.3 Water Services Act of 1997

The Water Services Act of 1997 [Act No. 108, 1997] provides for rightful access to a basic supply of water and basic sanitation. It provides for the establishment of national standards, norms, and tariff standards. It further organises the developmental plans for water services and provides a regulatory structure for water services organisations and intermediaries. It inaugurates water boards and water services committees and specifies their powers and duties. It arranges for funding support to water services institutions. It affords the collection of information in a national information system, and information dissemination, and rescindment of other laws (South Africa, Department of Water Affairs and Forestry 1997: 2).

2.4.4 National Environmental Management Act of 1998

The National Environmental Management Act of 1998 [Act No. 107, 1998] (South Africa, Department of Environmental Affairs and Tourism 1998) enables supportive control of the environment by providing clarity for decision making on matters concerning the environment. It also helps organisations that uphold good governance and complements the environmental roles implemented by state organs (South Africa, Department of Environmental Affairs and Tourism 1998: 2).

2.4.5 Municipal Systems Act of 2000

In SA, local governments are central to service delivery. For this reason the government developed the Act on how municipalities shall operate. The Municipal Systems Act of 2000 [Act No. 32, 2000] (South Africa, Department of Local Government 2000) promulgates the central principles, mechanisms, and processes that are required to assist local authorities to advance towards the socio-economic promotion of local communities. It also guarantees collective access to cost-effective essential services to everybody. The Act further outlines the legal nature of the municipality in relation to the local community within its boundaries. It encourages the community to work in conjunction with the political and administrative structures.

The Act further outlines the way municipal powers and functions are implemented and achieved. It affords freedom of community involvement and creates a simple and supportive framework to plan, manage performance, deploy resources, and institutional transformation. It empowers the underprivileged and ensures the institution of service tariffs by municipalities and credit control policies that accommodate their requirements. It also provides agreements for service delivery and municipal service districts. The Act makes provision for credit control and collection of debts. It makes provision for the observation and standardisation by other government spheres to progresively form a capable local government (South Africa, Department of Local Government 2000: 2).

2.4.6 South African National Standard for Drinking Water

The South African National Standard for Drinking Water [SANS 241: 2015] is about the assessment of risks of water quality, and monitors and verifies quality for improved water quality risk management. However, it does not provide an inclusive water management plan. It applies to water services organisations or water services intermediaries. It also evaluates the drinking water use against the determinants and set limitations of suitable health risk consumption for a lifetime. The standard aims to enforce compliance to the following key elements: risk assessment for water quality; intensive care of water quality; response monitoring; water quality verification; and water safety plan.

Accordingly, water services organisations and intermediaries, or both, shall apply risk-based management to guarantee that drinking water is harmless for human consumption. The standards applicable for consumable water are clearly outlined in SANS 241-1. These organisations or intermediaries bear the responsibility of quality consumable water (South African Bureau of Standards 2015: 3).

2.5 The Gauteng province context of managing WI

Most studies on infrastructure highlight the issues of rapid urbanisation and climate change which have caused the unprecedented levels of strain that infrastructure networks or systems currently experience. Designers of urban infrastructure did not anticipate the large numbers of people flocking to urban areas as is presently happening. According to Muller (2019b), cities in Gauteng started requesting residents to use water sparingly due to maintenance being undertaken by their supplier, Lesotho

Highlands Water Project. Gauteng receives water supply from some of the Lesotho dams which form part of the fourteen interconnected dams of the Integrated Vaal River System. There is a 25 percent water supply from Lesotho feeding the Integrated Vaal River System.

There have not been any water shortages in the Gauteng cities of Johannesburg and Pretoria as predicted by specialists. However, there are fears of mismanagement of water security at the Department of Water and Sanitation (DWS). Poor management of critical services has been witnessed after uncertainties in power supply which have resulted in water and electricity supply predicaments. Supply expansion, inclusive of the Vaal River system, is anticipated by DWS beyond 2040. The governments of Lesotho and SA have jointly taken a resolution to construct the Polihali dam. Construction has not yet started due to a lag in procurement processes that needed to be reshaped by the South African minister (Muller 2019b).

The world's cities are facing extraordinary patterns of water usage due to population increase. Gauteng province is facing the same challenge due to urbanisation and a 3 percent annual population increase. This requires an adequate and robust infrastructure to cope with the demand. A 3 percent annual reduction of water usage per person in the region of the Vaal River System is anticipated. The reduction will have to be enforced until 2026 if drought hits and the Polihali dam is not constructed. The local municipalities in the region receive 1 600 million cubic metres of water drawn from the Vaal River system as licenced by Rand Water. The system's remaining supply is shared amongst Eskom, mines, and agriculture. To manage water properly the risk of disaster must be reduced (Muller 2019b). The way people see and perceive the construction and operation of new infrastructure needs to take a new direction.

2.6 The CoT context of managing WI

The CoT operates within certain boundaries as far as water supply and sanitation services are concerned. These boundaries are shared with Johannesburg, Ekurhuleni Metropolitan Municipalities and the local unicipalities of Bojanala, Moretele, Bela-Bela, Dr. JS Moroka, Thembisile, Emalahleni, and Delmas. Sections of Moretele, Madibeng

LM's, and a small rural section of Midrand (City of Johannesburg) are fed from CoT bulk water supply. Thembisile in the Bronkhorstspruit area is jointly supplied by two large diameter pipes from Rand Water Board and CoT. Some sections of Midrand sewer systems discharge into CoT sewer systems (CoT 2017b: 8). The CoT owns bulk and raw infrastructure with a value of R8.7 billion and privately owned bulk and raw infrastructure of R1.7 billion (CoT 2017b: 20).

There are seven regions (Region 1 - Region 7) forming the CoT. The regions incorporate major residential areas as outlined hereafter. The city manages WI in each of the seven regions which are made up of the following major residential areas: Akasia, Atteridgeville, Babelegi, Bronberg, Bronkhorstspruit, Centurion, Crocodile River, Cullinan, Eersterust, Ekangala, Elands River, Ga-Rankuwa, Hammanskraal, Laudium, Mamelodi, Pretoria, Rayton, Refilwe, Rethabiseng, Roodeplaat, Soshanguve, Temba, Winterveldt and Zithobeni (CoT 2019b: 22, 24). Nineteen of SA's twenty-seven biggest cities receive bulk water from the water board. The City of Cape Town and Nelson Mandela Bay Metro run their own bulk supply (Palmer *et al*. 2016: 13), whereas eThekwini sources its water from Umgeni Water (Sutherland *et al*. 2014: 473 and Mnguni 2020: 204).

The city accesses water through regional/local water schemes, boreholes, springs, water tanks, dams/pools/stagnant water, and rivers or streams. The CoT Mayoral Strategic Planning session held in 2017 to review 2019/2020 IDP weighed the options of installing new or maintaining existing infrastructure. Expert advice was that the maintenance of existing infrastructure was a better option. This would also improve the stability of the city's returns and may bring income for future new infrastructure. It is vital to investigate an alternative to safeguard the infrastructure assets and ascertain a constant functionality of the network (CoT 2019b: 47, 54 & 55).

The water billing system's official total estimated number of clients for CoT is 720 000 residing on 580 000 stands and 200 000 extra clients from informal settlements. Formal clients, informal settlement clients, and external clients consume an estimated annual average daily demand (AADD) of 924 megalitres per day (ML/d). Water unaccounted for (water loss) is 27 percent for the city. The total bulk WI owned by CoT is 49 Rand Water connections; 4 city owned main water treatment plants; 2 city owned minor water treatment plants; 3 Magalies Water owned water treatment plants; a few privately owned package water treatment plants; several fountains, boreholes and springs; 860 km bulk pipelines (216 km owned private/externally); 170 storage reservoirs (19 private/external owners) on 119 sites with 1,913 ML capacity; 40 elevated towers with 14 ML (8 private/external owners); 99 pumping stations (19 private/external owners); and 235 primary Water Distribution Zones (per reservoir, water tower or direct link to the bulk network) (CoT 2017b: 20). The CoT has over 260 pressure control stations and a length of pipe reticulations of 10 677 kilometres at 250 m operating pressures (Loots *et al*. 2014: 2 & 4).

The Statistician-General, Risenga Maluleke, reported that the CoT led with 60 percent of its citizens eligible for free basic water supply compared to 59 percent of eThekwini municipality. A further outline of 3.6 million indigent residents was registered in 2018, of which 2.8 million enjoyed free basic water supply and 2 million got free electricity. There were also 1.8 million who enjoyed sewerage and sanitation (Ndaba 2019). Ndaba further reported that only two metropolitan municipalities, namely Ekurhuleni and CoT, offer two of the four basic services of the municipality free of charge.

There were various concerns raised in an intergovernmental relations forum by the DWS. These concerns were: response time to maintenance and repair of leaks, bulk supply, limited water resources, the supply of quality water to Hammanskraal and Temba, vandalism of the infrastructure requiring by-law enforcement, Bronkhortspruit dam that has reached operational capacity, and Rooiwal wastewater treatment plant (RWWTP) (CoT 2019b: 108-109).

2.6.1 The estimated funds to install and repair infrastructure

Regarding these multifaceted issues, it is necessary to first figure out from where the challenges emanate, given the delays, insufficient water supply, water quality, and vandalism. Theft of electrical cables is a headache for SA and CoT in particular (CoT 2019b: 128). The city's electrical infrastructure is also poor and requires an additional R6 billion for restoration (Moatshe 2018). Electricity plays a pivotal role in WI, and it is for that reason that the electricity shortfalls the city has encountered are mentioned.

There is a natural relationship between water and electricity – one does not go without the other (Potgieter *et al.* 2019: 19).

The CoT's utility services department anticipates receiving the biggest share of the funding for the 2020/2021 fiscal year for the municipal infrastructure. The share amounts to R1.1bn which is a total of 29 percent of the budget and is in line with the city's proposed integrated development programme. Most of the money will be used to construct wastewater treatment works and the remainder will go to electricity projects and the restoration of water networks (Moatshe 2020).

The revenue generated by the CoT from water services amounts to R5 554 736 736.00 which is 13.19% of the total revenue generated from the services rendered by the city (City of Tshwane 2022a, cited in Dube 2022: 19). The current state of the CoT's WI is that the Temba Water Treatment Plant produces sub-standard and non-potable water due to poor quality water abstracted from the Leeuwkraal dam. This situation results from partly treated sewage effluent from the RWWTP that eventually discharges into Leeuwkraal dam (Portfolio Committee on Water and Sanitation 2022: 2).

A member of the executive council, Mr Lebogang Maile, pointed out that an urgent focus should be placed on the 15 treatment plants and the RWWTP. Mr Maile further noted that Ekurhuleni Water Care Company will soon resume a two-year capacity expansion project for the RWWTP. The extensions of reservoirs are anticipated to cost R90m, and the restoration of water networks and the clearing of backlogs will cost R39m. A sewage system that costs R65m will also be installed in Saulsville and Mamelodi (Moatshe 2020). The RWWTP, skills shortages, lack of training, and political interference cause the CoT to experience underperformance.

Pooe, Worku and Van Rooyen (2016: 24) compared similar underperformance situations that prevailed in other municipalities and recommended training and development. Pooe, Worku and Van Rooyen's (2016: 28) study found that:

- There is a major correlation between unsatisfactory performance and the absence of training.
- Trained employees produced better results than those who were denied an opportunity to be trained.

- The training was misaligned to the required skills to perform the activities.
- Persistent protests by the communities even after the employees were trained by the city's departments, training academy, and the external service providers.
- Performance evaluation indicated percerptions of race, political party affiliation, and political interference.
- There was a shortage of suitably qualified functionaries for the key service delivery positions.
- The CoT's efforts to implement leadership and internship initiations were not implemented by the employees concerned.
- Monitoring and evaluation of performance was implemented for the increase in salaries and bonus pay-outs and not for the intended better service delivery.
- There is a lack of follow-up to check the performance of trained employees.
- The regions were weakened by the shortage of suitably qualified, trained, and devoted personnel.

2.6.2 Project management in the City of Tshwane (CoT)

Various issues that may be experienced include the processes from project initiation until project termination. One of the major drawbacks may be interference by project stakeholders which can be costly if they cause a project to halt. This may be due to stakeholders putting forth their demands, derailing the project, or seeking to make their presence felt. Sanggoro, Widyaningsih and Bintoro (2020: 164, 165) noted that disagreements and social problems can be a hindrance to project operation. Further to that, losses from these factors are where the project manager's difficulty in job execution begins. They further stress that the most essential part of all for the project manager is to identify the project stakeholders. Project stakeholders make or break a project.

WI projects are mostly executed within communities with different socio-cultural, economic, and political issues. Mentis (2015: 3; 14) argues that it is often misconstrued that project derailment arises from risks when it is in fact uncertainties that cause derailments. The derailments being referred to may either be in the form of project cost, project scope, project time, or project quality. The fact is that risks can be measured, in comparison to poorly measurable uncertainties. The engagement of stakeholders and encouraging them to feel ownership are key to the project's success. There is limited literature as far as project management for the CoT is concerned.

2.6.3 Mismanagement of the CoT

There have been numerous protests about service delivery which involve battles between political parties. The African National Congress (ANC) and the Economic Freedom Fighters pushed to oust the Democratic Alliance (DA) from the city's leadership. The parties carried on with such actions despite the DA having won with a DA-led coalition which defeated the ANC in 2016 and gave them the mayoral seat. The city had already received resignations from two mayors since the DA-led coalition took office. The Premier of Gauteng Province, David Makhura, spoke on how best to manage the city, announced the dissolution of the council and the arrangement of new elections within 90 days. The city was under a cloud of mismanagement which, coupled with irregular expenditure, led the municipality into administration (Dludla 2020).

Khale (2015: 675) voiced concern about the CoT having received numerous qualified reports in the past years from the South African Auditor General. The Premier further added that the city had taken a stance to monitor audit outcomes identified in the Auditor-General's report. The following audit outcomes were identified by the Auditor-General: unauthorised, irregular, fruitless and wasteful expenditures, and deliberate ignorance of procurement processes. The CoT faced various underperformance issues ranging from an inability to pay creditors and poor revenue collection. These malpractices overlooked the city's corporate governance processes. The Auditor-General further announced the appointment of an administrator to manage the city within seven days. The Premier mentioned the 25 percent contribution of CoT and Johannesburg to the gross domestic products of the province (Dludla 2020), which highlights the importance of improving the administration and management of the CoT.

Nganyanyuka *et al.* (2018: 615, 629) conducted a study in Tanzania in 2018 where citizens condemned the authority and management of the local authority. Residents were mostly complaining of selective service delivery to customers by the water authority officials (MWUSA-this name is a pseudonym). The MWUSA's customers suffered supply interruptions, low pressure, poor water quality, leaks, vandalism, worn-out infrastructure, request for bribery for service, etc. to mention a few. The kind of malpractices by MWUSA functionaries required serious consequential management intervention. Most of these underperformances arose because of functionaries' reluctance to execute their obligations. However, from the literature studied, the CoT has not revealed any malpractices such as those revealed in Tanzania.

2.6.4 The dissatisfaction expressed by the CoT residents

In other parts of the CoT, the residents have expressed their dissatisfaction with the supply of contaminated water (Portfolio Committee Human Settlement, Water and Sanitation 2019). Table 2.1 provides a brief outline of the residents' dissatisfactions.

Table 2.1: CoT residents' dissatisfaction

Dissatisfactions expressed by the CoT residents
Contaminated water supplied by the CoT to the residents of Hammanskraal.
CoT's rejection of assertions from the residents regarding contaminated water.
Request by CoT to the residents to provide scientific proof of contaminated water.
Non-adherence of the CoT to the master plan from 2004 for the upgrade of the infrastructure.
Of 15 wastewater treatment works for the city, only two were functional and four in serious condition.
Lack of future planning by management.
Human rights violations by CoT for substandard quality water supplied to the residents.
Estimated and inconsistent water billing system.
Ignorance in reply to the residents' (Hammanskraal Residents Forum) memorandum of demand.
Response by the CoT after Hammanskraal experienced a total shutdown by the residents.

Source: Portfolio Committee Human Settlement, Water and Sanitation (2019).

The issues presented emanated from the lack of interventions from management when things were still easy to control. Ignorance of the master plan by the city led to management's failure to execute their duties of service delivery to the community. The community dissatisfaction was prompted by the city management's lack of diligence.

According to the Portfolio Committee Human Settlement, Water and Sanitation (2019), the CoT management acknowledged that indeed the city is facing problems regarding

WI. Management made an undertaking to adhere to the city's turnaround strategy. They indicated that underinvestment had prevailed over the past ten years regarding the upgrade and maintenance of water reticulation. Poor planning was acknowledged by the CoT management with a commitment to redress the situation. The management agreed to form forums with communities to address the issues around planning.

The Water Research Commission (2016: 26) outlines the following service quality index score for the SA metropolitan municipalities in terms of the delivery of decent quality services rendered to communities:

- City of Cape Town- 7.01
- City of Tshwane- 6.97
- City of Johannesburg- 6.77
- Mangaung- 6.62
- EThekwini- 6.53
- Ekurhuleni- 6.41
- Nelson Mandela Bay- 5.83
- Buffalo City- 5.6

A service perception level rating was set from zero to ten wherein less than five meant that urgent performance improvement is required and ten is an outstanding performance.

This literature review has unveiled several management gaps at the CoT. The shortfalls were extracted from the recommendations of the National Council of Province select committee on finance about the CoT as a remedy to improve performance. The management shortfalls were unlawful awarding of contracts, individualising the matters which needed the attention of other stakeholders for success, unattended loopholes in the organisational structure, slow pace to report matters to the law enforcement agencies, disregard for the water and sanitation standards, politically motivated protests with demands of sub-contracting, and misalignment with other departments (National Council of Provinces Finance 2017). The recommendations copied from the National Council of Province select committee on finance report assisted the researcher to form a basis for identification of the management challenges. They provided a meaningful platform for the researcher to clearly identify the issues regarding management shortfalls and politically motivated shortfalls.

2.7 Planning for WI

The first step for successful water utility management is to plan for the future. Soppe, Janson and Piantini (2018: 86) recommend that a business that wants to continue for the next five years needs to uphold the strategic goals of the organisation. The authors envision the following steps to be followed by a utility manager to build a successful utility:

- Evaluate how the external factors will impact the long-term objectives.
- Involve the stakeholders.
- Select the actions to sustain uninterrupted internal development.
- Develop a strategic plan and indicate the financial needs and potential source of funds.
- Organise a five-year business plan and make funds available.
- Introduce a performance management system.
- Apply a business plan and provide the funds for the strategic plan.

At the management level, planning should bring better plans that incorporate the issues that SA currently faces with the challenges of water. The leadership challenges faced by the country are far from over and the utilities need a total overhaul of leadership or face catastrophic consequences. The behaviour of the leadership in SA has gotten out of hand to the extent that even the slightest decision that needs management intervention is politically interrupted for self-enrichment and this is what leads to service delivery protests (Mngomezulu 2020: 39-40; 44; Mbandlwa, Dorasamy and Fagbadebo (2020: 1644 & 1649); Masuku and Jili 2019: 1-2).

Managers must learn to adhere to the budget allocated for maintenance. Ochieng (2016: 22) points out that each time there is an issue with the municipal finances, the maintenance budget is compromised. The author puts forth a proposal to adjust maintenance funds by introducing new pricing mechanisms to gain support for the better use of water. Ineffective planning capability by the managers disadvantages the authorities' business plans to attract investors.

The WI in SA faces a vulnerable future of unpredictable and cyclical climatic variations. Managers are required to plan against eventualities and the undesirable exposures that climate change may bring, including a great deal of damage that the infrastructure may experience with unbudgeted financial implications. O'Neill (2010: 81-82) points out that climate is characterised by:

- More abnormal hot days and nights with extra heat waves.
- Fewer chilly days and nights.
- A rise in the number of days without frost.
- Vulnerable areas will experience drought more frequently.
- Rising air temperature will intensify water evaporation and increase the occurrence of harsh drought.
- Less, but more frequent and severe precipitation.
- Frequent and severe storms.

Planning for WI depends on several socio-economic activities. These parameters are, amongst others: population, economics, the use of water, the production of food, transportation, technology, gas emissions from the green-houses, surface temperatures, and the use of natural resources (Makarigakis, and Jimenez-Cisneros 2019: 4). It is therefore imperative, as O'Neill (2010: 80) advises, that in the planning phase designers must factor in temperature, precipitation (high, low, or drought), and severe weather conditions.

The CoT's planning period for water and sewer infrastructure necessities is 45-50 years CoT (2017a: 15). Planning depends on the present and future requirements of this infrastructure. The city's planning seeks to achieve the following objectives: compliance to set operational requirements and standards; use of the infrastructure to its optimum level or exceed the design life; effective use of capital, maintenance, and operational costs; and compliance with land development objectives. According to Pienaar (2013: 163), a suitable plan and budget rely on the proper calculation of maintenance size to confront the backlog. However, the most challenging activity is for asset managers to reduce losses from ageing infrastructure, notably leaks and breakages. For this reason, Meijer *et al*. (2020: 1) propose prioritising rehabilitation and maintenance because of budget limitations.

These planning objectives triggered the high-level objectives set by the city namely: water security and guaranteed supply; introduction of the ‘Blue Drop’ and ‘Green Drop’ certification programme[1]; equipping of proclaimed townships with waterborne sewers and tap water; equipping unproclaimed areas with basic water; establishment of organisational design principles in the form of backup emergency storage facilities at reservoirs and extraordinary standards in dolomitic settlements. The hydraulic models on operating and future infrastructure networks of the CoT are maintained and updated quarterly (CoT 2017b: 15). A study by Potgieter *et al*. (2019: 20) revealed that the CoT’s state of readiness for electricity disruption only caters to short-term disruptions. Consequently, the relevant Water Services Authorities (WSAs), Water Services Providers (WSPs), and power generation authorities have inadequate preparations to alleviate long-term power interruptions that would affect water supply. The city is highly exposed to power interruption risks in the medium to long term.

Existing infrastructure systems assessment originates from the high possibility of an increase in the current annual average daily demand. During the execution of these assessments all proclaimed townships, regardless of the ervens’ occupation status, are factored into calculated unit water demands. For future systems planning of anticipated future developments and informal settlements, and annual average daily demand is factored factored into the system. Assessment of existing networks and potential future development is through computerised hydraulic modelling. The required pressure ratings, permissible flow speeds, acceptable pump capabilities, and reservoir storage capability are assessed according to present and future network requirements (CoT 2017b: 15). At the planning phase, planners quantify that half of the lost water escapes through leaks, and the remaining half through private and illegal connections (Galaitsi *et al*. 2016: 12).

[1] Edokpayi *et al*. (2020: 188) and Mashele (2017: ix) define Blue Drop Certification Programme as a programme that has been introduced to certify that the water discharged from a tap conforms with the set South African National Standards for drinking water quality. In addition, the treatment of wastewater in South Africa is taken care of by the Department of Water and Sanitation and it is called Green Drop Certification Programme (Edokpayi *et al*. 2020: 188).

Reducing the quantity of water used assists in determining the demand – notably from industrial, agricultural, and domestic consumers. Consequently, SA authorities must identify better governance actions to guarantee and maintain quality and quantity amidst escalating water scarcity (Maphela 2015: 4). The scarcity of water in the local authorities of Gauteng is confirmed by Ochieng (2016: v), because of the population increase.

To plan for the WI networks, one must know the usage patterns per sector in a specific municipality. According to Reddick and Kruger (2019: 7), SA has the following water use patterns in the following economic sectors:

- Agriculture- 62 percent
- Municipal- 27 percent (Rural- 3 percent, Urban- 24 percent)
- Mining- 3 percent
- Industry- 3 percent
- Afforestation- 3 percent
- Energy- 2 percent

Water sources in SA are as follows: surface water (68 percent), return flows (13 percent), groundwater (13 percent), and others (6 percent seawater/ brackish water desalination) (Reddick and Kruger 2019: 7).

In trying to manage the escalating challenges that the local authorities face, most cities are currently reorganising their policies to incorporate the strategies of climate change (Madonsela *et al*. 2019: 2). Armitage *et al*. (2014: i-iii) noted that the current challenges of lack of sufficient provision of water for the citizens of SA cannot be exaggerated. The institutional system of local authorities is fragmented with each operating as a single standalone department with its management component. This system of operation produces poor communication outcomes and disintegration of services. In terms of equitable service delivery SA faces a challenge in the provision of basic services to previously disadvantaged individuals. The country should first sort out the provision of of basic services before advocating the greening of projects (Armitage *et al*. 2014: iii).

With that in mind, Maphela (2015: 2) explains the seriousness of water management as a global phenomenon that needs focused and undivided management attention. A gradual diminishing of water that is intensified by the global climatic variations has also been observed. The location of SA dictates the subcontinent's water availability which has historically been very scarce. It is therefore necessary to manage this valuable resource efficiently to curb future deficiencies. Maphela (2015: 3) shares information from the Department of Water and Energy Efficiency that while the country struggles with water, in other parts of the country such as in Soweto this resource is unjustifiably wasted.

According to Muller (1999: 7), SA has, over the years, had to deal with many endless obstacles and restrictions such as:

- Financial limitations.
- Institutional resistance to change.
- Sectors and functionaries self-safeguarding their own interests first.
- Water institutions implemented restrictive measures from the supply side.
- Consultants used by the water sectors do not have alternative planning review measures.
- The fear that water conservation measures will result in reduced service levels.
- Allocation of water to consumers without regard to efficient usage.
- Cheap planning measures that disregard operation and running costs.

2.7.1 Strategies to educate residents to save and conserve water

Armitage *et al*. (2014: vi) state that the transition towards water-sensitive settlements needs the following aspects of management: policy improvement: organisational structures; community involvement; construction of the infrastructure; and operation and maintenance. They further suggest that SA must work properly with limited human and financial resources to manage the transition. To transition smoothly, local legislation and regulations need to be strengthened. In other words, municipalities must use what they have more effectively and efficiently.

For example, Weaver *et al*. (2019: 22) suggest that social learning about water-related issues should be proposed for citizens. General water knowledge sessions should be facilitated face-to-face as well as through informal conversations with citizens. The issues under discussion will trigger, amongst other things: practising how to preserve water; the best method to safely conserve water; individual water rights; and the responsibilities of a citizen concerning water. Such sessions will encourage behaviour change. Amongst the performance indicators of change will be the implementation of water-saving practices and the notifications of water leaks to the municipality.

Zeraebruk *et al*. (2014: 105) point out that for communities to enjoy a peaceful life there should at least be water supplied directly to households through proper connections with the networks. It is not sufficient to have the water supplied through rationing to the communities with the use of trucks, and this method should not be considered a standardised supply. The lack of water connections and lack of continuous supply within households aggravate social costs and has a negative health impact on communities.

The municipalities in SA are experiencing major problems as far as water services are concerned. The DWS (2018: 2) revealed the following statistics related to the performances of the municipalities in SA:

- Sixty-four percent of South Africans have a consistent water supply.
- Fifty-six percent of wastewater treatment works are in horrible condition.
- Forty-four percent of water treatment works are in undesirable condition.
- Eleven percent of these treatment works infrastructure are not functional.
- Forty-one percent of municipal water supply does not produce any returns.
- Municipal water lost through leakages is estimated at 35 percent.

The DWS (2018: 2) warned that municipalities lose R9.9 billion every year. To achieve water security, an amount of R33 billion is required each year for the next decade to resuscitate the municipalities. More than half of the country's wetlands have been lost, and the remaining half are in appalling condition. The situation is worsened by SA's under-priced water which means the authorities recover less than they have anticipated. These impacts will continue to worsen if not swiftly addressed.

South Africa’s five largest metros are Johannesburg, Ekurhuleni, Tshwane, Cape Town, and eThekwini. Their sizes and complexities escalate the challenges that SA faces and are not easily manageable. Their populations are in the region of over four million, while other cities have one million or fewer people (Turok and Borel-Saladin 2014: 5, Table 1). Turok (2016: 222-223) further asserted that they have diverse social systems, differing interests, special characteristics, and have regions as spatial entities. Drawing from the conclusions of Turok and Borel-Saladin (2014: 11), SA must not be complacent regarding urbanisation, particularly with its social, economic, and environmental implications.

2.7.2 How water utilities with skilled and experienced employees increase performance

The multifaceted negative issues faced by water utilities have far-reaching consequences if attention is not given to upskilling of staff. Water utilities are different, with each experiencing its own challenging problems. For this reason, appropriate skills are required to lead these utilities. Zeraebruk *et al*. (2014: 106) are adamant about the fact that where there is a lack of skills and unmotivated staff, the processes and leadership are bound to fail.

Laitinen *et al*. (2020: 10) advise that for the water services to acquire a full and functional status, the following aspects must be considered:

- Proceed with innovative training and education across all school levels.
- Up-skill and motivate employees for utilities to reap increased performance.
- Equip people with technical training that is relevant and integral to the institutions and socio-economic requirements.
- Enlighten people about the impacts of external turbulences such as climate change, political conditions, and urban environmental fluctuations.

Pooe, Worku and Van Rooyen (2016: 29) recommended the following measures to the CoT for better operational efficiency:

- Career growth paths and the programmes for development.

- Customised skills training opportunities as an incentive and to inspire the employees.
- The modules for the training must align with the city's operational requirements, and the customer's needs and desires.
- The CoT should partner with research institutions and academic institutions for the appropriate training and development.
- A system to monitor and evaluate the performance of trained learners is a necessary tool.

The use of technology in water utilities should not be underrated. The New Zealand Controller and Auditor General (2017: 11, 13) suggested that to manage the water services, technology must come into play to assist in the efficient use of water and ease water pollution. Another additional advantage is that it may enhance water services delivery. Good management of water utilities depends on several aspects such as how information is used. This can assist managers to be effective and efficient in the delivery of services to the communities.

Kumpel *et al*. (2018: 16) noted the success associated with implementation of water safety plans: increased levels of operations and management performance; water safety meetings; water quality assessment actions; attending to consumer dissatisfactions, infrastructure improvement, and improved financial support.

According to the World Health Organisation and International Water Association (2017: 1, 10), there have been improved performances from the countries which have implemented water safety plans. Improvement was realised in operations and management, organisational familiarity and awareness, and water quality. Water safety planning is defined as a form of broad risk assessment and risk management that involves a wide spectrum of stages in the drinking water supply system from the source to the consumer. The following benefits accrued are:

- Enhanced system management.
- Better awareness, knowledge, and appreciation by staff.
- Increased promotion and sharing of ideas between staff about the water-saving plan.
- Advanced communication and partnership with stakeholders.

- Advanced quality of water.
- Advanced observation and surveillance.
- Increased capability and training.
- Advanced communication and partnership between water suppliers.
- Advanced storage of records and data collection at water suppliers.
- Advanced measures of management and operations.

2.7.3 Service delivery, payment of services, and government water tanks

According to the Department of Cooperative Governance (2018: 28), municipalities must deliver basic services, make sure that the infrastructure is maintained, maintain openness, be accountable, and engage with communities regularly. The Ministry of Cooperative Governance and Traditional Affairs with the Municipal Infrastructure, Support Agent, intervene where there is underperformance in a municipality concerning the improvement and maintenance of infrastructure projects. Currently, there is inadequate expertise to manage infrastructure projects, examine tender documents, and consult with stakeholders. There has been a slow pace of scheduled maintenance of the infrastructure. Consequently, there has been under expenditure of the infrastructure improvement grant from the national government.

Non-payment of the services rendered, especially water and electricity, has far-reaching negative consequences in SA. The issue of repairs and maintenance is hampered if those who provide the services are not paid. The situation becomes worse when political interference (Masuku and Jili 2019: 2) plays a role, by connecting the payment for services to politics (Maphela and Cloete 2019: 544), when the concealed reality is about the usage. It is also about how the residents understand and value the whole value chain of the infrastructure system. Maphela (2015: 6) outlines the relationship between poverty and inequality. The author points out that willingness and capability to pay plays a pivotal role in water demand management (WDM).

The Council for Scientific and Industrial Research (CSIR) (2010: 42) has presented some of the reasons for the shortfall of paymentfor services rendered:

- Only a few customers pay for the services.

- Consumers who qualify to pay are reluctant to do so.
- Consumers who qualify for the free basic services exceed their allocated limit and are loath to pay for the extra usage.

Indeed, these shortfalls relating to the non-payment of services were also identified in a study conducted by Maphela and Cloete (2019: 544) and in the draft report by Muller (1999: 8).

According to Muller (2019a), SA is starting to experience supply failures resulting from heat waves and late rains in some areas, whereas there is satisfactory water supply from dams at urban settlements. For example, in Cape Town water managers' encouraged the residents to use a smaller amount of water plans so as to extend the life of the infrastructure. However, the persistent drought exposed the planning of the Cape Town water managers, who thought they would be able to get away without constructing new WI. In Gauteng province, for example, the reservoirs ran dry because of residents excessively watering gardens (Muller 2019a).

In Eastern Cape Province, the dam at Adelaide ran unnoticed down to one percent full and resulted in supply failure with no funding to resuscitate the situation. The same issues of failing to plan also occurred in towns and villages countrywide (Muller 2019a). Wafer (2019: 87) and Madonsela *et al*. (2019: 2) recall the experiences of the City of Cape Town (CoCT) in 2017 and 2018 when the city nearly ran dry. No matter how large a network of pipes the city lays, it is never sufficient. Simpson *et al*. (2019: 16) envision that because of the aftermath of the drought, the CoCT will consider the tariff structure that the underprivileged will have to pay in the future.

In Adelaide, Eastern Cape province, supply failures escalated due to local authorities distributing water before confirmation of adequate supply or setting new ways to regulate unnecessary usage. These happened because of both poor planning and poor management during periods of drought and are still persistent (Muller 2019a). Supply authorities are more likely to face supply failures if they do not plan well in time before droughts hit.

The Minister of Human Settlements, Water and Sanitation, Lindiwe Sisulu, procured 41 000 water tanks across the country for drought-stricken and informal areas. Presently procured tanks are 2 342 in Eastern Cape, 1 700 in the Free State, 12 130 in Gauteng, 4 274 in Kwazulu-Natal, and 1 200 in Limpopo. Tanks for Mpumalanga and North West provinces are still to be procured (600 each). This has been done to improve hygiene and water supply as SA fights the outbreak of coronavirus which causes COVID-19 disease (3SMedia 2020a). According to literature the total tanks allocated were 22846. Literature is silent about the remaining 18154 tanks, neither does it explain the allocated tanks for the Northern Cape and Western Cape provinces.

When commenting on the state of water scarcity in SA, the chief operating officer of Abeco, Mannie Jnr. Ramos, compared the parity between the first and third-world countries. There is increasing water scarcity in Eastern Cape, water shutdowns in KwaZulu-Natal, water-shedding in Polokwane, Free State water riots, water cuts in Tshwane and Mpumalanga, etc. A request to build infrastructure to cope with the demand and other eventualities were also mentioned. He further detailed South African average water consumption of 237 litres per person per day, as compared to 173 litres per day world average, as a problem. Further to that, with existing water resources under pressure, the need for planning is required (3SMedia 2020b).

2.8 Chapter summary

This chapter summarised the management issues related to the CoT performance regarding their water infrastructure. The strategic pillars outlined in the literature are meant to drive the city's vision 2030 to success. The vision is reinforced by the city's IDP which guides the city's opportunities, care, safety and cleanliness, and reliability. The city aims to stabilise its administration, revitalise the economy and improve service delivery to every resident within its boundaries. The CoT experienced socio-economic issues which were not predicted and that made it difficult to improve their economy.

The unprecedented issues that have arisen and the suppression of the city's development have been exacerbated by the flocking of immigrants to the city, putting pressure on the infrastructure. Residents are reluctant to pay for the services provided by the municipality, since they believe they have a constitutional right of access to water. The CoT, amongst the biggest metros in the country, is challenged by its size, the overwhelming population, and the complexities which make it difficult to manage.

The water supply and sanitation services of the CoT are shared amongst other cities in the Gauteng province. The city is divided into seven regions that are subdivided into twenty-four residential areas which receive the water supply from regional or local water schemes. The mayoral strategic planning session in 2017 recommended maintenance of the existing infrastructure as a better option than new installations. Twenty seven percent of water use is unaccounted for which poses a major management challenge for the city. The city owns a considerable amount of water infrastructure such as reservoirs, pumps, pump stations, boreholes, pipelines, pressure control stations, and water treatment plants, to mention a few.

Sixty percent of CoT's residents enjoy a free basic water supply. The city is further challenged by response time to the maintenance of the water leaks, bulk supply, insufficient water resources, inadequate supply to Hammanskraal and Temba, and vandalism of water infrastructure and electrical cables. In addition, the Bronkhorstspruit dam and RWWTP have reached their operational capacity. Infrastructure is in a state of disrepair and requires billions of rands for maintenance. The bigger share of the budget given to the city's municipal infrastructure will see a greater refurbishment of the water networks, waste water treatment plants, and electricity projects.

The CoT has received several qualified audit reports and the prevalence of service delivery protests has further worsened the performance of the city. A lack of suitably qualified persons appointed to positions of authority has contributed to a deterioration of the city's performance. Training offered to employees does not align with the skills required to perform the work. Employees' performance monitoring and evaluations were connected to their race groups and political affiliations. Political infighting has been apparent in the delay of, and in some cases, the halting of progress in the city's projects. The city experienced considerable mismanagement, wasteful expenditure, ignorance of procurement processes, and irregular expenditure. The city was not capable of managing the creditors and had ailing revenue collection.

2.9 Conclusion

This chapter presented the managerial skills expected from role players to make sure the CoT performs satisfactorily in providing adequate water for its residents, and highlighted the skills lacking in the CoT management. For example, the CoTs' managers were not decisive and this delayed the progress in the city's WI development and maintenance. The chapter further discussed the importance of maintenance to the WI. The requirement for the managers to factor water consumption patterns into their planning, to overcome community protests, was discussed. The strategic pillars which underpin the running of the CoT were identified.

The chapter illustrated that the high levels of urbanisation and immigration into the CoT overwhelmed the smooth running of the city and resulted in overloaded infrastructures. The WI was unable to cope with the demand, resulting in multiple water main breakages. The high levels of service delivery protests in SA and the CoT and their causes were discussed. The chapter identified that the communities of the CoT were deliberately excluded from participating in meetings, and thus they were not able to raise their concerns. Where residents were denied service in some regions of the CoT, their concerns were referred to the head office in Pretoria by the local employees.

The study discussed SA's sharing of water resources with other SSA countries. The discussions about water shortages have triggered the issue of wastewater recycling as required by Sustainable Development Goal 6.

The study discussed WI assets owned by the CoT and the water supply boundaries shared with other cities. The water supply schemes, resources, and the organisations that supply the CoT with water were also mentioned in this study. The chapter discussed the total number of the CoT's clients billed for using the water and the total estimated water consumed by the residents. The total cost to repair, maintain or replace the dilapidated or broken WI for the CoT was also covered in the chapter. Similar challenges to these encountered with WI in the CoT, have been resolved elsewhere by applying space technology and the application of such technology to CoT's WI will be discussed in Chapter 4.

This chapter concludes that projects must not be executed without involving the project stakeholders. Project stakeholders make or break the smooth running of the project. Any form of mismanagement leads to the financial underperformance of the municipality, to inadequate service levels and often to citizen protests. Financial underperformance may also lead to the municipality being placed into administration. The findings of this chapter illustrate the gap in knowledge, about WI development and maintenance in the CoT, for the researcher to investigate and raises questions needing to be answered regarding whether it is a political or a management issue.

The next chapter discusses the challenges that managers find themselves having to deal with to manage the WI.

CHAPTER 3: CHALLENGES OF MANAGING WATER INFRASTRUCTURE

3.1 Introduction

The challenges of managing WI are recurrent, endless, stressful, demanding, and require a lot of effort to solve. Managers of WI must deal with different customers in the value chain. These customers are residents, managements of the local authority, employees, water supply authorities, contractors, newspapers, etc. In that light, the management team must be strategic and must be made up of people with technical and managerial capacities to handle all challenges.

Lund (2015: 5906) noted water systems do not exist in isolation. These systems operate in an environment of a wide political spectrum, social governance structure, law, and social anticipations. Brown *et al*. (2015: 6114) noted the high expenses that are involved in managing the activities of water. A study conducted by Khale (2015: 674) revealed that 84.37 percent of CoT residents are satisfied with the service delivery offered by the municipality. Respondents further displayed positive perceptions and reported a good performance on water, lights, and refuse removal. Hard work and commitment by city employees were also reported by 87.13 percent of the study respondents.

While the CoT is well known for its comparatively low service delivery protests (Van Rooyen and Pooe 2016: 138-139), this chapter establishes how they accomplished this. The following objectives are outlined in the CoT's 2019/20 IDP: "to provide a democratic and accountable government for local communities; to ensure the provision of services to communities in a sustainable manner; to promote social and economic development; to promote a safe and healthy environment; to encourage the involvement of communities and community organisations in the matters of local government" (CoT 2019a: 2). These objectives as outlined are most suitable for an organisation to aim for.

This chapter covers the definition of WI and water as an important commodity, international challenges of managing WI, the drought situation and other challenges in SA, the CoT as a WSA, WSP, the WI challenges, lack of adequate management, installation and maintenance of WI, and climate change, as summarised in Figure 3.1.

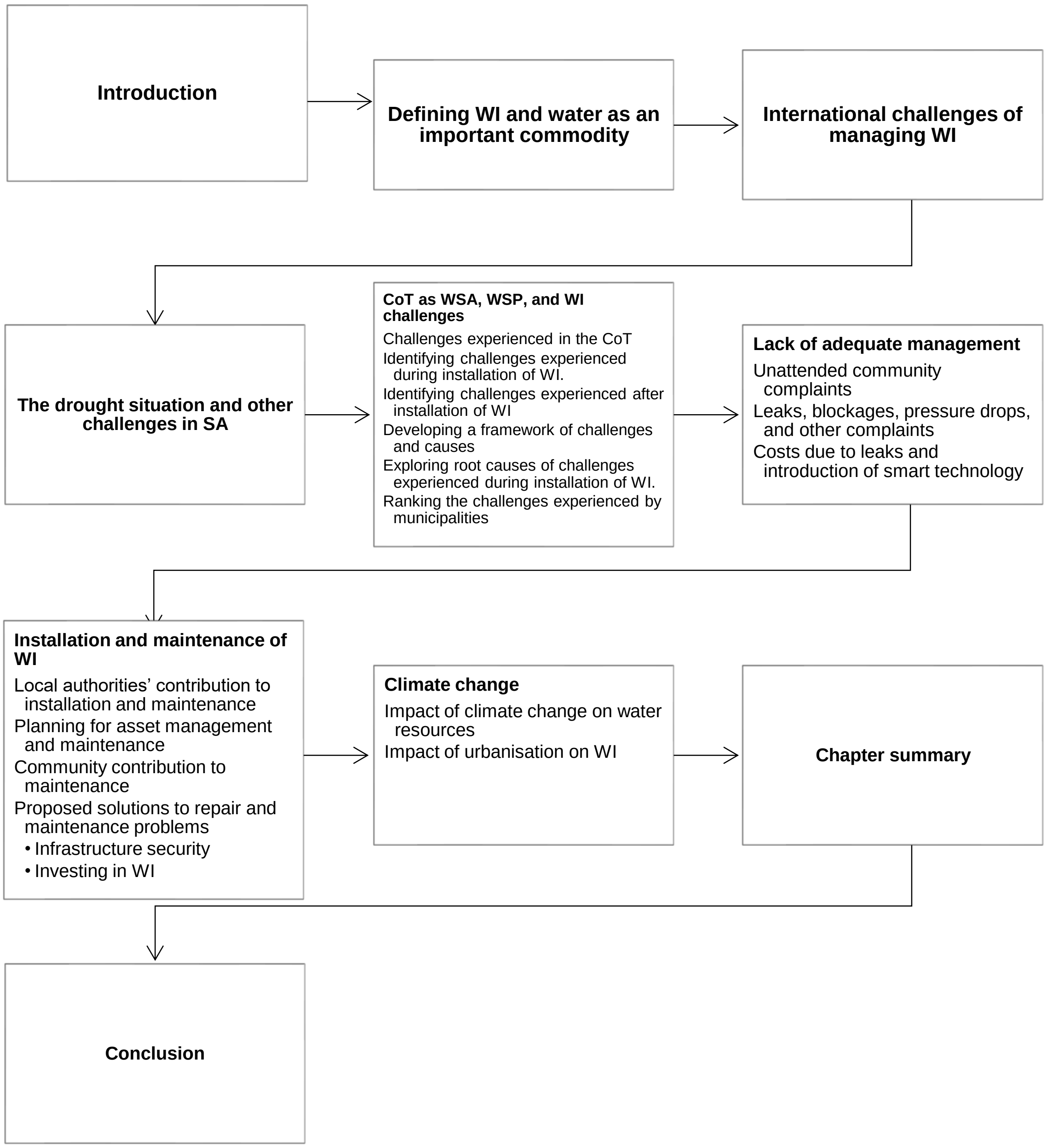

Figure 3.1: Challenges of managing the WI framework

3.2 Defining WI and water as an important commodity

The definition of WI differs from one research study to another. In the context of this research, the Water Resources Coordination Centre (2012: 29) defines WI as a network of existing, scheduled, or works in progress linked to water that involves large dams, irrigation schemes, and projects to convey water from one drainage area to another. Wafer (2019: 85) argues that a single pipe acting on its own does not qualify to be defined as infrastructure. The interconnection of pipes forming the broader network, to convey water to communities or sewage to water purification plants qualifies for the definition of infrastructure.

Boulenouar and Schweitzer (2015: 1-2) define infrastructure asset management (IAM) as a sequence of logical and synchronised management applications to assist performance augmentation with the least costs and least possibility of asset breakdown. Further to that, they indicated that in the context of the water sector these are tangible equipment such as pipes, pumps, meters, generators, storage tanks, valves, etc. These assets should be looked after by making certain that a long operational lifespan and the best possible cost-effective performance are achieved.

To achieve cost-effective maintenance and spares require management to pay particular attention to the purchase of locally manufactured equipment to ease supply. Locally manufactured equipment makes it cheaper and easier to procure spares. Importing water supply technologies creates a challenge for the procurement of spares (Sambo 2015: 87).

Osman, Ammar and El-Said (2017: 29) identified the following gaps in WI research:

- The failure of infrastructure which results in the effects of traffic jams when repairs are undertaken.
- The total period of inconvenience from the breakage of infrastructure until it is fixed.
- Alternative approaches to repair of the infrastructure and the effects on issues of time and cost of the repair process.
- Unknown information on the repair and travel times while trying to do the improvements.

- No dedicated models to deal with the repairs of repetitive problems of pipe breakages even in emergency situations.

Water is a scarce and precious commodity that is required by species to maintain their life and survive (Zeraebruk *et al*. 2014: 93-94). No human or any live creature on earth can live without water (Soeprobowati 2018: 2). Stephens *et al*. (2020: 2) and Makarigakis and Jimenez-Cisneros (2019: 1) note that the quantity of water on Earth has been the same for billions of years. Stephens *et al*. (2020: 2) assert that since the creation of the Earth, water has been circulated amongst the three reservoirs. These reservoirs are the oceans, ice sheets, and glaciers (the cryosphere), and the storage on land and the atmosphere. It is interesting to note that 96.5 percent of the water on Earth is currently contained by the oceans.

There is an average salt content of 35 grams per kilogram of seawater. Approximately 1 percent of the Earth's water is salty groundwater, and roughly 2.5 percent is freshwater. Most of the fresh water on Earth (68.5 percent) is contained by the cryosphere and almost 31 percent is obtainable from the surface in the form of rivers and lakes, and soil moisture (mostly from underground water in aquifers). The surface water is enough to meet the required freshwater quantity that humans need to consume globally (Stephens *et al*. 2020: 6).

The increasing scarcity of safe drinking water is a thorny issue that has received global attention due to increasing urbanisation. This phenomenon is inevitably experienced by populations around the world, notably in developing countries (Amit and Sasidharan 2019: 410). Studies have shown that world populations suffer either intermittent water supply, no water, or both. These situations grow worse year by year and little, or in some cases no, attention is given to the requests to save water. This shows the level of attention that humans must pay when they open a tap or notice any leak.

3.3 International challenges of managing WI

Masvingo city in Zimbabwe experienced water supply challenges such as growing population, poor infrastructure, the declining economy, and climatic variation

(Mapfumo and Madesha 2014: 1). The San Francisco Regional Water Quality Control Board, a supervisory body said that, looking 50 years into the future, a clever resolution regarding the management of water and wastewater is needed (Harris-Lovett, Lienert and Sedlak 2018: 3). Soppe, Janson and Piantini (2018: 12) articulate that what the people want from the water utilities is obvious and uncontested. They require uninterrupted service delivery with enough, trustworthy, convenient, and safe water.

Gondo (2012: 27, 28, 29) highlighted Ethiopia's challenges with the policies and advanced technology systems in the water and sanitation divisions. Studies conducted by Gondo (2012: 27), Ndeto (2010: 186) and Nyarirangwe (2008: 79) in the towns and cities of Ethiopia did not find any significant improvement in the WI asset management. A study by Semunigus (2020: 62) discovered a lack of asset management in Ethiopia, this time in the roads infrastructure. Eeffective systems of asset management support the local economies and communities. Asset management boosts the physical value of assets and extends their life cycle. Assets include amongst others: municipal water, wastewater, roads, bridges, and buildings.

Gondo's (2012: 40-41) empirical study in Ethiopia revealed the lack of an asset management plan dedicated to the planning and management of the local authorities' water and sanitation infrastructure assets. The author stated that the local authorities did not know much about the six "Whats" which are:

- What asset belongs to you?
- What is the value of the asset?
- What is deferred maintenance?
- What is the condition of the asset?
- What is the asset's remaining service life?
- What is the first asset to be fixed?

Gondo (2012: 33 & 40) asserts the following drawbacks as obstructions to the breakthroughs of asset management plans in Ethiopian towns and cities. The challenges that were being experienced were:

- Unsuitably qualified staff that execute the planned process.
- No dedication from the authorities.
- Lack of suitable equipment such as computers.

- No coordination between the divisions of the local authorities.
- No finances.
- The organisations have no suitable strategies, and
- Lack of political will to embrace the system software for effective asset management

According to Nag and Garg (2013: 4), India is constrained by restrictions to create surface water sources, and by a drop in the level of groundwater tables. The country's situation is worsened by daily disruptions to the water supply. In India, urban areas rarely enjoy a continuous water supply for 24 hours. There are currently government-funded projects that struggle to provide an uninterrupted supply (Nag and Garg 2013: 4). There are deliberate interruptions at intervals, also called water-shedding. One section of the establishment's water gets shut-off to allow for another section to be supplied.

The world is experiencing an increase in the urban population, and India is not immune to the related challenges. They experience an increase in population in the urban centres which makes it hard for the supply authorities to cope with the perpetually increasing water demands. The authorities must reshape to realign with the increased demands and revisit their supply planning patterns. Other shortcomings that managers could not overcome were the questionable quality of water, insufficient service delivery, inappropriate management of funds by urban local bodies, overloaded responsibilities of operation and maintenance, and wastewater that is released untreated. India has a history of unmetered water supply in urban settlements. This aspect contributes to the difficulties in the pricing of water and the collection of revenues (Nag and Garg 2013: 4 & 22).

A study by Bichai and Flamini (2018: 5) unveiled some of the challenges that global cities face, namely:

- Lack of global context for the application of ideas or models.
- The discontinuity between the water sector academic and practical fields.
- The silo operations of the academic fields.
- Inadequate, unpredictable, unsafe, and unsustainable urban water services.
- Disjointed water resources management.

- Inadequate water services.

Laitinen *et al*. (2020: 1), writing about Finland, describe the good delivery of urban water services as “resilience”. The authors mention that resilience has become a subject for discussions in urban water services. They propose a definition of resilience in the perspective of their study as being the adherence to a good service level, a rapid response to regain progress from the aftermath of natural disasters, unreliable infrastructure, or inappropriate organisational management.

The authors further distil the disorders faced by urban water utilities and outline a few common causes. The water services face internal and external turbulences, ranging from technical, financial, environmental, and policy variations. Technical and financial disturbances are classified as internal issues ranging from a skills shortage to budgetary constraints. Environmental and policy variations are aspects of climate change, and a change in political leadership may affect legislative amendments which may influence the policies. These changes may have detrimental consequences on the health, environment, and economy of the consumers. However, Laitinen *et al*. (2020: 9) rated Finland as the best country in the world with low corruption levels, good government service delivery, and collaboration between government and private organisations.

Song (2012: 22) found that China faced the following persistent challenges in their infrastructure:

- Inadequate provision of infrastructure.
- Inconsistent level of infrastructure across the regions.
- Poor or lack of cost recovery.
- Insufficient financial resources.
- No maintainable principles to shape urban growth.

The city of Seoul in the Republic of Korea has grown rapidly over the past five decades. It is one of the most successful metropolises in the world with advanced technologies of water as well as good policies governing water. Despite this status, the city is not immune to the challenges of climate change, old infrastructure, and the social burdens that are forever escalating (Kim *et al*. 2018: 2).

The challenges facing countries are not extremely different from each other, but there is a variation from one to another. The New Zealand Controller and Auditor-General (2017: 3, 10) articulated the challenges experienced by New Zealand local authorities regarding WI. Among others, they experienced an increase in population, infrastructure which had exceeded its useful life, contaminated drinking water, flooding, and climate change to mention a few. The escalating numbers of urbanisation, like in other countries, exerted pressure on New Zealand's water resources and exposed the infrastructure to severe strain. However, some parts of the country experienced a decline in the numbers of the population. One of the challenges here was whether to continue or halt the development of infrastructure.

In the United States (US) much of the WI faces dilapidation because of age, insufficient maintenance, and environmental effects (Renwick *et al*. 2020: 1). The issues surrounding the management of WI differ from continent to continent and from country to country. Literature from the US Environmental Protection Agency (EPA) (2014: 1) reveals the similarities to other aspects of WI around the world. These issues are related to the mounting limitations on freshwater resources. The limitation arises because of drought, flooding, pollution, population growth, and other various competing uses. Literature suggests that the various water challenges that the US faces could be resolved with the help of technology. They have support from USEPA which aims to bring change and embraces innovative technology, safeguards, guarantees, and strengthen the water resources.

The water treatment plants do not meet the required standards for drinking water due to the deterioration of water sources. In a nutshell, the following challenges are being experienced by the US:

- Insufficient water due to the rapid decline of water sources.
- Degeneration of water sources that place purification plants in a compromised position of dispensing substandard water.
- WI that has exceeded their useful life.
- The effects of climate change.
- Lack of access to basic amenities such as water and sanitation (USEPA 2014: 2-3).

Water utilities are faced with various challenges which are similar with large and small utilities. The study cited literature from the EPA's Office of Inspector General (2006: 4-10) wherein the following challenges were detailed for small water utilities in the US namely:

- Shortage of financial resources.
- Inadequate returns.
- Matured infrastructure.
- Difficulties in sourcing funding.
- Cost of scale.
- Management restrictions.
- Shortage of long-term planning.
- System operator capabilities (technical capability).
- Lack of understanding of the regulations.

Despite the long list of challenges mentioned above regarding WI and African cities, the good side of African cities do exist. Some cities have been equal to the task of supplying water to poor communities. The cities outlined in Table 3.1 are good examples of this.

Table 3.1: Cities – their reliable supply and access to improved water for the poorest

City	Reliable supply in hours/day	Access to improved water (poorest 40%)
eThekwini (Durban)*	24	100%
Lusaka*	20	99%
Ouagadougou*	23	98%
Dakar*	24	97%
Nyeri*	24	96%
Niamey*	24	94%
Kampala*	18	93%
Nairobi	20	86%
Hargeisa	20	76%
Tanga	24	75%
Accra	18	65%
Addis Ababa	16	100%
Maputo	12	97%
Kinshasa	11	93%
Mombasa	4	92%
Dar es Salaam	8	89%
Kaduna	14	29%

***-** indicates the city with comparatively good service for the poor.
Source: Heymans *et al*. (2016: xii).

3.4 The drought situation and other challenges in SA

Reddick and Kruger (2019: 7), Bwapwa (2018: 14), Cole *et al*. (2018: 38), Green Cape (2017: 14), and Maphela (2015: 2) assert that SA is rated the 30th driest country in the world, with a drought situation persisting for the past ten years (Mahlalela *et al*. 2020: 2743). SA is presently using its renewable water resources excessively. The majority of the country's WI has reached a condition of disrepair and there are seriously low water levels in the reservoirs. However, there is still a possibility to reinstate it to the normal workable condition with substantial financial investment and political buy-in (Donnenfeld, Crookes and Hedden 2018: 1). There must be a better strategy to educate the residents about the efficient use of water. The drought crisis in the different parts of the country should teach us a lesson about the approach to the efficient use of water. Studies point out that there are challenges the world faces in the water sector due to climate and population increase in the 21st century (Butler *et al*. 2014: 347).

To respond to the drought situation that received media attention in the run-up to day zero, a study was conducted by Booysen, Ripunda and Visser (2019: 1-2) for a water-saving maintenance campaign in Cape Town schools. The campaign revealed a struggle by schools to effect proper maintenance of their water systems. A further finding by the study was that the issues further intensified due to the following factors: shortage of funding by the government; disorganised government policies; schools not well equipped with skilled staff. After the fifth day of the campaign, it was evident that maintenance was very important and a water-saving of 28 percent was realised. As a result of the savings, Cape Town schools were no longer attracting the spotlight of water-saving campaigners.

According to Donnenfeld, Crookes and Hedden (2018: 2), the drought situation which hit SA between the years 2014-16 triggered water security debates at a high level in the country. The authors further argue that the drought did not trigger water scarcity, rather it revealed the weaknesses in the country's water arrangement. The country already has limited water with over 60 percent of rivers experiencing excessive use. The issues of population growth, urbanisation, increasing earnings, increasing irrigation, non-renewable power generation, and expanding manufacturing segment exacerbate the conditions of water demand.

Muller and Paasch (2017: 8) mention a drought in a semi-arid region which resulted in the drying out of the Mokolo River. The Mokolo River drought was caused by the excessive use of water by the Medupi coal-fired power station in Lephalale. However, measures have since been put into place to secure enough supply of water from the Mokolo-Crocodile (West) Water Augmentation Project. The Inspection Panel of the World Bank reported in 2011 that approximately six million cubic metres of water would be withdrawn annually from the residents living in the vicinity of the river. The water loss is anticipated to spike to twelve million cubic metres each year after the water-intensive flue gas desulphurisation systems is installed.

The authors further envision nearly 170 million cubic metres of water to be extracted annually from the Crocodile River which will be refilled with wastewater from Gauteng. However, the anticipated plan creates anxiety that the Crocodile River, Limpopo River, and groundwater may be polluted. The reason for the fear is that the Crocodile River systems flow into the Limpopo River. The Medupi power station's extreme levels of water consumption have denied the communities in the vicinity the right to water, food, and health.

The drought situation in SA has triggered discussions in many municipalities, DWS, and amongst water practitioners. The discussions covered the drought, high water use, and the placing of water restriction policies. Parks *et al*. (2019: 1) state that water shortages will persist in the cities of the world throughout the twenty-first century due to climate change. The effects of water shortages created a crisis in the City of Cape Town and resulted in economic and social challenges. The impacts caused business interruptions in the tourism and agricultural sectors. To this end, the city devised a long-term strategy that would bring the supply and demand for water into balance. The city responded with the introduction of measures to limit the presence of water; revise the fines for extreme water use; install devices in the consumer's properties to manage consumption; and introduce an innovative way of communication.

The use of water in SA should remind citizens that they live in a water-scarce country (Cole *et al*. 2018: 38). However, mines and factories are major causes of excessive use of water and they should start better practices as they are always the hardest hit. Drought always results in devastating outcomes for communities, for example, Cape Town experienced the most severe drought predicament in the past three decades (Satgar and Cherry 2020: 318). Other municipalities have also struggled with drought dilemma; Hay *et al*. (2012: 440) established that some communities in the Eastern Cape sourced untreated raw drinking water from rivers, springs, and boreholes. Table 3.2 outlines the recommendation of a study with the measures to implement, and a means to arrive at, an amicable solution.

Table 3.2: Recommendations for water conservation and use in SA

Recommendation	Measures to be implemented
Introduce actions to preserve water and restrain excessive use.	Efficient use of water through infrastructure repairs and rebates for water-saving appliances. Layered pricing structure. Policies to be enhanced with campaigns to increase awareness.
Increase the treated and reused wastewater	The current 40 percent of untreated wastewater should be treated to increase the country's quantity.
Escalate groundwater extraction.	DWS anticipates major expansion in the use of groundwater SA.
Supplementary technologies could be useful in the future.	Technologies were not explored.
Renewable energy.	Increase energy generated from renewable sources to ease water demand. Lower carbon emissions to reduce water pollution.

Source: Donnenfeld, Crookes and Hedden (2018: 18-19)

Toxopeüs (2019) raises the issue of unevenly distributed primary water resources in SA, at the same time explaining the challenges of water scarcity the country faces. The author commends Lesotho and Swaziland for providing half of SA's total water supply as a move in the right direction. The author posits that most of the areas where economic and social activities happen in abundance are located where the Earth's natural inclination is against the water flow. The rapid growth of the population and the concurrent water shortage adds up to the list of challenges on the overloaded WI. These challenges escalate regardless of the water and sanitation infrastructures' pivotal role played in the growth of the economy and social development. Mahlalela *et al*. (2020: 2743) confirmed that as the demand for water rises, SA is held back by a lack of proper planning and inappropriately managed water resources, and fewer funds allocated to storage facilities.

Toxopeüs (2019) envisions the risk of failure of South Africa's public infrastructure. The author characterises the risks as poor governance, gross neglect of maintenance, and poor engineering capability. The various aspects that are vulnerable to the risks are water resources, water supply, and sanitation infrastructures. Increasing demand overloads the bulk water resources infrastructure which also lacks proper maintenance and is under a threat of failure. However, while some other areas are still at risk, the major urban areas' water supply infrastructure appears satisfactory. Chauke (2017: 79) and Ochieng (2016: 22) expressed their views that operating with insufficient funds to maintain the infrastructure derails the effective management of the water resources in SA. Services are not maintained because of insufficient expenditure allocated to maintenance, and subsidies are not enough to maintain the WI.

Leburu (2017: 9) reflected on the challenges and proposed that if the perceived high level of corruption and defective maintenance of the infrastructure are not responded to, the situation could become worse. A common dilemma that creates confusion with water utilities is whether the infrastructure should be maintained or replaced, and this affects the projections (ANC National General Council 2015: 38).

SA municipalities have been characterised by unaccountable officials, a lack of "institutional capacity", "mismanagement of funds", "high levels of corruption", "lack of public participation", understaffed, skills deficiency notably in the project management and financial management, under expenditure, lack of resources to complete the projects, and nepotism and corruption in awarding the tenders (Managa 2012: 2, 3, 4, 6).

There is a great difference in the condition of sanitation and wastewater treatment infrastructures in major urban areas in comparison to rural areas. Major urban areas in SA have satisfactory sanitation infrastructures while rural areas face deterioration. Toxopeüs (2019) calls attention to the deaths of school children due to the collapse of pit latrines that attest to the shocking state of sanitation in some areas of the country. The challenges escalate because of the ageing infrastructure which is poorly maintained. The type of maintenance approach is reactive instead of preventative which results in cost escalations and reduces the lifespan of the infrastructure. South Africa has taken a strategic decision to discontinue approvals or developments of new water resources infrastructure. The decision however can be reversed on condition that water is effectively conserved, and that WDM is already in place in the areas of execution (Toxopeüs 2019).

3.5 CoT as water service authority, water service provider, and WI challenges

The CoT is a WSA, and its Water and Sanitation Department is a WSP (Shambare 2018: 22). A WSA is defined as a district or rural municipality authorised to oversee that access to water services is guaranteed. A WSP is any person or entity entrusted with the provision of water services to clients or water services institutions but excludes a water services intermediary. A water services institution (WSI) is a water service authority, water services provider, water board, or committee (South Africa, Department of Water Affairs and Forestry 1997: 10).

The institutional responsibilities regarding water services provision and information to consumers are tabulated in Table 3.3.

Table 3.3: Institutional responsibilities for water services provision.

Institutional responsibilities for the provision of water services	
Water Services Authority	**Water Services Provider**
Guarantee collective access to services	Obligation to provide water services
Planning	Effectiveness and efficiency
Regulate	Consumer charter
Provision	Client relations
Service to industry	Client-responsive billing
Regional schemes	Business plan
Obligation to disseminate information	Obliged to disseminate information

Source: World Bank (2011: 95).

Shambare (2018: 34) details the CoT's approval process for infrastructure service installation. The organisation intending to do services installation must first establish if the city has enough capacity to handle the envisaged infrastructure. The project will be registered only after establishing that the city can handle the infrastructure, which can be a lengthy process. Registration of the project is subject to granting of this approval. After the project approval, a concept report is drafted and submitted to the city for approval. Approval of a concept report then opens the gates for submission of drawings and designs, which also need to first be approved by the city.

Further to that, an installation contractor will be appointed by the city. The city or the implementing consultant deals directly with the installation contractor. The CoT, the project implementers, and the installation contractor jointly visit the site for the scope of work. The city will explain the installation guidelines to be observed. City engineers and technicians will conduct regular inspections to monitor and confirm scope adherence. The necessary tests will be conducted after which certificates of conformance to the standards and specifications will be issued.

3.5.1 Challenges experienced in the CoT

In 2017 the three Metropolitan Municipalities in Gauteng Province, namely the City of Johannesburg (CoJ), the City of Tshwane (CoT), and the City of Ekurhuleni (CoE), were invited to parliament to present their reports to the Select Committee on Finance. Their presentations were based on the feedback about the quality of service delivery to the consumers, and the expenditure reports in compliance with the requirements as set out by the Committee (National Council of Provinces Finance 2017). This discussion however concentrates only on the presentation delivered by the CoT as it is the focal point of this study.

The CoT presented to the National Council of Provinces select committee on Finance the performance of the budget and the progress made with the IDP. This committee played an oversight role in the projects which were carried out by the CoT. The names of the projects they focused on were the Townlands Social Housing Development site, RWWTP, and the Temba Water Treatment Plant sites.

The purpose of the activity was to fulfil the constitutional obligation to play an oversight role by assessing the performance of the budget and the progress made with the IDP. This study omitted the outcomes of Townland Social Housing Development as this does not fall within the focus of this study. As a confirmation Ochieng (2016: 12) noticed at the time of that study that the stormwater systems at the CoT were insufficient, sewer reticulation systems were inadequately maintained, and the infrastructure was dilapidated.

According to Olivier (2021: 284-285), the matters of liabilities were aggravated by the CoT's generally low level of productivity and irregular expenditure of R1 684 million in the 2017/18 financial year. The procurement processes are characterised by irregularities, with the "worst" financial health and position that requires rescue. Olivier (2021: 288) further noted that corruption has manifested in the CoT, and Poplak (2017) added that it happened under the ANC term of office with extravagant outsourcing to a company called PEU without competitive tendering. The outsourced company (PEU) installs smart meters and broadband at an annual rate of R1 billion. The organisation makes an annual turnover of R630 million on smart meters only.

The biggest of the 15 waste water treatment works in the CoT is RWWTP which was constructed in 1951 and has reached its maximum operational capacity of 180 megalitres (Ml). The plant services parts of Soshanguve (South), Pretoria North, Rosslyn, Wonderboom, and Atteridgeville. Tenderers were invited to supply the funds to implement the maintenance project as part of the scope. The city budgeted R10 million for professional fees and R19 million in the operational budget for maintenance (National Council of Provinces Finance 2017). Kopung (2017: 195) has established that the long process to finalise the appointment of contractors cause delays and affects the project output. For example, the infrastructure projects are delayed as a result of tender adjudication. The author further noted that this aspects cause under expenditures in several municipalities.

The Temba Water Purification Plant services more than 95 000 households in, Temba, Kudube, Stinkwater, New Eersterus, and other southern parts of Moretele Local municipality. The project under consideration involves additions and improvements to double its capacity from 60 Ml to 120 Ml per day, Leewkraal Dam raw water extraction point, and pump improvements. Reportedly, a contract valued at R516 624 million was awarded in 2013 to last for three years. The project had been able to source 225 local labourers, sub-contractors, and suppliers with a total expenditure of R107.2 million (National Council of Provinces Finance 2017). A detailed outline of the challenges faced by both water works appears in Table 3.4.

Table 3.4: Challenges experienced with the CoT WI

Rooiwal Wastewater Treatment Plant challenges	Temba Water Treatment Plant challenges
Hydraulic and organic overload that results in high sludge production and defective discharges.	Community protests lasted for a year.
The 33 percent primary settling capacity is less than the required capacity.	Power utility's failure to upgrade to an adequate power supply.
Pollution of the groundwater because of excessive sludge as a result of failed dewater.	Lag to relocate the existing services by the supply authority.
A secondary settlement with inadequate capacity results in partly treated runoff.	Limited budget.
Partly treated runoff affects the consumers in the low-lying areas such as the Temba Water Treatment plant and others.	Extra approval processes are required from the Gauteng Department of Agriculture and Rural Development.
Cable theft.	A supplementary design to handle the sludge due to disapproval by the Gauteng Department of Agriculture and Rural Development.
Deformed and overloaded sludge conveyor belts that fail to dewater the process.	Department of Water and Sanitation is required to do further approval to desilt the Leeuwkraal dam.
Frequent failures of electrical and mechanical components due to ageing equipment.	
Absence of preventative maintenance.	
Insufficient staff to run the plant (fitters and turners, electricians, and process controllers).	
The National Department of Water and Sanitation has instructed the city to improve the quality of runoff.	

Source: National Council of Provinces Finance (2017).

According to the Portfolio Committee on Human Settlement Water and Sanitation (2019), there are challenges that the CoT faces concerning the substandard water supply. Table 3.5 summarises the challenges that inhibit the CoT from operating smoothly.

Table 3.5: Other challenges faced by the CoT

Challenges that inhibit the CoT from operating smoothly
Contaminated drinking water by Rooiwal Wastewater Treatment Plant (*E. coli*, nitrites, nitrates, and so on).
Inward migration of people into Tshwane.
Sewer flowing into the river system (Apies River into Leeuwkraal dam).
Contaminated water extracted from Leeuwkraal dam to Temba Water Treatment Plant.
Flawed data migrated from Magalies Water into the CoT system.
15 Wastewater treatment works for the city, only two were functional and four were in serious condition.
Lack of planning by management.
Inadequate technical capability.
Inadequate security.
Vandalism and theft.

Source: Portfolio Committee Human Settlement, Water and Sanitation (2019).

3.5.2 Identifying challenges experienced during installation of WI

In SA it is common practice for pipe installations to be underground due to susceptibility to damage and wear probabilities of above-ground installation. Often pipes are installed parallel to roads, power lines, and electric railway lines. Pipes are installed for operation under different conditions to convey municipal water through pumps or gravity to:

- Convey raw water from a dam or river to water treatment works.
- Convey clear water to reservoirs.
- Distribute treated water from reservoirs to consumers.

These raw and clear water pipes are installed within areas formally registered as servitudes. A common problem in SA is the encroachment of consumers' pipes into servitude areas (Shand 2013: 121). A servitude area requires the careful installation of consumer pipes as encroachment into this area is generally not allowed.

All over the world the migration of people to urban settlements creates a challenge to the management of infrastructure (Osman 2015: 108-109). Chen *et al*. (2018: 1) concluded that rural infrastructure has a more stable number of consumers than urban infrastructure has.

The practical challenges experienced during the process of infrastructure maintenance and renewal range from the inaccessibility of streets, community's limited access to homes, traffic jams, deep trenches with little or no barricades, leaking water pipes, water supply cut-offs, electricity supply cut-offs, vandalism and theft of water pipes and accessories, excess materials left lying around by contractors after installations, etc. Celik and Budayan (2016: 395) highlight the irritations caused by construction developments in urban settlements. Bonthuys, Blom and van Dijk (2018: 10) state that the Water Services Act obliges all SA municipalities to have an Asset Management Plan for their water and sanitation infrastructure.

Folkman (2018: 3) states that water main breaks cause flooding, service interruptions, economic effects, water loss, escalating maintenance costs, long hours for workers, traffic and business interruptions, and destruction of property. The most vital and serious aspect used to measure the state and rate of failure of below-ground pipeline reticulation is the frequency of breakages. Osman, Ammar and El-Said (2017: 28) confirm disruption to water services and traffic flow interruptions along city roads after water mains breakages.

Kruger (2018b: 1-2) confirms that the main issues that fuels residents' anger are water and electricity cut-offs for several days due to asbestos pipe replacement. These happened in several streets in Lephalale municipality for several days in July 2018. The issues residents complained about were broken telephone and electric cables, water and power cut-offs, unsafeguarded open trenches in driveways, damaged paving over ramps, sand heaps in streets, and no notices for any interruptions. The complaints mentioned were low water pressure, water flows, gushing water from pipes and open fire hydrants, temporary supplies buried without inspection, and standby workers not being available over weekends – the list goes on and on.

Adeoti (2010: 95) raises political meddling in awarding jobs to contractors, operational inefficiencies, insufficient maintenance of WI, and defective service. These aspects are viewed as the result of customers' reluctance to pay for services rendered. A common practice that most studies have revealed in SA is the non-payment for services by residents, including residents in CoT (Chauke 2017: 78). This fact seriously affects the operations of the municipality. This is a culture that emanated from even high-ranking officials and that is followed by other categories of residents. There is no municipality or any government that can grow without services payment. The government pays for water and electricity and other services which residents then fail to pay for.

The same non-ratepayers demand good and uninterrupted services from the service providers. Maphela's (2015: 4) study revealed a culture of non-payment for services, notably in the townships. The results further indicated that the six kilolitres of water supplied by the CoJ was an insufficient quantity for the residents of Soweto. Furthermore, the differences in socio-economic circumstances and structural aspects of dwellings were also identified. Consequently, those aspects were identified as gaps that needed to be researched further.

3.5.3 Identifying challenges experienced after installation of WI

Challenges experienced by the CoT could be addressed with a well-integrated approach by City managers, contractors, and the community. Community neglect by the government after installation of WI results in single-sided backup and management of service delivery (Al'Afghani, Kohlitz and Willetts 2019: 285). The CoT has not encountered a major challenge regarding power supply interruption on water supply operations (Potgieter *et al*. 2019: 19). However, the city is currently experiencing declining service delivery, especially in the areas of housing delivery, infrastructure, and other services (Magidi and Ahmed 2019: 336).

Miya and Grobbelaar (2015: 931) are of the view that the challenge to the delivery of services emanates from the backlog in the maintenance of infrastructure. This is the result of a lack of IAM. The escalation of emergency repairs, and the number of customers has increased management's reactive style of managing as well as increasing pressures from supervisory bodies. The challenges being observed are: unproductive style of managing the infrastructure, under-planning for new infrastructure development, coupled with poor infrastructure management.

Ruiters and Matji (2015: 661-662) identified the following managerial challenges as far as WI is concerned: a lack of a commercial subsidy of economic infrastructure; maintenance and restoration of infrastructure; financial controls and cost-reflective charges; overall management of the threat of raw water supply; and the transformation programme of the government. Furthermore, a major challenge is a constant supply of free basic water, especially in rural areas, inappropriately designed tariffs, and unrealistic targets set by the government demanding additional investment. Defective operation and maintenance of the infrastructure are common.

Osman, Ammar and El-Said (2017: 28) identified the Key points for consideration when teams are sent off for work: fitness, competence of the construction team to execute the type of work, and the teams' travelling time between the breakage sites. There is no cheaper way to assess the condition of buried pipes' and this is an exceptional asset management challenge.

Osman, Ammar and El-Said (2017: 28) further outline factors that may affect the optimum breakdown response plan, namely: the extent of the area being serviced; the prediction of when the mains will break; obtainability of the repair method, and apparatus that will suit the breakage type; the uncertainty of the time it will take to repair; and the time necessary to travel between repair sites. Pipe breakages coupled with blockages, overflowing manholes, and flooding of public spaces in various local authorities are occurrences that interrupt communities' daily lives. Moreover, they are a nuisance to the environment, public safety, and hygiene (Meijer *et al.* 2018: 2; Pienaar 2013: 163). These failures from sewer lines may result in sinkhole formation, groundwater contamination, loss of bedding supports, infiltration and hydraulic overloads, cavity formation, and pipe collapse (Pienaar 2013: 163).

These challenges are not worth mentioning without mentioning the relevant execution strategies to minimise or overcome their existence. Ndah (2016: 18) revealed that pipes of larger diameter have more severe consequences and need a proactive approach to defining their circumstance and developing a restoration plan. The plans as suggested are substitution by conventional open cut manner, existing pipe section repair, and restoration with structural pipe lining resolution. A long list of challenges requires a serious framework of execution.

Meijer *et al*. (2018: 2) and Shand (2013: 121) list some of the challenges after installation such as water loss, the likelihood of property destruction, and interference with traffic movement. Laitinen *et al*. (2020: 8) and Shand (2013: 121) suggest that the installation of pipes should occur concurrently with road construction. Having a road constructed and later re-excavated to lay pipes may result in damage to existing infrastructure. Coordination of this sort is an example of the managerial concept of planning and cost-saving. In instances such as a road crossing, power line interruptions, and so on, require arrangements with different departments, a costly activity.

3.5.4 Developing a framework of challenges and causes

While the challenges experienced for WI differ from one water utility or local authority to another, there is a large percentage of similarities. These similarities or variances are mostly dependent on several factors which can also be the determinants of success or failure, including materials, terrain, installation methodology, climatic conditions and so on. A poorly installed water or sewer reticulation network will perform poorly and may even result in network failures. It is of the utmost importance that utility managers must have all pictorial views of every section of the networks. Managers must make sure that network inspectors execute their work diligently.

A study conducted by Mokgobu (2017: 87) pointed out infrastructure repairs and maintenance challenges such as vandalism and theft; shortage of functionaries; resource deficiency; leaks and broken pipes; poorly trained or inexperienced staff; and lack of consistent maintenance. Similar challenges were found in a study conducted by Chauke (2017: 76-79) for the CoT. These deficiencies lead to infrastructure breaking. To this end, a table of various challenges experienced by local authorities has been developed. Miya and Grobbelaar (2015: 941) identified the following challenges and the frequency of their occurrence (Table 3.6).

Table 3.6: Challenges of water and wastewater impacting on service delivery

Challenge	Frequency
Shortage of technological inventions for infrastructure	1
Isolated operations within departments of municipalities and municipal-owned entities	1
Minimal collection of revenue from the public	1
The ever-increasing population within municipalities	1
Shortage of internal skills to manage contracts	1
Reduced service for external contractors	2
Unobtainability of spares for serious equipment	2
Leaders' inability to execute advanced asset management and maintenance approaches	2
Unpredictability in senior management contracts of some higher positions	3
A dearth of historical data about infrastructure	3
Low staff morale at municipalities and municipal-owned entities	3
Ageing and endless weakening of infrastructure	4
Equipment malfunctions and extended turnaround time due to procurement processes	5
Shortage of skilled technical staff within water and wastewater divisions	7
Theft, destruction, and sabotage of municipal infrastructure	8
Inadequate funding for maintenance and capital projects	8
Shortage of appropriate maintenance	10

Source: Miya and Grobbelaar (2015: 941).

Table 3.7 provides a ranking of the challenges which have over the years been noticed to impact service delivery in SA municipalities. The ranking is based on frequency of occurrence

Table 3.7: Challenges impacting service delivery in general

Challenges	Ranking
The incapability of decision-makers and shortage skills in the water sector	24
Unreliable political undertakings vs. expectations vs. reality (finance and infrastructure)	15
Deteriorated infrastructure	10
The balance between public rights and obligations vs. responsibilities	7
Dispersed roles and responsibilities of Local Government	6
The capability of courts / legal system to resolve the cases	5
Illegitimate connections	5
Insufficient prioritisation of water security	5
Failure to pay for services	3
Research gaps	3
Using technical solutions to solve political issues	3
Political issues associated with service provision	2
The socio-economic implication of lack of service delivery	2
Rapid urbanisation	2
Influence of climate change on water availability	1

Source: Sershen *et al*. (2016: 450)

3.5.5 Exploring root causes of challenges experienced during installation of WI

There is very little literature available as far as the installation of WI is concerned. This is also attested to by Osman's (2015: 110) observation regarding the lack of research regarding infrastructure construction and coordination. The biggest concern in this regard is that organisations are therefore operating infrastructures in isolation without sharing the shortfalls they encounter. They are loath to disseminate information to other organisations (Osman 2015: 109).

Today one of the most critical issues that utility managers face is the lack of budget. The proposed budgets do not always get approved by higher ranks as anticipated. These budget shortfalls create a backlog, especially when rolled over to another year, and this creates a massive burden. Most studies have demonstrated how budget shortfalls impact the management of infrastructure operations, such as installations and maintenance (Lawhon *et al*. 2018: 723; Miller *et al*. 2018: 1; Boulos 2017: 42; Schwartz *et al*. 2017: 03 & 08; Ruiters and Matji 2016: 291; Ruiters and Matji 2015: 662 & 663). Squeezing the approved budget to accommodate the work of a proposed budget may result in defective workmanship eventually leading to multiple breakdowns. Pienaar (2013: 164) devised a method of calculating budget shortfall as: proposed budget - approved budget = backlog.

3.5.6 Ranking the challenges experienced by municipalities

Table 3.7 illustrates several of the challenges that have been experienced by water utilities or local authorities regarding WI based on frequency of occurence. This type of ranking allows water utilities to focus their actions on the most important challenges. Similarly, the frequencies listed in Table 3.6 indicate to the water utilities and municipalities where they should concentrate their resources, that is, on the higher frequencies. It also helps utility managers and local authorities to know where most of the challenges lie and where the most complaints from the community are likely to arise. A performance scorecard of their WI is a good planning tool for utility managers.

3.6 Lack of adequate management

South African municipalities are facing the challenges of unethical leaders who are being suspended regularly for long periods. The suspension of officials with monthly pay just adds to the levels of fruitless expenditure. Mbandlwa, Dorasamy and Fagbadebo (2020: 1642-1643) confirm that such challenges are caused by poor and unethical leadership in the local government system. The authors assert that the poor systems to fight corruption and unethical conduct place the service delivery in a vulnerable position. The perception of consumers is that all public service officials are corrupt. There is also a perception that officials gain employment in government institutions with the aim of self-enrichment. The progress made by the democratic government is far from being recognised, due to the various challenges that local authorities must deal with. The ever-increasing issues of nepotism, money laundering, and interfering with tender processes have resulted in community protests.

Various problems may impact the technical and financial performance of a water utility. High-performing utilities are the result of effective management of the operations. Soppe, Janson and Piantini (2018: xiii) outline the various steps that must be followed for water utilities to perform and to respond to the turnaround time of operational and managerial capacities. For the water utilities to keep running at a productive level a few positive steps are necessary. These steps are, amongst others: water meter installation, an update of the customer database, setting up new billing and collection systems, and recording the location of pipes by means of a geographic information system (GIS). These are steps towards the development of better technical and financial performance.

Larsen *et al*. (2016: 929) noted that centralised urban WIs are condemned for being unmanageable, with a poor capacity to handle vigorous socio-economic, demographic, and environmental variations. Moreover, not considering other options leads to a dearth of innovation in urbanised water systems. Ruiters and Matji (2015: 662) opined that management of infrastructure is moving at slow pace to respond to equity and service delivery needs of SA, and this drawback is envisaged to be the low salaries and lack of capacity of selected groups in the engineering field and government. This results in a failed infrastructure at the municipal level. Similarly, the SSA energy infrastructure projects have experienced failures in “management”, “maintenance”, “nepotism” and “theft and vandalism” (Ikejemba and Schuur 2018: 15).

These issues require managerial interventions before they get out of hand. Supervision is also another factor for consideration. If not done properly a break in supervision may lead to complaints from the community at a later stage. Kruger (2018a: 3) reported that in a meeting a resident complained about the appointed contractor’s length of experience, missing supervision, and no control. That raised the question of how the contractor was appointed to replace asbestos pipes and install the required pipes. Similar complaints from residents were recorded, including thirteen days without water, no water pressure, telephone cables damaged, street blackouts, and other serious conditions.

The limited supply of water does not only frustrate the community but also places the supply authority’s employees under pressure. Soeprobowati (2018: 4) states that a restricted supply needs clever managerial interventions bearing in mind reasonable distribution considering environmental tolerance.

Van Rooyen and Pooe (2016: 139) identified that management of CoT's execution of their duties is underpinned by five drivers as recorded in the city's IDP: Batho Pele (a governmental programme that means 'putting people first'), revenue management, outcomes-based assessment, performance management, and regional approaches.

Fisher-Jeffes, Carden and Armitage (2017: 4-5) report on a meeting between researchers from the University of Cape Town (UCT), academics from the Universities of Stellenbosch and Witwatersrand, and officials from municipalities of Cape Town, eThekwini (Durban), Johannesburg and Tshwane. Urban infrastructure management, operation and maintenance, educating the community about the use of water, identifying infrastructure and the need to plan were identified as important strategies. The meeting concluded that undivided support from management is required not only to execute issues of water infrastructure, but also the rest of the urban infrastructure.

Ncunyana (2015: 13-14) attests that the Tshwane water resources management network was established to rectify the city's water-related issues. The CoT established the Tshwane water resources management network which aims to:

- Expedite and create a knowledge-sharing platform to overcome the water resource management challenges.
- Provide strategic guidance and sustenance (such as results-orientated solutions on water issues, application of water conservation and WDM approaches, learning from other studies and implementing better practices).
- Encourage the improvement of policy and execution.
- Identify potential short-medium and medium-long-term developments for execution.

Charalambous, Foufeas and Petroulias (2014: 25) recommended long-term approaches that water utility management must initiate for water loss control. They further commented that as a result for water utilities to realise their vision activities must not be interrupted and this requires a buy-in at all levels for success. Mahaffey (2016: 152 & 154) stated that management and technicians may find difficulties assessing the conditions of water mains, due to limited supply of tools and techniques, operating pressures, entry necessities, and long distances. Tools and techniques that cater to for every condition and assessment thereof have not yet been obtained anywhere.

Decision-making must be compared with how other organisations do things, better known as benchmarking. This serves as a reference point for local government in their grading and selection of possible infrastructure project investment (Tanner *et al*. 2018: 12). Managers must have a thorough knowledge of the condition of their WI, for timeous repairs and to avoid total catastrophe (Ndah 2016: 13).

The EPA (2012: 10-11) proposes that the state of the present infrastructure resources should be examined, a period of restoration, repairing and replacement, and accompanying expenses. In preparation of asset management plans the following questions must be answered by municipalities; what is the present condition of the organisation's resources? What is the necessary maintainable service level? Which resources are necessary to withstand performance? What are the lowest lifespan costs? What is the highest funding approach?

Managers must be aware of generic management of water supply problems and deal with these before they actually become a problem. Brown *et al*. (2015: 6118) list these as: a) network layout; b) design regarding sizing of pipes etc.; and c) network operation as compared to design. The major planning concern that managers must face presently is to make sure the existing infrastructure meets current needs fluctuations.

3.6.1 Unattended community complaints

According to the Portfolio Committee on Human Settlement, Water and Sanitation (2019), the CoT ignored its constitutional obligation to render a service to the residents of Hammanskraal by supplying harmful water. The circumstances of the residents, many of whom were unemployed, were poor and were represented by the Hammanskraal Residents Forum. The residents drank water with traces of *E. coli*, nitrites, nitrates, and other harmful contaminants which were unsuitable for human consumption. The CoT asked the residents to provide scientific evidence of the contaminated water. This issue attracted attention when CoT remained adamant that the water was suitable for human consumption. The CSIR supported the Hammanskraal Residents Forum by providing results that proved the toxicity of the water. The representatives of the Hammanskraal Residents Forum wanted the CoT to declare the Hammanskraal water crisis a disaster. The basis of their proposal was the fact that 50 villages in this locality depended on this contaminated water source and their neighbouring municipality received a contaminated downstream flow.

Tsagarakis (2018: 3) states that most of the complaints made to water utilities are about technical issues or quality of performance. Dascalescu, Cohl and Teodosiu (2011: 1789) confirm that complaints regarding water and sanitation are associated with water quality deviations, the quantity supplied, or grid breakages. Considering that the main reason for water networks is to provide the community with sufficient water supply with adequate pressure, such complaints are understandable (Amit and Ramachandran 2009: 2).

Mabula (2017: 5) reported that complaints were lodged by Marapong residents regarding a situation where sewerage overflowed for two weeks for one kilometre. Residents mentioned that the blockages prevented children from playing in front of the school and obstructed the businesses of nearby hawkers. The residents' frustrations were shared with the local newspaper to put pressure on the municipality to develop a plan to unblock the sewer lines that were exposing residents to health risks.

Manzini (2015: 12) observed that municipalies did not support the improvement of infrastructure and maintenance before 1994, and that resulted in services being preferred to certain race groups. According to Mbandlwa, Dorasamy and Fagbadebo (2020: 1643) the current democratic order has made it possible for the water and sanitation services to be shared across all the deserving people. Shava (2018: 42) highlighted the delays in the CoT, while Motubatse, Ngwakwe and Sebola (2017: 96) lambasted the slow pace in the removal from office of unaccountable officials, which results in service delivery protests.

After the Hammanskraal Residents Forum's case, the South African Human Rights Commission (SAHRC) instituted a public enquiry because another study by the CSIR which tested the prevalence of health hazards from borehole water for the Stinkwater catchment areas in Hammanskraal came back confirming *E. coli* and other faecal contaminants, waterborne pathogens and high nitrate levels. Buang Jones, the provincial head of SAHRC, broadened the scope of enquiry to previously awarded WI tenders, and to institute consequence management (Moatshe 2019).

3.6.2 Leaks, blockages, pressure drops, and other complaints

Ogutu, Kogeda and Lall (2016: 17-21) conducted a study in the CoT, and found that the greatest number of leaks occur at street corners and intersections with smaller diameter pipes susceptible to failures. Leaks affect communities negatively by causing asset destruction, polluting the environment, interrupting other infrastructure, and resulting in interferences to network consistencies. Creaco and Pezzinga (2014: 1) state that leaks result in severe problems because filtered water is lost. A study by Nsanzubuhoro (2019: vi) reported that water leaks are a local and international dilemma, with water losses estimated to be above a third of the total water received by water distribution networks (WDNs).

Mabula (2019: 2) reported a sewer leakage in the Marapong township of Lephalale municipality which continued overflowing for two months. One resident reported having complained without success. The municipality denied that the sewage flowed openly for two months. There was also fear from the community that children would drown in the damming sewage. Such problems have far-reaching results if not managed. Ogutu, Kogeda and Lall (2018: 16-18) remarked on the need for improved infrastructure management, because of observed escalating urban pressures and pipeline failures.

Consumers need enough water pressure at their draw-off points, rather than opening a tap and getting only drops of water. On the other hand, excessive pressure can cause pipe bursts and therefore escalate water leakages (Gaius-Obaseki 2010: 397). Mothetho (2017: 22) recommends pressure management as a form of leakage control. It is important to decide whether to replace pipes sooner or later, judging from historical data generated from the occurrence of repairs and bursts.

Detection of leaks at an early stage is crucial to municipalities. Adedeji *et al*. (2017b: 20272) point out that leaks create pressure drops that are experienced downstream of the networks. Kabir, Tesfamariam and Sadiq (2015: 2) reported that water services regularly wait for water main breakdowns before the development of preventative restoration or exchange programmes rather than being pre-emptive. The core source of pipe deterioration is ageing while leaks are characteristics associated with pipeline failures (Sakai *et al*. 2020: 3, 4).

Pietrucha-Urbanik and Tchorzewska-Cieslak (2015: 236) list the causes of failure of water networks and as follows: right-angled and longitudinal cracks 42 percent, connection leakages 38 percent, worn-out fittings 9 percent, and other damages 11 percent. Mahaffey (2016: 154) suggests various tools and techniques for failure detection, such as closed circuit television pipe inspection technology, electromagnetic inspection, acoustic inspection, ultrasonic testing, radiographic testing, thermographic testing, etc.

Water leaks are referred to as being a major problem in most of the studies where research has been undertaken in the WI. Water leaks tend to pollute the environment and as such pose health risks to residents. A study conducted by Landu and Brent (2006: 255) in the Rosslyn industrial area in the Tshwane Metropolitan area recommended that water losses must receive urgent attention in order for progress to be made in the environmental performance of the water supply system within the municipal management territory (Landu and Brent 2006: 225). A search of the literature reveals very limited information locally and internationally concerning the magnitude of leaks to bulk pipelines (Nsanzubuhoro 2019: 1-3). This opens a window of opportunity for entrepreneurs to invent devices to detect the extent of leakages to bulk pipelines.

Abu-Mahfouz (2015) reported that the CoT experiences over 50 000 water leaks per year which amount to 25.7 percent (87.9 million cubic metres) per annum of the non-revenue water (NRW), compared to 20 to 40 percent in Europe (Kanakoudis and Tsitsifli 2019: 1). The city requires a minimum of R12 billion to permanently repair leakages and WI that has exceeded its life cycle (Moatshe 2018). The budgeted amount is R15 million but the required amount per year is R80 million just to keep up with the pipe replacement costs. The Water Research Commission (2013: 15) defines NRW as water that is wasted because of leaks and commercial losses or water which is lost and never reaches the consumer's draw-off points. Palmer *et al*. (2016: 22) and the Water Research Commission (2013: 16) identified the following as mismanagement practices that result in NRW: poor planning, ignorance of maintenance, insufficient maintenance funds, and poor maintenance procedures. An announcement by Darryl Moss that CoT had approximate values of 26 percent of water revenue and 18 percent real water losses respectively earned the city the title of better metro (Moatshe 2018).

3.6.3 Costs due to leaks and introduction of smart technology

Abu-Mahfouz *et al*. (2019: 3) found that almost every water supply network experience leaks, but the quantity of lost water varies from network to network. Adedeji *et al*. (2017b: 20272) highlight the worldwide cost implications associated with leaks. South African municipalities experience an estimated annual water loss of 36.8 percent which amounts to R7 billion, compared to an average of 36.6 percent for the world (Mckenzie, Siqalaba and Wegelin 2012: iii; iv). Leaking pipes and other types of pipe failures are inevitable in local authorities.

Leaks detected early are a sign of effective management and control of water losses. Managers can dispatch teams early to repair and maintain the breakages (Adedeji *et al*.: 2017b: 20279). Leak detection devices are widely being used, Adedeji *et al*. (2017b: 20273). The devices can assist cities overcome water supply interruptions which cause pollution in the networks because of pressure drop, backflow, and suction of pathogens (Jeandron *et al*. (2015: 3).

Alvisi *et al*. (2019: 2) recommend the use of smart water meters to find and avert leaks. The authors advise that households should pay attention to water leaks as they are just as important as gas leaks. Galaitsi *et al*. (2016: 12) advise that half of the missing water results from leaks with the remainder through private, and frequently illegal, connections.

The CoT's ageing water infrastructure needs total replacement but the cost of this would be impossible to support. An international study by Boulos (2017: 42-43) revealed that the need for replacement of ageing infrastructure is a global phenomenon with unaffordable costs, which leaves communities in dire straits. This gap as identified can be closed by the introduction of smart water network technology that monitors infrastructure before its total overhaul. This international study by Boulos further pointed out that an existing asset with ownership costs that are above a new asset warrants replacement. Managing assets strategically places more emphasis on optimum service level at the lowest operational lifespan cost.

Leakages create unevenness in pressure and increase costs to consumers and departments (Sithole *et al*. 2016: 1). Consumers do not easily notice leakages that take place every day. Smart water leakage detection and metering is a device that can assist the consumer and water authorities in leak detection and better management. Kanakoudis and Gonelas (2016: 11436) suggest that extreme pressure management could positively help to reduce the leaks and bursts on water supply networks, and thus the high costs. However, Thompson, Masiya and de Wet (2013: 1) noted the limitations in the previously conducted studies which only focused on the use of water management devices (WMDs) and ignored the satisfaction of consumers. The authors conducted a study in the eThekwini and Cape Town municipalities to ascertain consumers' satisfaction with the WMDs' control and regulation of domestic water supply. They found a lack of explicit consultation with the affected communities, absence of monitoring and evaluation of the extent of the effects and effectiveness of the WMDs, concern about the health of consumers arising from the water use patterns because of the WMDs, and the absence of policies to outline the WDM (Thompson, Masiya and de Wet 2013: 101-102).

Kanakoudis and Gonelas (2016: 11437; 11445) state that the installation of pressure-reducing valves is vital for the reduction and control of pressure from water mains. The positive benefits of reduced pressure are mainly noticed in a reduction in the number of leaks and recurrence of pipe breaks. Consequently, maintenance and travel cost reductions are realised. While most municipalities struggle with their water management, Ojo (2018: 24) confirms that the CoT has a good system of managing its water.

Kanakoudis and Muhammetoglu (2014: 885) recommend the use of active leakage control devices to detect unnoticed leaks within zones. The flow meter records data that pinpoints exactly where leaks are located. However, other technological mechanisms such as noise loggers, leak noise correlators, ground microphones, and sounding sticks can also be of assistance. The devices may be temporary or permanent and depend on pipe sizes, material, reticulation size, and the pressure within the installation. Helium tracing, where gas and supplied water are mixed, locates the leak where the two escape, through a helium gas detector. Bello *et al.* (2019: 5) suggest acoustic methods as the generally used test practice for leak detection and location in water distribution networks.

The Infrastructure, Housing & Development Planning Working Group (2019: 2) recommended that Lephalale Municipality should source more funds to fix leaks because repairing is cheaper than new installations. In a situation of a fixed budget, Shin, Joo and Koo (2016: 385) argue that replacing aging pipes with completely new pipes irrespective of deterioration is not an effective move. It is for this reason that managerial interventions are required to cure these problems. Ruiters and Matji (2016: 291) view limitations to service delivery of WI projects resulting from high costs. The ever-increasing costs make it difficult for most developing countries to cope with expenses for infrastructure. Therefore, the repair route is in line with the industry norms as compared to total replacement.

3.7 Installation and maintenance of WI

Ruiters and Matji (2015: 662 & 663) note that SA's water and sanitation receives a limited budget with poor revenue controls and maintenance underinvestment. Installation projects are largely executed by contractors for municipalities, government, water boards, etc. A WI project is an immense task that requires the full-time involvement of the rest of the project team, the management/supervisory team, the installation contractor, and the involvement of communities. Installations that are not executed properly may result in complete shutdowns and endless maintenance. According to Lawhon *et al*. (2018: 723) and Nilsson (2017: 484), African states and their partners have a desire for modern infrastructure installations, but budget constraints prevent this.

The DWS (2018: 19) views intermittent water supply and clogged and exposed sewage flows as the most disturbing aspects that need attention because they result in damage and demonstrations. Miya and Grobbelaar (2015: 931) argue that municipalities' ignorance and backlog of water and sanitation infrastructure are hindrances to the provision of basic services. Pienaar (2013: 163) and van der Mescht and van Jaarsveld (2012: 1) stated that the deterioration of municipal infrastructure was due to insufficient funds being allocated for maintenance.

Van der Mescht and van Jaarsveld (2012: 3) recommended extra support for operation and maintenance as follows:

- Archive as-built records.
- Update asset registers.
- Provide aid through technical functionaries' selection and staffing.
- Mentor recently appointed functionaries.
- Assemble maintenance plans and schedules.
- Offer help regarding 0peration and maintenance budgets.
- Offer support to management.

Ndah (2016: 5, 13) states that water reticulation deteriorates with age resulting in leakages, malfunctioning, and declining trustworthiness of installations. Resource investment into future replacement is essential for the consistency of buried WI, the reliability of which is vital for the protection of public health and safety. Leaks and deterioration of WI also result in unused or wasted water damaging road infrastructure and other services.

3.7.1 Local authorities' contribution to installation and maintenance

Local authorities, regardless of their magnitude, are faced with the challenges of having to choose whether infrastructure must be maintained, replaced, or expanded

(Tanner *et al*. 2018: 4). Falk, Kumar and Srigiri (2019: 266) proposed an equal community contribution towards maintenance.

Luong and Nagarur (2001: 3286) demonstrated the criteria to be followed for the replacement of a pipe. Firstly, a pipe requires replacement after outperforming the total number of breaks irrespective of age. Secondly, a pipe that has previously broken should be exchanged if its time of operation in the earlier state has passed its defined period of replacement. If the above aspects do not prevail, under normal circumstances a pipe will be repaired. The researcher views this technique as a suitable policy basis (local and national) for better management strategy regarding repairing or replacing of water pipes.

Previous studies on the installation of WI are silent about logging the location of pipes, water meters, shut-off valves, pressure-reducing valves, and boreholes via the global positioning system (GPS). This gap as identified needs to be researched further and which requires logging these assets via GPS. This could overcome the practice of haphazard excavations to find pipes, water meters, shut-off valves, etc. because the positioning of these assets will be permanently identified.

According to Gómez-Martínez *et al*. (2017: 3), a GIS is used by Canal de Isabel II to log data for the location of every pipe connection, its age, material, diameter, and depth in the regional urban water network for Madrid. The network covers 8000 square kilometres with a water supply network of 177 local authorities. Gómez-Martínez *et al*. (2017: 1) and Osman (2015: 108) advise that the lack of replacement of worn-out infrastructure increases the risk of failure in buried water pipes resulting in interruption of service to consumers. Worn-out infrastructure is a major challenge experienced by water suppliers. Kanakoudis and Muhammetoglu (2014: 885) warned about the importance of recognising leaks timeously as quick attention to these repairs avoid extensive water loss.

Boulos (2017: 44) noted there are numerous aspects such as pipe depths, number of consumers connected from the same pipe, and proximity to critical services (streams, wetlands, hospitals, schools, industrial areas, cluster housing, airports, military services, etc.), that can influence pipe failure.

The GIS can be a storage system for water and wastewater pipe data. The system can store data such as distance, diameter, material, pipe location, period the pipe was laid, soil condition, and history of pipe (breakages, leakages, and failure history) (Boulos 2017: 44).

Mahaffey (2016: 155) notes that models can be generated by computer-aided design and GIS after the pipeline records are obtained. The models can generate appropriate information for pipes such as pressures, flow proportions, entry points size and spacing, material, pressure ratios, diameters, connection method and length, direction and accessibility, geological conditions, nearby watercourse or river and general landscape, availability of high voltage power lines, railway lines and potential sources of power supply, and pipeline operational restrictions. After all these aspects are identified, a determination can be made about suitable inspection tools.

Li and Mahmoodian (2013: 103, 107) define the service life of a pipe as the age at which the pipe achieves the function it was intended for until exhaustion. Studies have revealed that an increase in the diameter of pipes makes them more vulnerable to collapse. Pipes face extra exposure to collapse when corrosion is external rather than internal. Tougher pipes experience less exposure to the risk of collapse. According to Folkman (2018: 3) and Kabir, Tesfamariam and Sadiq (2015: 2), water utilities depend on pipe failure prediction representations to design preventative or proactive repair and replacement active strategies. Gómez-Martínez *et al*. (2017: 1) suggest a pipe break prediction strategy of estimating asset lifetime and then plan the repair and renewal of pipes accordingly. While the water pipe network upgrades are necessary, Li, Yang and Sitzenfrei (2020: 2) argue that upgrades of the water distribution networks are time-consuming and expensive.

3.7.2 Planning for asset management and maintenance

It is important for maintenance funding to be included at the time of installation to avoid asset breakdowns that may result in total shutdowns. Tanner *et al*. (2018: 13) point out that maintenance not budgeted for leads to the degradation of infrastructure which could result in a state of disrepair. Palmer *et al.* (2016: 6) assert that paying insufficient attention to infrastructure operation and maintenance creates a fertile ground for service delivery failure. Muller (2014: 41) concluded that the uninterrupted functioning of water and sanitation services and newly installed infrastructure requires maintenance to avoid the risk of disrepair. The City of Johannesburg manager has placed a particular focus on increasing repairs and maintenance on basic infrastructure, to improve quality during the 2018/19 financial year (City of Johannesburg 2019a: 10). The CoT could also learn from this initiative to become the best city.

According to Mckenzie and Wegelin (2009: 173) maintenance of WI has been ignored for quite some time in SA, notably in the previously disadvantaged areas. Where maintenance has been executed, such infrastructure is always in poor condition. It is imperative to clear the maintenance backlog before executing a workable WDM. The proper results of WDM can only be achieved when the system is operational. Over time there has been a noticeable decline in support for the implementation of WDM, arising from factors such as the poorly maintained reticulation systems, the absence of political buy-in from municipal politicians, and consumers not upholding the initiative (Mckenzie and Wegelin 2009: 173).

Shand (2013: 124) stresses that the installation contractor should adhere to drawings with pipe beddings and compaction underneath as a vital factor. Pipe backfilling in the early stage of installation to remedy pipe floatation is recommended with the first 1000 m tested for pressure. Pipe coatings and linings should be pre-checked to prevent accidental damage. However, different pipe materials require different installation methodologies and processes for the prevention of accidental damage.

Abuzayan, Whyte and Bell (2014: 307) and Gondo (2012: 27) hold the view that a lack of effective asset management inhibits the acceptance and application of software monitoring systems. Abuzayan, Whyte and Bell (2014: 307) recommended the following improvements for the water and sanitation divisions:

- Introduce an asset management plan.
- Equip the local authorities with adequate financial capability.
- Employ experienced personnel.

- The organisational strategy must be supportive.
- Improve commitment to stakeholders.

Local authorities and other government bodies still resist embracing new technologies for asset management. The modern world of new technologies can benefit role players to:

- Simplify access to the information about an asset.
- Check the precision level of an asset.
- Improve effective business collaborations about the services.
- Maintain higher service levels.
- Improve the service life span of an asset (Gondo 2012: 27-29).

Regarding operation and maintenance, Hay *et al*. (2012: 437) assert that if these aspects are not properly executed, the water supply, treatment, and reticulation of the infrastructure may experience unbearable losses. Curt *et al.* (2018: no page) noted that when IAM is introduced in an organisation it decreases risk and impacts due to efficient maintenance, operation, and renewal of infrastructures involved. Pathirana *et al.* (2018: 3), Voost (2017: no page), and Boulenouar and Schweitzer (2015: 3) outline the five basic pillars of IAM as follows: asset register, service level, asset breakdown, asset maintenance approaches, and long-term funding. These pillars are outlined in detail hereunder.

- **Asset register**

This is a register to record what assets are in the ownership of the organisation, the location of the assets, the condition under which the assets are operating, how long they can be used, and what the assets are worth.

- **Service level**

This is the amount of assistance that stakeholders and clients may claim from an organisation. The requirements that an organisation must adhere to as mandated by regulators. The results that an organisation provides. The physical competencies of assets of the organisation.

- **Asset breakdown**

This is the method followed to identify how assets can break or fail. The possibilities of an asset failing and the results thereof. The cost implications after the failure of an asset. Any other overheads that may be incurred due to this asset failure, for example, social or environmental, etc.

- **Asset maintenance approaches**

Any other approach that may exist to handle the operation and maintenance, employees, and finances. The best possible approach for the organisation.

- **Long term funding**

The cost implications for reintegration, repair, and replacement of serious assets. Check if the organisation has enough capital for the maintenance of assets for the service that is necessary. Check if the rate at which clients are charged will sustain the system for necessities in the long run. In the event rates are lower, the tariffs, taxes, and transfers are added to the financial plan.

3.7.3 Community contribution to maintenance

According to Dean, Fielding and Newton (2016: 1/18), the starting point for developing community involvement is to first detect the water management knowledge of that community. A supportable approach to water management needs extensive community approval of policy variations, practice and technology, and community involvement. Hove *et al*. (2019: 10) confirm respondents' emphasis on their involvement in planning, execution, and management of water supply. Dean, Fielding and Newton (2016: 1/18) conducted a study in Australia that pointed out that older people with higher education living in non-urban areas have advanced knowledge of water.

Regarding demand-driven methods of rendering community water and sanitation amenities, the emphasis is on the significance of community involvement and management (Rosenqvist, Mitchell and Willetts 2016: no page). Chowns (2015: 263) confirms that in both technical and financial issues, community management has proven itself inadequate. Maintenance is poorly executed with lower standards and slow repairs when committees are incapable of funds collection and saving.

According to Nurbaiti and Bambang (2018: 3) community participation can be in different forms – monetary, ideas, physical power, material donation, and involvement in making decisions. Although community participation plays a pivotal role, it is discouraged by other factors arising from internal and external forces. These factors may arise internally from the community, for example, the character of a person, or externally from villagers' roles, community frontrunners, local government, non-governmental organisations, etc. (Nurbaiti and Bambang 2018: 3). A study conducted by Falk, Kumar and Srigiri (2019: 266, 267) in India stressed the significance of the inclusion of the young, less educated, and women in decision making. They further emphasised the importance of an environment where communication is the key as well as equity in the community.

Mannix *et al*. (2018: 5) identified a breakthrough by the government of Malawi that introduced the specific standard hand-pump (Afridev) and enforced that it should be used. This benefited the country immensely with the involvement of the community in issues of operation and maintenance of boreholes. Supplies were sourced locally, and unscrupulous suppliers were side-lined from participating in the selection process. Good quality materials were purchased with experienced installation contractors issuing guarantees to the government.

Communities need to adapt to changes in policy, practice, and technology. An assessment of community knowledge of water management is necessary for building an involved community (Dean, Fielding and Newton 2016: 1/18). Lund (2015: 5905) stated that the building and sustenance of a water system is dependent on society for success. Many decisions on water management are mostly made by end-users and operators, and few by administrators of the system. Social and economic background and system support are necessary to complement the decisions.

3.7.4 Proposed solutions to repair and maintenance problems

The multifaceted challenges and causes that have already been discussed have been listed and solutions are sought by this study. To this end, a study conducted by Mokgobu (2017: 88) revealed three-tier solutions where repairs and maintenance were investigated. Regarding repairs and maintenance on the first tier, the study unveiled the following: shortening complaints reporting time through social media or free calls; more personnel recruitment with free transportation; recruitment of locals for skills transfer; and standby duties for a quick response.

The second tier of solutions to avert repairs and maintenance delays are: to create free complaints reporting mechanisms; appoint qualified personnel; create community and municipality collaborations; community education to avoid negative attitudes and protection against vandalism and create a community infrastructure ownership environment. The last tier, which includes enforcement for protection against vandalism and theft, requires the introduction of yard connections; swift reporting of the crime to the police; enforce heavy fines for offenders; appoint water inspectors and security guards; security devices installation; and community education (Mokgobu 2017: 88).

The National Council of Provinces (2017) presented certain efforts and recommendations to solve the challenges faced by the Metropolitan Municipalities in Gauteng Province; CoE, CoJ, and CoT. This literature will only point out the efforts and recommendations which were directed to the CoT. The following recommendations were put forth to the CoT:

- Involve law enforcement agencies to investigate unlawful awarding of contracts.
- Involve the DWS and the province regarding conditional grant funding.
- Source the funds from the Development Bank of Southern Africa to bridge the infrastructure funding gap.
- Accelerate the application of the organogram by bridging the skills gap and employing suitably qualified employees.

- Reinforce the relationships with the South African Police Service (SAPS) and Metro Police for the theft of the cables.
- Comply with the standards as distributed by the NDWS for quality water and sanitation services.
- Align the city's maintenance and improvement plans to those of the Human Settlements Department.
- Transfer the skills after completion of Temba Water Purification Plant and budget allocation to maintain the maintenance process.

Literature has unveiled the similarities and differences of water utilities between the CoT and the various cities around the world, for example, similarities have been identified by Renwick *et al*. (2020: 1); Li, Yang and Sitzenfrei (2020: 2); Mnguni (2019: 937); Sutherland (2019: 1); Shambare (2018: v); Chigonda and Chazireni (2018: 141); Department of Water and Sanitation (2018: 19, 20); Hernández-Bedolla *et al*. (2017: 14, 17); Tanner *et al.* (2018: 3); Boulos (2017: 42, 43); Mokgobu (2017: 8); Morris (2017: 24); Nilsson (2017: 481); Bond (2016: 330); Setlhogile and Harvey (2015: 2); Nag and Garg (2013: 4). Dissimilarities have been identified by Dludla (2020); Masolane (2019: 55); Moatshe (2019); Portfolio Committee Human Settlement, Water and Sanitation (2019); National Council of Provinces (2017); Pooe, Worku and Van Rooyen (2016: 26) and Khale (2015). These similarities and differences have helped to identify the gaps in knowledge about WI management that was used as the basis for the interviews, the survey questionnaires, and the focus group discussions of this study. These similarities and differences are listed in Table 3.8.

Table 3.8: Similarities and dissimilarities between CoT and other cities of the world

Similarities	Dissimilarities
Population growth in urban centres.	Adequate tools of the trade in the CoT.
Urbanisation.	Service delivery protests in CoT.
Persistent water supply cut-offs.	Inadequate security for the infrastructure.
Lack of maintenance of the infrastructure.	Fighting political battles at the expense of CoT.
Budget constraints for the utilities.	CoT is unable to pay creditors and has bad revenue collection.
Political interference.	Deliberate ignorance of procurement processes by CoT.
Inadequate service delivery.	Unlawful awarding of contracts.
Questionable water quality.	Disregard of the water and sanitation standards.
Climate change.	Misalignment of CoT with other government departments.
Infrastructure has exceeded useful life.	
Lack of technically skilled staff.	
Theft and vandalism.	
Poor planning.	

3.7.4.1 Infrastructure security

Security concerning reservoirs in remote areas and other WI vandalism also pose challenges and could benefit from satellite surveillance. Satellite surveillance can replace having to have security officers full-time on-site who sometimes are attacked by criminals. Vandalism and theft of the infrastructure have been identified in previous studies, where the security of these assets was highlighted as a challenge that needed further attention (Birkett 2017: 1; Chauke 2017: 79; Mokgobu 2017: 88; Portfolio Committee on Water and Sanitation 2014: 1/6; South African Local Government Association 2014: 2; Congress of South African Trade Unions 2014: 1-3; Copeland 2010: 1, 4).

Some of the exposures that water infrastructure systems suffer are terrorist attacks such as contamination of water (Birkett 2017: 3). The attacks can occur in water treatment plants, pump stations, pipelines, and storage facilities in the form of physical or cyber-attacks (Copeland 2010: 1; Gilbert *et al*. 2003: 99-100). The US had learned a lesson after the terrorist attacks that took place on 11 September 2001 when the water supply was interrupted. After the attacks security measures were expanded extensively around water infrastructure and water treatment facilities (Copeland

2010: 1).

According to Kitchin and Dodge (2017: 19 & 20), cyber-attacks and cyber terrorism in cities are forecast to increase in the foreseeable future regardless of security technology. These acts could lead to interruptions to the electricity grid, traffic backups, and threats to life. Although other cities' infrastructures and services have experienced these types of attacks, their impact has been relatively low. They only last for a few hours but have huge cost implications. Scanlon *et al*. (2016: 8) view vandalism and theft as general misconduct regarding water services with a loss of financial savings. Some or most of the electricity and water infrastructure networks in various cities use computer programs and networks to produce the performance results, it is for that reason the researcher visited literature about cyber-attack and cyber-terrorism.

Copeland (2010: 2) warns that WI systems that serve a large part of the population are more susceptible to terrorist attacks than those that supply a smaller section of the population. According to the Congress of South African Trade Unions (2014: 1-2), the issues of vandalism and theft of WI originate from neglect, under-investment, and under-resourced police service, while the South African Local Government Association (2014: 2) concluded that the causes of problems around dysfunctional WI are not yet adequately detected and measured.

South African Local Government Association opined that there could, therefore, be less attention given to operation and repairs, accessibility of water resources, insufficient bulk services, theft, and vandalism. Similarly, the Portfolio Committee on Water and Sanitation (2014: 1/6) noted the steps that the challenges of theft and vandalism raise; partnership with security agencies, installation of surveillance systems, involvement of the community, municipality law enforcement, expose the perpetrators and engage organisations trading with scrap metals.

3.7.4.2 Investing in WI

Pietrucha-Urbanik (2015: 244) views infrastructure as the largest resource of a city and requires acceptable maintenance management of old pipes to augment operational success. Investment in WI is a major task that should not be underrated. Morris (2017: 24 & 28) states that much of the infrastructure in the American West is in seriously frail condition due to underinvestment, negligence, and political disagreements for decades. Similarly, in SA's DWS, water boards, municipalities, and other organisations generally experience failure of operation and maintenance of both the water and sewer infrastructures (Department of Water and Sanitation [DWS] 2018: 19). Cost-saving measures should never be the first thing that comes to mind as far as WI installation is concerned.

Banos *et al*. (2010:261) attest that a well-organised and recognised methodology to improve water distribution networks does not exist yet. However, currently, the trustworthiness of WDNs has raised an alarm for water utilities and researchers. Privatising access to water has never been beneficial for the developing world (Liddle, Mager and Nel 2014: 3). The economy is dependent on WI and any interruptions of water supply harm the local economy (Tanner *et al*. 2018: 22). However, reparation and maintenance are only done if the cost is less than the cost of NRW (Samkange, Mahabir and Dikgang 2019: 14; Toxopeüs 2019; Adedeji *et al*. 2017a: 466).

The residents of Flint, Michigan complained of obscene tasting and stinking drinking water due to authorities embarking on cost-saving measures of changing the water supply (Morris 2017: 24). The challenges of water quality are similarly thorny in SA. The challenges emanate from mining activities, industrial effluents, agriculture, infrastructure that exceeded its service life, and defective operation and maintenance (DWS 2018: 31). Water infrastructure is situated underground (Folkman 2018: 3, Morris 2017: 28), therefore proactive maintenance is difficult. Despite this the CoJ Executive Mayor prioritised investment in infrastructure for the financial year 2018/19 to enhance a consistent WI service (City of Johannesburg 2019a: 8).

The value of WI owned by the DWS is R143 billion, Water Boards R160 billion, and Municipalities R370 billion (DWS 2017: 22). Abunada *et al.* (2014: 4) view water distribution networks as an important portion of urban infrastructure and involves great investment, operation, and maintenance costs. Designing this type of infrastructure is a complex undertaking because of the interconnections amongst the networks. In cases where bigger networks consist of pumps and tanks, the complexity of the design increases. Gómez-Martínez *et al*. (2017: 1) attest to investing in assets for the restoration of service level, while Wafer (2019: 94) proposes immediate investments of resources into infrastructure to ensure future water supply.

Ndah (2016: 19) endorses the need for significant investment in WI as being vital for inspections, reparation, restoration, and replacement of ageing services. A study by Palmer *et al.* (2016: 39) concluded and recommended that local authorities require inclusive and coordinated urban infrastructure investment planning, inclusive planning that aligns the national government and local authorities, and the full delegation of powers to cities to effect better planning and service delivery, abolition of intergovernmental fragmentation of grants for infrastructure investments, and municipalities that must be the innovation hubs through fostering partnerships. Samkange, Mahabir and Dikgang (2019: 19) urge the government to adjust WI maintenance budgets, notably for high water demands with ageing infrastructure and climate change.

3.7.5 Climate change

Zhang (2012: 2062) defines climate change as any major climatic variation in the form of temperature, precipitation, or wind lasting for a prolonged period of a decade or longer. Van Vuren *et al.* (2015: 1) state that when designing for WI, "climate change" and "socio-economic developments" must be considered. Harris-Lovett, Lienert and Sedlak (2019: 218) state that WI and environmental management challenges require a coordinated approach, including discussions amongst role players. The risks of water pollution associated with climate change, along with urbanisation, will exacerbate the challenges of water quality and water security for cities (Romano and Akhmouch 2019: 4, 7; Hoekstra, Buurman and van Ginkel 2018: 8; Zeraebruk *et al*. 2014: 93).

According to Engelbrecht and Monteiro (2021: 34-35), the Paris Agreement on Climate Change requires that the levels of global warming should be kept below 2° Celsius and preferably less than 1.5° Celsius. Any temperature between 1.5° Celsius and 2° Celsius signal "dangerous climate change" levels. The global carbon emission per unit of energy rated SA among the top five in the world. The authors further reported that eliminating high carbon dioxide emission volumes by the 2020s, and the easing of zero net emissions by 2050, would not surpass a 2° Celsius limit.

The African continent is the most exposed of all continents to climate change. Currently, the effects are being experienced in the various water resource fields of forestry, agriculture, conservation and tourism, urban and rural development, and human health. South Africa’s temperature is predicted to increase by almost 1.5° Celsius in the coastal region and 2° to 3° Celsius inland by the year 2050. The rainfall is anticipated to surge in certain parts of the country with devastating droughts in other parts (Ochieng 2016: 7-8).

3.7.5.1 Impact of climate change on water resources

Climate change will bring about rapid changes in the next 50 to 100 years. The impact will intensify design failures of infrastructure if attention is not exercised during the project planning and design phases (O’Neill 2010: 86). Climate change has far-reaching consequences for the cities of the world. Van Leeuwen *et al*. (2019: 1) predict that as the population of the world grows, the main increase will be in the population of the world’s cities. This exposure to the cities escalates water-related challenges, and the solutions will need to be derived from the cities themselves. Management of the various cities of the world must bring improvement to the governance processes within a decade to overcome the challenges. This will avert the persistent effects of water insecurity, urban floods, and heat stress. The infrastructure that has reached the end of its useful life is among the costliest and most challenging to the cities of the world.

Makarigakis and Jimenez-Cisneros (2019: 1), Schewe *et al*. (2014: no page), Stoakley (2013: 1) and Zhang (2012: 2061) maintain that climate change presents a major risk to freshwater assets, adversely affecting accessibility and quality of water. Hajibabaei, Nazif and Sereshgi (2018: 538) assert that the related environmental and economic factors can affect drinking WDNs, and therefore their restoration and maintenance are important. Cele (2016: 17) points out that the chances of interrupted water supply are unpredictably high in the African continent, especially in southern Africa because of the effects of climate change. According to Ncunyana (2015: 12-13), the effects of climate change have worsened the problems of increasing water demand and supply break in the CoT.

Kanakoudis and Tsitsifli (2019: 1) and Charalambous, Foufeas and Petroulias (2014: 25) observe that shortages of water and climate change are the main contributory elements to problems related to water the world over. Climate change has now become the leading point of discussion in government and infrastructure management circles, more so even than social, political, and economic programmes, and should be considered in strategic planning for water resources (Meissner 2017: 25-26).

Hajibabaei, Nazif and Sereshgi (2018: 538) view networks delivering drinking water as vital mechanisms for the coordination of urban water, but studies that on their environmental impact are few. These authors concluded that pipe diameters of 200 millimetres and 500 millimetres ductile iron pipes have a more extreme effect on the environment than polyvinyl chloride.

Literature has pointed out that WI is vulnerable to environmental conditions. In the long run, exposed infrastructure becomes rusty, and excessive expansion and contraction and solar heat damage cause cracking and dislocation (ageing) (Boulos 2017: 42-43; Venter 2016: 38). These aspects, therefore, need to be factored into planning and designs for the future of WI. Brown *et al*. (2020: 1) confirm that the present WI designs are not suitable considering climatic inconsistencies and change because they display instability due to excessive weather and fluctuating climatic conditions.

Climate change has driven SA into worse weather patterns consisting of heavy rainfalls, severe droughts, life-threatening floods, and other unprecedented climatic conditions. The system of management for water resources by the government makes this even harder to manage. Aspects of water-related service delivery protests, dangerous droughts and floods, industrial pollution, infrastructure failure, and absence of access to clean water increase community displeasure. These factors, if not effectively attended to, may result in water warfare in SA (Adam 2020: 58). However, Adam (2020: 69, 70) states that the main reason for possible water wars in SA is poor governance, deteriorating infrastructure, and waste mismanagement. Issues of limited water access, supply imbalance, privatisation of water services, and government corruption add to the list of reasons for water wars.

Zuniga-Teran *et al*. (2020: 711) highlighted pollution as being another climatic health hazard that progressively threatens urban residents' lives. Maphela and Cloete (2019: 536) and Maphela (2015: 2) note that the fast population growth in SA worsens the environmental contamination due to excessive use of water and water pollution. Extra stress is experienced by the environment due to the absence or shortage of wastewater and waste treatment plants (Bieker, Cornel and Wagner 2010: 2905).

According to Adam (2020: 61), world climate change exacerbates three challenges experienced by water resources: increasing water demands; the high number of water shortages; and persistent industrial and agricultural pollution. Eklund and Thompson (2017) comment on the rural to urban migration in Syria as a result of climate change as being one of the factors that led to the 2011 unrest which produced six years of civil conflict. The issue of climate change is a major challenge that requires a concerted effort between world governments.

3.7.5.2 Impact of urbanisation on WI

SA's urbanisation rate is estimated to be between 60 and 64 percent, which is higher than that of China, Brazil, and Nigeria (Shambare 2018: v). The issue of people flocking from rural to urban areas also contributes to the lack of service delivery with more people putting pressure on the infrastructure, especially WI (Madonsela *et al*. 2019: 1; Mnguni 2019: 928; Nsanzubuhoro 2019: iv; Samkange, Mahabir and Dikgang 2019: 19; Owen 2018: 1; Hoekstra, Buurman and van Ginkel 2018: 8; Keys, Wang-Erlandsson and Gordon 2018: 1; Pakizer and Lieberherr 2018: 53; Urich *et al.* 2013: 301) Stoakley 2013: 1; Adeoti 2010: 95; and Bieker, Cornel and Wagner 2010: 2905).

Bieker, Cornel and Wagner (2010: 2905) state that rapid urban growth is not skewed to a certain part of the world but is a worldwide phenomenon. For example, Tsiko and Togarepi (2012: 692) point out that managers in Harare, Zimbabwe, are unable to deal with urbanisation happening at such a fast rate, and CoT is not immune to the challenges of rapid migration of residents from rural to urban areas (CoT 2019b: 52). The CoT experiences rapid urban growth due to the influx of immigrants from African countries (Molepo, Maleka and Khalo 2015: 347).

A recent study by Magidi and Ahmed (2019: 335-336) assessed the urban sprawl for the CoT with the assistance of remote sensing and landscape metrics. The period assed covered the years 1984-2015 using Landsat satellite imagery. Data analysis based on Landsat metrics gathered via remote monitoring revealed that CoT has increased in size by 109 percent in 31 years.The project was triggered by regular changes in land use and an uncontrolled increase in urban dwellers. The main factors identified were formal and informal settlements, industrialisation, transport networks, and mushrooming economic activities. The authors pointed out that it was important to monitor these activities to help the city to plan better and develop strategies and policies and make informed decisions on how to better manage the use of land.

Society needs to transform socially and politically regarding how to handle urban water infrastructure, technologies, the use of water, and culture (Jacobs-Mata, Funke and Banoo 2018: 4). Half of the world's population currently resides in urban areas (Cosgrove and Loucks 2015: 4834), with a third being urban SSA residents in 36 cities each with residents exceeding one million (Bond 2016: 330).

One of the reasons for people moving from rural to urban areas is exposure to unsafe water supplies. However, immigrants in new urban settlement face exposure to air pollution, poor housing situations, communicable diseases, amongst other factors. Koop and Van Leeuwen (2017: 388) point out that the world is experiencing urbanisation at an alarming rate while rural areas are experiencing population decline. South Africa is the only African state amongst the fifteen world states with the highest figures of immigrants (Pison 2019).

Tacoli, McGranahan and Satterthwaite (2015: 4, 6) state that rapid urbanisation causes the following problems, particularly in the nations which still struggle to make ends meet:

- Shortage of sufficient housing.

- Shortage of basic infrastructure and services.
- Overcrowding and congestion.
- Increased vulnerability to environmental hazards.

The African continent is leading as far as urban population growth is concerned with Asia coming second. The African continent's urban population growth had been very quick and is forecast to spike by 50 percent by 2030 (Jacobsen, Webster and Vairavamoorthy 2012: 2). African urbanisation is characterised by slower income progression, lack of a firm economic base, little savings, intangible infrastructure, lack of human resources, and lack of basic amenities (Manzungu *et al*. 2016: 60).

3.8 Chapter summary

This chapter reveals that there is a high percentage of satisfaction amongst CoT residents regarding service delivery by the city and that residents commend good performance in services such as water, lights, and refuse removal. The CoT has hard-working employees who have created high marks for the city and as a result there are less service delivery protests. Literature surveyed drew attention to the CoT objectives as detailed in the 2019/20 IDP. Infrastructure asset management is also defined in the context of this study.

The chapter reiterated the way things are done locally and internationally. The management gaps that must be filled such as logging of GPS coordinates of valuable infrastructure, smart water network detectors, consumer satisfaction index and vandalism and theft during and after installation of infrastructure have been identified as being the subject of research in this study. Literature investigated the approval process which must be followed in the CoT concerning water services installations. The process defined amongst other elements each stakeholders' roles as installation contractors, implementing consultants, CoT, project implementers, city engineers, city technicians and so on.

The relevance of the study has been highlighted by pointing out burning issues. These issues affect various communities, municipalities, etc. in terms of management during and after installation of services, and reveal the need for this study. The literature on operational inefficiencies by CoT was discussed. These inefficiencies include lack of proper monitoring and management of maintenance, and reactive maintenance management style. A framework of the challenges, the causes, frequency of occurrence and possible remedial solutions, was presented.

The literature has also identified in detail the interventions required from management. Managing the cost implications of infrastructure maintenance, and better managerial decisions regarding repair or replacement of pipe failures, were discussed. Planning, operation, and maintenance were also pointed out as being deficient. Managerial capacity came as a challenge notably in the lack of innovative ideas. Reasons for management failure at the municipal level were articulated. Researchers from different South African universities and the four major South African metropolitan municipalities reviewed matters regarding urban infrastructure management, operation and maintenance, and other needs for further planning. The discriminatory pattern of the delivery of services has been a thorny issue for CoT residents. The CoT water pollution and sewer blockages have attracted the attention of authorities causing them to investigate the city's litany of failures.

In terms of infrastructure, a list of the complaints was drawn from the literature. Literature pointed out the environmental impacts that resulted from certain failures. It further exposed and quantified the failures in terms of the cost implications. Remedial solutions such as smart leak detection technology, leak control devices, pressure reduction, etc. for management of these failures were also outlined. A brief explanation of network failures was discussed, as was the inadequate budget for the installation and maintenance of infrastructure. There was a brief discussion of the similarities and dissimilarities between CoT and other cities of the world.

The literature pointed out that management should treat pipe breakage data as an important point of reference for the introduction of preventative maintenance strategies. The budget for maintenance should be incorporated into the main budget from the inception of a project. The chapter discussed that maintenance pillars such as asset register, service level, asset breakdown, asset maintenance approaches, and maintenance funding are the key to success. Proposed solutions outlining repairs and maintenance have been deliberated. Infrastructure security was discussed in the light of losses suffered by the municipality or community after theft and vandalism.

The chapter noted the aftermath of urbanisation on cities and overloaded infrastructure. South Africa and the CoT in particular experience this rapid movement of people from other sub-Saharan countries. Consideration of climate change and socio-economic dynamics stimulate the designs for new infrastructure. The risks associated with WI, and the severe consequences of climate change to CoT in terms of water demand, supply, and interruptions have been exposed.

Community contribution to issues of WI illustrate positive developments. The various authors have articulated the necessity of community involvement as the starting point of positive developments. Investments in infrastructure is regarded as key according to the literature. The dependency of the economy on WI also came under focus. It was also revealed from this literature that CoT is a WSA and a WSP, with the responsibilities of WSA and WSP tabulated. Literature also pointed out that feedback from meetings must be shared with employees and in some cases with communities.

3.9 Conclusion

In terms of the challenges of managing WI, literature unveiled that the residents are satisfied with the service delivery of the CoT regarding water; lights and refuse removal. The residents commended employees for hard-work and low service delivery protests. The chapter discussed the local concept as key to the economy of SA. The local concept includes but not limited to the procurement process in terms of appointing contractors for the installation of WI.

This chapter articulated the pre- and post-installation damages associated with infrastructure such as municipal properties, community property, and human health exposures to risk. The literature revealed reactive maintenance and a lack of monitoring and maintenance. The chapter outlined the challenges experienced and profiled them in the form of a framework, and the frequency of challenges and provided the proposed solutions.

Management interventions in response to the challenges of maintenance cost implications, and repair or replace decisions were discussed. The literature discussed a lack of innovative ideas from management. Literature discussed the reasons for the failure of management at the municipal level. The operation, maintenance, and management of urban infrastructure triggered SA universities' researchers to focus their research on these activities.

Pipe breakage data should serve as the key for management to introduce a preventative maintenance approach. The budget for maintenance should be integrated from the inception of the project into the main budget. Maintenance pillars such as asset register, service level, asset breakdown, asset maintenance approaches, and maintenance funding are key to success. A comparison of how the CoT does things in comparison to other cities serves as a base from which the city benchmarks itself.

The next chapter discusses in detail the application of space technology to WI and the economic influence on the economy of the CoT and SA.

CHAPTER 4: THE APPLICATION OF SPACE TECHNOLOGY

4.1 Introduction

Space technology refers to spacecraft, satellites, space stations, backup infrastructure, tools, and processes established and used by the aerospace environment in spaceflight, satellites, or space exploration (Ojoyi 2016: no page). The involvement of SA in space research started in 1820 with the establishment of the Astronomical Observatory and astro-photography with an effort to establish the distance to the closest star (Ligate 2015: 4; Ghadaki 2010). The Astronomical Observatory was established in Cape Town (Dubow 2019: 665). South Africa today is leading the African space research and is benefitting tremendously from the investments. Africa's expansion into space activities is realised by collaborating through conferences and workshops with organisations like the US National Aeronautics and Space Administration (NASA) (Ligate 2015: 10, 15).

This chapter focuses on the application of space technology and the challenges of managing WI in a selected SA municipality. The literature explores the internal issues, but also local, national, and international, regarding the application of space technology regarding WI. For example, space technology could help to detect the location of buried infrastructure.

Kganyago and Mhangara (2019: 2-3) noted efforts to address data gaps and sustainable development programmes by most African countries who are embracing Earth observation (EO) and geospatial technologies. The following African countries, Nigeria, Egypt, Algeria, Kenya, SA, and Gabon have established their own space agencies. They are 21st century players in the space industry with their own EO satellites.

On 14 September 2014 the South African Council for Space Affairs (SACSA) made a presentation to two parliamentary portfolio committees: Trade and Industry, and Science and Technology. Satellite communication, satellite aided positioning, timing and navigation, and EO were mentioned as the three pillars of space technology. The benefits of space technology to society and the importance of policy formulation to regulate the industry were discussed (Parliamentary Monitoring Group 2014: 1).

The services offered by these pillars of space technology include food security, water security, urban management, disaster management, nature preservation, land use, tracking of droughts, climate change and desertification, treaty conformance, human rights violations, and environmental violations (Parliamentary Monitoring Group (2014:1). The responsibility for policy formulation, regulation, and monitoring lies with the Department of Trade and Industry and SACSA. The Department of Science and Technology (DST) and the South African National Space Agency's (SANSA) ensure that the set regulations are adhered to.

SANSA is an entity of the DST and derives its mandate from the South African National Space Agency Act of 2008 [Act No. 36 of 2008] and SANSA (Kganyago and Mhangara 2019: 4). While it is a worldwide occurrence that the space sector is undergoing swift change, global players must adapt to the changes and notably new entrants into the sector. The SANSA (2020a; 13) envisions four fundamentals that motivate space industry innovation, namely, national security and scientific goals; downstream space applications growth; drive for human space exploration, and the fourth industrial revolution. Figure 4.1 shows the framework for the communication of information on space technology in this chapter.

Introduction

The contribution of space technology to Africa's economy

The contribution of space technology to South Africa's economy

The fourth industrial revolution

- The origins of industrial revolutions
- Africa and fourth industrial revolution

Legislative framework governing space technology

- South African National Space Agency Act of 2008
- Space Affairs Act of 1993
- Space Affairs Amendment Act of 1995

African space technology players

- The four main types of orbits
- Africa launches satellites

Practical role of space technology

- The benefits of space technology for water treatment
- Array of benefits from space technology
- Enhancing innovation in the CoT

Linking WI to space technology

- How space science technology can assist in resolving challenges
- Assistance provided to African communities by the US NASA
- Remote sensing
- Explanation of remote sensing
- Challenges facing remote sensing

Chapter summary

Conclusion

Figure 4.1: Space technology framework
Source: researcher's creation

4.2 The contribution of space technology to Africa's economy

Africa is gradually showing positive developments with investments in the space and satellite industry despite the ongoing coronavirus pandemic. Records show that the year 2019 has been exceptional in the history of the space industry in Africa. The African continent has spent more than $717 million on satellite projects. They have so far developed and launched satellites to the value of over $4 billion on the continent. There has been increased government participation and increased national space budgets. The governments of Egypt and Rwanda made a breakthrough by establishing their space agencies in the second semester of 2019 and the first semester of 2020, respectively. Africa's space programmes budget of $250 million in 2019 has been increased to $490 million in 2020. The capital expenditure to procure satellites was not included in the previously mentioned budget (Space in Africa 2020).

As the participation of African countries continues to grow, space players with a minimum of one satellite in space increased from eight to eleven. Other African countries will follow suit in the space initiative, as more satellites are currently being developed by various African institutions. African countries' satellites may be increased from 41 to 110 by the year 2024 if 19 countries do their launches as planned. The African budgets in 2020 were restricted as far as space programmes were concerned. The continent was unable to produce to the fullest, due to the uncertainties caused by the coronavirus (Space in Africa 2020).

On the commercial side of the space industry's economy, satellite-enabled products and services have grown within the African market. The divisions which generate more profits are driven by global and regional communication satellite operators. The space industry is experiencing a promising window of opportunity. There are flourishing projects in the areas of observatories and telescopes across the continent which bring increasing investments (Space in Africa 2020).

Africa is active in the following segments of the space industry: satellite systems and payload manufacturers, satellite services such as satellite internet broadband, broadcast, and media, EO and geospatial data, global navigation satellite system, fixed and mobile asset tracking, and maritime surveillance. They also manufacture ground stations as well as equipment. The continent has experienced substantial growth notably in the areas of space science and astronomy products and services. The growth is influenced by the increasing need for these services by government and academic institutions (Space in Africa 2020).

4.3 The contribution of space technology to South Africa's economy

Githathu (2020) explains that the SA space sector received a boost of R4.5 billion by the government. The budget aims to encourage the public and private sectors to come together, to bring forth the development of infrastructure and to support economic growth through the creation of jobs. The SANSA plans to build additional satellites for EO and other space science missions. According to Githathu (2020) and SANSA (2020b) there is a new ground station in the pipeline with an expanded data section, data visualisation centre, activation of satellite-based augmentation system over Southern Africa, new products and services, and human capital development and training.

According to SANSA (2020b) and Githathu (2020), SANSA will establish a space infrastructure hub to heed the request of SA President Cyril Ramaphosa. The CEO of SANSA, Dr Val Munsami, outlined that they retrieved ten rands in return for every rand they expend (Githathu 2020). The SANSA is respected for running its affairs properly by appropriately using state funds, and not involving itself in the malpractices of state capture (South African National Space Agency [SANSA] 2020c). The four directorates of SANSA namely EO, Space Engineering, Space Operations, and Space Weather enable them to fulfil their mandate (Space in Africa 2018).

During the Space for National Development Conference plenary sessions the panellists and other interested space sector experts engaged the officials of SANSA on various matters. Among the issues under discussion were the role that space can play to accomplish the growth of Africa, how to use EO to manage natural disasters, the introduction of innovative technologies for the growth of SA's space sector, and the role that space can play in the 4IR, and how to globalise the SA space industry (South African National Space Agency 2019).

Campbell (2018) outlined the priorities of the national space strategy as environmental resource management, health, safety and security, and innovation and economic growth. To this end, SANSA is spreading its business to include private and government consumers all over Africa. Furthermore, SANSA prides itself on EO data and imagery with the ability to monitor vegetation, crop production, crop disease, the use of land, urban development, water bodies (quality, growth, and decline), cloud cover, and many more. The SANSA space science has been assessed and is now the space weather supplier for the African continent, a qualification which was granted by the World Meteorological Organisation.

4.4 The fourth industrial revolution

The eighteenth century saw the commencement of the industrial revolution (García Ferrari 2017: S2630). The world is still changing fast in regard to the advancement of technology (Kluger 2020a: no page; Mdluli and Makhupe 2017: 4). The pace at which people are adapting to the changes is slow. Literature, however, points out that technology and the internet of things (IoT) are developing at a fast pace. Industrial production faces challenges such as environmental interruptions, pollution, global warming, high energy demands, reduction, and an ageing workforce. In addition, the challenges faced by industrial production require drastic change with solutions from the 4IR (Wang *et al*. 2016: 2).

To deal with the forthcoming 4IR and technological shortcomings, Dadios *et al*. (2018: 87) encouraged governments and organisations to:

a) Embrace international trade and investments.
b) Demolish anti-rivalry firewalls and invite rivals in information and communications technology.
c) Develop employees with good education, trainable, flexible and cost-effective labour regulatory framework.
d) Introduce education and training systems for public and private sectors.
e) Accumulate supplementary institutional, organisational and physical capital.
f) Create a collective social system to secure people.
g) Invest in data collection with an effort to monitor, test and evaluate.

When assuming his presidency, SA President Cyril Ramaphosa, advocated the 4IR as part of his national economic strategy. Skills shortage, and an inadequate supply of managers, researchers, and other employees to implement the 4IR, are the result of SA's ailing education system. The quality of our infrastructure is in an appalling condition, with poor governance and effects of state capture, poor records in the creation of policy and applications, dragging of feet regarding cyber security and information security (Sutherland 2019: 1). There is no determination of the direction surrounding its developments. Dadios *et al.* (2018: 48), Mdluli and Makhupe (2017: 4), and Schwab (2016: no page) recall the uniqueness of the 4IR judging by its speed, and breadth, depth, and impact.

According to Hattingh (2017: 20, 22), there are two core obstacles acknowledged by the World Economic Forum that impact SA. These obstacles are inadequate understanding of disturbing changes, and misalignment of strategies between the working class and innovative technology. A prediction was that starting from the year 2020 going forwards, there would be major changes to the work environment worldwide. It is time to prepare the current generation for a new future.

4.4.1 The origin of industrial revolutions

Sutherland (2019: 4) states that the first industrial revolution started in the United Kingdom (UK) between the years 1760-1850. The US then followed suit with the second industrial revolution in 1870-1970 proceeding with the third from 1960 to date. Today the US is the world leader in technology (Schäfer 2018: 7). These revolutions do not just come and disappear, they stay for a period of time. The first industrial revolution took 90 years, the second took 100 years and we are still in the era of the third which started in 1960. The 4IR is also called the "auto-cannibalism" period, in which industries fight to be the first inventors. The trend is now changing from an upward curve to a downward curve, due to the fast pace of technological development (Sutherland 2019: 4). African countries must adapt to the changes and become the originators of the forthcoming fifth industrial revolutionary era like the US and UK did in the previous industrial revolutionary eras.

As mentioned above, industrial revolutions have undergone stages – the first, second, third and presently the fourth stage. Sutherland (2019: 4), Balkaran (2018: 3), Schäfer (2018: 5-6), Dadios *et al*. (2018: 8-9), Nhede (2018: 204), Waidner and Kasper (2016: 1303) and Schwab (2016: no page) outline the stages as "Industrie 1.0", the period of steam engines, "Industrie 2.0" the period when electric power lines were assembled, "Industrie 3.0" Information technology and electronics, and presently we are on "Industrie 4.0", the smart technology and interconnections. The era of the second industrial revolution saw the construction of WI (water and sewage systems) in urban settlements (Sutherland 2019: 4).

Extensive recommendations have been made by the Presidential Commission on 4IR, which influence all parts of the economy. Some of the developments are the speedy processing of high demand spectrum licences by the Independent Communications Authority of South Africa; the decision to build a University of Science and Innovation in Ekurhuleni; the construction of nine new Technical and Vocational Education and Training (TVET) Colleges; a new 5G ready smart city is being developed at Lanseria; and the response time to issue water use licences has been reduced from 5 years to 90 days (South Africa, The Presidency 2020: 10/23-11/23, 14/23 and 18/23).

Technologies in the 4IR have introduced developments such as artificial intelligence, robotics, the IoT, automated vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing (Sutherland 2019: 5, Dadios *et al.* 2018: ii, Schwab 2016: no page). Dadios *et al.* (2018: 17) define IoT as the interconnection and relationship of electronic devices, structures, buildings, and electronic devices equipped with sensors or actuators enabling reception, transmission, and information processing. Research has shown that government officials worldwide are in a state of nervousness due to digitalisation (Nhede 2018: 201).

Focussing on the 4IR, societies must adapt quickly to the changes and accept that what they have learned must now be unlearned and they must prepare to relearn. The 4IR requires well educated, more trainable, and cost-effective employees for the labour market. The public and private sectors must start developing education and training systems (Dadios *et al.* 2018: ii). South Africa should start preparing the workforce for changes anticipated for the 4IR or risk being left behind (Balkaran 2018: 17). Sutherland (2019: 12) encourages developing countries to invest in training. Nhede (2018: 203) views training and development as the required strategic tools in the public sector to cope with the forthcoming dynamic years of the 4IR.

A literature study conducted by Piccarozzi, Aquilani and Gatti (2018: 9 & 19) of 68 systematically selected papers about 4IR revealed that 54 percent (37 papers) were theoretical, and 46 percent (31 papers) were empirical. They concluded that studies about 4IR originated from a theoretical perspective and recently have more realistic contributions. However, the topic of 4IR is new to management studies and can be helpful to managers anticipating pursuing innovations.

4.4.2 Africa and the fourth industrial revolution

According to Cilliers (2018: 1, 3, 4, 25), the African continent has a huge and rapidly growing population, anticipated to reach 2.1 billion people by 2040. Manufacturing in the continent experiences swift growth and is six times more profitable than agriculture. As part of the 4IR, manufacturing is anticipated to change, and prepare the continent for economic reforms to higher productivity and development. The continent is going backward regarding the average earning levels when compared to other areas of the world. As a result, the continent is characterised by a deficiency in infrastructure and education.

Sutherland (2019: 6) communicated a painful message that not much can be pointed out to have been invented in Africa in relation to the 4IR. This message encourages Africa to put all available efforts and resources into training and development. It must be incorporated into the vision of the African continent for the rest of the 4IR duration. This could see Africa as the biggest inventor in the 4IR until overlapping into the next industrial era.

The continent must reflect and relook at policies to overcome its own African barriers, and invest into the 4IR collectively. Natural resources (gas, oil, metallic ores), agricultural products (citrus fruits, flowers, palm oil) (Sutherland 2019: 14), that are extracted and produced locally must now be locally processed. Processing of these minerals and products requires local technology that suits the new world. Nhede (2018: 211) revealed that certain SSA countries are still resistant to digitalisation.

A concerted effort of all African countries is required without relying on one country that perceives itself as a superpower. Africa cannot only be a producer then ship the good internationally to be processed. African minerals and goods get processed internationally and shipped back with their prices doubled or even trebled. To manufacture locally in Africa requires the political field to be levelled first. Africa must minimise imports as much as possible to let the local economy to grow.

The future replacement of labour by automation requires governments to keep abreast by training workers to equip them for the recent technology (Shava and Hofisi 2017: 213).

4.5 Legislative framework governing space technology

Like any other industry, space technology has regulations and policies governing its operations. In SA these are: South African National Space Agency Act, 2008 [Act No. 36 of 2008], Space Affairs Amendment Act, 1995 [Act No. 64 of 1995], Space Affairs Act, 1993 [Act No. 84 of 1993].

4.5.1 South African National Space Agency Act of 2008

The South African National Space Agency Act of 2008 [Act No. 36, 2008] promotes the use of and cooperation in activities related to space, space science research, improvement in scientific engineering, and maintains a favourable atmosphere for technological development in the space industry within the national government policy framework. The Act established SANSA for the provision of objects and functions and described how SANSA should be managed (South Africa, Department of Science and Technology 2008: 2). The South African National Space Agency was launched on 09 December 2010 which saw the transformation of South Africa’s space landscape (South African National Space Agency 2011: 3).

4.5.2 Space Affairs Act of 1993

The Space Affairs Act of 1993 [Act No. 84, 1993] provides for a council to be established for the management and control of the Republic's space affairs. The Act empowers the council to determine objects and functions in prescribing the method of its management and control and for provision of matters connected thereto (South Africa, Department of Trade and Industry 1993: 2).

4.5.3 Space Affairs Amendment Act of 1995

The Space Affairs Amendment Act of 1995 [Act No. 64, 1995] amended the Space Affairs Act of 1993 [Act No. 84, 1993] and then appointed a vice-chairperson for the South African Council for Space Affairs. It also provided further delegation of certain powers, duties, deletion of obsolete provisions, and provisions for matters in relation thereto (South Africa, Department of Trade and Industry 1995: 2).

4.6 African space technology players

African countries have made remarkable progress in space programmes. There are 41 satellites that have been launched into orbit by African countries, three of which have multilateral ownership. The African space industry 2019 report outlined the exponential growth of African countries in this regard from 1998-2019. The African continent's space industry collected more than $7 billion annual income, with a growth projection of 7.3 percent, expected to exceed $10 billion in 2024 (Space in Africa 2019b). Egypt hosts the African Space Agency with approval granted by African heads of states during the African Union's last summit in January 2019 (South African National Space Agency 2020a: 14), a positive move supported by the South African National Space Agency (2020c).

There are 19 African countries that have national space programme with an escalating number of space technology businesses interested in offering services to the continent. The initiator of Space in Africa, Temidayo Oniosun, commended the African growth in space technology. Oniosun stated that the space industry is presently reawakening the African continent with acceleration in governments' investments. Africa can solve serious agricultural, security, and telecommunication problems and problems in various other fields with the assistance of space technology. For example, satellites have assisted Mali herders to travel to places to locate water for cattle. Satellite assistance with Africa's TV programmes and a satellite internet connection to rural classrooms was arranged in Angola and Rwanda (Space in Africa 2019b).

The Nigerian capital, Abuja, is forecast as being the first African city to have an astronaut set foot into space by 2030 (Tella 2018: 48; Xiaokun 2016: para. 10 line 2). The Nigerian government saw the potential as they had already made the breakthrough of owning and operating the first sub-Saharan telecommunication satellite. China launched Nigeria's first telecommunication satellite (Xiaokun 2016: para. 9 lines 1-2). Launches of African satellites are executed by non-African countries or by foreign space agencies. The African continent does not have the facilities to launch the satellites into orbit that are presently operating (Klinger 2020: 9).

Ngcofe and Gottschalk (2013: 1, 3-4) state that the African continent is perceived as a dependable data collector and user of EO satellites. South Africa, Egypt, Algeria, and Nigeria lead other countries in the consumption of EO data. South Africa expanded its space-related involvement after 1994 at the start of the democratic era. Ngcofe and Gottschalk (2013) further commented about the African continent's passive consumption of EO satellite data. They also proposed that Africa should have their own EO satellites.

In terms of the development of space science and technology, Ngcofe and Gottschalk (2013: 3) mentioned Africa's two institutions in Morocco and Nigeria. Fifteen member countries form the Nigerian-based institution, which uses English as its medium of instruction. The member countries are Cameroon, the Democratic Republic of Congo, Ethiopia, Gambia, Kenya, Liberia, Malawi, Nigeria, Sierra Leone, South Africa, Sudan, Uganda, Tanzania, Zambia, and Zimbabwe. The French-speaking nations' institute is in Morocco and serves thirteen member countries. These countries are Algeria, Cameroon, Cape Verde, Central African Republic, Cote d'Ivoire, Democratic Republic of Congo, Gabon, Morocco, Mauritania, Niger, Senegal, Togo, and Tunisia.

Besides these two institutions, Africa participates in the international programme of the United Nations space-based Information for Disaster Management and Emergency Response. This organisation has regional offices in Algeria, Nigeria, and SA. Kenya houses the Regional Centre for Mapping of Resources and has the support of 14 contributing African countries. The Pan African University is another institution that will enhance Africa's space initiatives, particularly in the field of EO. The institution will have five centres scattered around the African continent with SA as the home of space sciences (Ngcofe and Gottschalk 2013: 3).

The network of African academic institutions, namely the Pan African University, has existed since 2010 after a resolution was taken by the African Union Summit of Heads of State and Government. Their common goal was to develop an institution of science, technology, innovation, social sciences and governance. As the African central base of higher education and research, the institution will furthermore strive for success in research internationally with technical, economic, and social advancement for Africa (Tabeti and Somia 2019: 18).

4.6.1 The four main types of orbits

Low Earth orbit is the closest to the Earth's surface. The transmitters of satellites in low Earth orbit do not need to be as powerful in communication as others. Such satellites can orbit the Earth at an estimated average period of 90 to 100 minutes, with a good record of intelligence, surveillance and reconnaissance, environmental observation, and small communication satellites. Medium Earth orbit has no prescribed altitude – they are positioned between the low Earth orbit and geosynchronous Earth orbit. Each revolution takes less than 12 hours. An example of a constellation of satellites that is in medium Earth orbit is the GPS constellation of satellites (Space Operations 2018: I-10).

Satellites in highly elliptical orbit follow a long elliptical path, with the satellites being far away from the Earth's surface (satellites apogee) on the one side and closer on the other (perigee). Their orbit takes between 10 to 12 hours (depending on the inclination) in the northern and southern hemispheres. Geosynchronous Earth orbit is synchronised with the rotation of the Earth and rotates at a uniform velocity as the Earth rotates (Space Operations 2018: I-10), thus enabling a satellite to stay above a constant spot on the earth. The diverse types of orbits, their altitudes and their uses are shown in Table 4.1.

Table 4.1: The diverse types of orbits, altitude, and functions

Orbit	Altitude	Use
Low Earth orbit	Up to 1609 km above the Earth's surface	▪ Communications. ▪ Intelligence, surveillance, and reconnaissance. ▪ Human spaceflight ▪ Weather collection
Medium Earth orbit	Approximately 1609 km to 35 398 km above the Earth's surface	▪ Communications. ▪ Position, navigation and timing
Highly elliptical orbit	Long ellipse altitudes 965.4 km at perigee (nearest to earth) and 40225 km at apogee (farthest from Earth)	▪ Communications. ▪ Intelligence, surveillance, and reconnaissance. ▪ Missile warning ▪ Scientific
Geosynchronous Earth orbit	Approximately 37007 km above the Earth's surface	▪ Communications ▪ Intelligence, surveillance, and reconnaissance ▪ Missile warning ▪ Weather collection

Source: Space Operations (2018: I-11)

Satellites are situated far away in space and are orbiting the Earth every minute of every day. The kind of vandalism to infrastructure projects that happens on Earth is not possible with satellites in space; however, military actions against satellites in space destroy them. According to Janosek (2020), the actions of China illustrated that space can become a combat zone. A 2007 China successfully piloted an anti-satellite experiment. The country used its kinetic kill vehicle to shoot down its weather satellite, to demonstrate that space warfare is possible.

The US has the following number of satellites in space 353 intelligence, surveillance, reconnaissance, and remote sensing, 391 communications, 31 navigation, and 94 science and technology development. The following catastrophic effects would be experienced if satellites were to be attacked: shut down of television networks, internet connections, automatic teller machines, financial institutions, air traffic control, road and rail traffic networks, GPS signals, and weather stations (Janosek 2020).

4.6.2 Africa launches satellites

According to Space in Africa (2019b), eight Africa countries launched 32 national satellites into orbit between 1998 and 2019 (Algeria, Angola, Egypt, Ghana, Kenya, Morocco, Nigeria, and South Africa). Three additional satellite projects used for regional operations RASCOM-QAF1, RASCOM-QAF1R, and New Dawn received joint funding from African organisations. The 32 satellites function in various operations such as earth surveillance (14), communications (10), technology display (8), scientific research, educational development, and military operations. The African space technology industry employs 8 500 functionaries, 2 000 of these being from commercial companies and the remainder from governments. There are 14 satellites built by Africa's engineers in and outside of Africa. Airbus Defense and Space (France), China Great Wall Industry Corporation, RSC Energia (Russia), Surrey Satellite Technology Ltd (UK), and Thales Alenia Space (France) are busy sealing business deals in Africa (Space in Africa 2019b).

Eleven African countries have so far managed to launch 36 satellites into orbit. After these successful launches, countries were keen to construct another five satellites. Woldai (2020: 107-108) mentions the African countries involved with the construction of the five satellites which were planned to be launched into orbit by 2021 to replace the failed ones. According to Iyanda (2021) Nigeria is the one country that may receive a successful late launch of 2021, and other Africa countries may see successful launches in 2022. As Africa's space initiatives continue to grow, Croshier (2022: 04) finds that Africa plans to subcontract the launch of 114 additional satellites in orbit by 2025.

Satellites have demonstrated their ability to assist in solving the challenges faced by the African continent (Woldai 2020: 107-109). These challenges have been experienced in the following activities: vegetation, zoning of land, water detection and quality, and town planning or land size increase (Larsen and Davis 2019).

Table 4.2 outlines the country of ownership, names of satellites, and the year in which each satellite was launched. A summary of the names of countries and the number of satellites is Algeria (6), Angola (1), Ghana (1), Egypt (9), Ethiopia (1), Kenya (1), Morocco (3), Multilateral (3), Nigeria (6), Rwanda (1), South Africa (8) and Sudan (1) (Space in Africa 2019a). As can be seen in Table 4.2, some satellites have multilateral ownership, but their launch dates were not mentioned.

Table 4.2: African countries' satellites (constructed, purchased, or rented)

Satellite	Country or organisation	Year launched
ALSAT1	ALGERIA	2002
ALSAT2A	ALGERIA	2010
ALSAT1B	ALGERIA	2016
ALSAT2B	ALGERIA	2016
ALSAT1	ALGERIA	2016
ALCOMSAT-1	ALGERIA	2017
AngoSat-1	ANGOLA	2017
GhanaSat-1	GHANA	2017
NILESAT 101	EGYPT	1998
NILESAT 102	EGYPT	2000
EGYPTSAT1	EGYPT	2007
NILESAT201	EGYPT	2010
EGYPTSAT2	EGYPT	2014
EGYPTSAT-A	EGYPT	2019
NARSSCube-2	EGYPT	2019
NARSSCube-1	EGYPT	2019
TIBA-1	EGYPT	2019
ETRSS-1	ETHIOPIA	2019
1KUNS-PF	KENYA	2018
Maroc-TUBSAT	MOROCCO	2001
MOHAMMED V1-A	MOROCCO	2017
MOHAMMED V1-B	MOROCCO	2018
RascomStar-QAF-1	MULTILATERAL	
RascomStar-QAF-1R	MULTILATERAL	
NewDawn	MULTILATERAL	
Nigeriasat-1	NIGERIA	2003
NIGCOMSAT1	NIGERIA	2007
NigeriaSat-2	NIGERIA	2011
NigeriaSat-X	NIGERIA	2011
NIGCOMSAT1R	NIGERIA	2011
NigeriaEduSAT-1	NIGERIA	2017
RwaSat-1	RWANDA	2019
SUNSAT	SOUTH AFRICA	1999
ZACUBE	SOUTH AFRICA	2003
SUMBADILA	SOUTH AFRICA	2009
KONDORE	SOUTH AFRICA	2014
nSight1	SOUTH AFRICA	2017
ZA-AEROSAT	SOUTH AFRICA	2017
ZaCube-2	SOUTH AFRICA	2018
XinaBox ThinSAT	SOUTH AFRICA	2019
SRSS-1	SUDAN	2019

Source: Space in Africa (2019a)

4.7 Practical role of space technology

Space technology is currently used for various applications in SA such as EO, remote sensing, aviation industry, research and development, weather forecasting and many more. Various SA universities are part of the space science programme which forms part of their curricula. The South African National Space Agency (SANSA) has started recruiting students in maths and science to join their initiatives in space science.

Marshall (2017) maintains that satellite data assists consumers to fight climate change, and they also link the world through the internet and various communication channels. As many as 12 of the United Nation's 17 Sustainable Development Goals can be accessed through the assistance of satellite networks. Their imagery can help to update farmers about the growth of crops, the need for water, the need for adding fertiliser, and the time to harvest. Satellites can help to determine the surface area of the land to cultivate. They provide an ability to monitor water levels in reservoirs, with detectors providing ongoing information about rising and declining levels for customers.

The various practical roles that can be played by space technology in SA to manage WI are communication, health, safety, security, advanced water filtration and purification systems, detection of water levels in reservoirs, monitoring earth's natural resources such as groundwater, water leak detection, underground water pipe detection, and monitoring water quality. The EPA (2014: 6) states that innovative technologies like water quality sensors, remote sensing, and satellite imagery can create the most affordable data. The sensors and the enhanced telemetries make the water quality and quantity data accessible through enhanced information technology systems.

A global company, Utilis, has conducted trials with various water utilities in connection with the efficiency of their satellite technology. The technology uses satellite imagery and innovative algorithms to track spectral traces of potable water. The satellite technology detects the water in the ground before the leaks are apparent. The detected information is transmitted in the form of GIS reports with details of the street locations. A certain water utility confirmed the efficiency of the technology, which successfully detected the leaks for underground water pipes to within a radius of 100 metres. The current satellite technology spotted 44 leaks in Halifax and Keighley in the United Kingdom (UK) and saved them a daily water loss of 333 000 litres (Aquatech 2018).

Suresh, Muthukumar and Chandapillai (2017: 1) demonstrated that android smartphones can visualise the water flow inside pipes, and transfer this information to the water utility's portal. Ray and Goswami (2020: 309) further applied a methodology that monitors the rate of flow in various diameters of pipes. The acquired flow data is then transmitted to a cloud platform, where the different activities of the water flow and the data is stored in the municipal database. The records then reveal to the municipality any abusive or illegal use. The system monitors water use, and alerts can be sent to customers regarding wasteful use of water. The system does not need to be equipped with a server. Any action, policy, or bye-law adjustments that may have to be revisited will be supported by this smart technology.

Consumers tend to misuse water if they realise that it is unmetered. Ray and Goswami (2020: 308) noted a trend in the change of rural and urban customers' attitudes towards the use of water if they were aware of the presence of intelligent metering. It is therefore vital for consumers to know that the sensors in the intelligent metering perform their function of real-time monitoring of water leaks and wastage. Moreno (2020) and the World Water Assessment Programme / UN-Water (2018: v) report that over two billion people globally do not have access to clean water. Furthermore, over four billion people are unable to access safe sanitation. It is anticipated that by 2050 water consumption will increase by one-third because of the worldwide population growth (World Water Assessment Programme / UN-Water 2018: v). Despite this situation, and of the degrading water resources, there are still consumers who use water in abundance for unnecessary purposes.

4.7.1 The benefits of space technology for water treatment

Radonic (2020) observes that there are many technological innovations associated with the treatment of water and the operations of water utilities. The NASA innovations have contributed to breakthroughs in the development of advanced filtration water bottles. NASA developed technologies for space exploration that are presently commercially used in our daily lives on Earth. NASA started to invent water purification systems as early as 1960 to purify and recycle the water for the Gemini program.

Radonic (2020) recalls the 1968 NASA preparations for lunar missions that brought about the development of a water purifier the same size as a cigarette pack. The device was designed for low power consumption and monitoring, after the spinoff success of the Apollo-era technology. The device did not have chlorine but instead emitted anti-bacterial silver ions into the water supply system. Later, as the system developed, NASA approved a private organisation Carefree Clearwater Ltd. from Georgia, to produce an improved type of electrolytic silver ion cell for commercial and industrial applications.

According to Radonic (2020), the system is designed to release ions into the water as a small electrical current travels through copper and silver electrodes. The ions react swiftly by killing bacteria and algal formation in the water, disintegrating the enzymes, and as a result, straining off the ions and dead organisms. The process has been proven by independent studies to be active against biological agents such as *E. coli*, *Pseudomonas, Staphylococcus, Streptococcus* and *Salmonella*. The process is widely used for swimming pools, cooling towers, hot water spas, decorative fountains, and ponds. Less chlorine in the purification system yields positive results such as reduced eye irritation, a reduced amount of dry skin and less exposure to cancer.

The new developments in space science may help the African continent as well as the global community in fighting water pollution. According to World Water Assessment Programme-UN Water (2018: 3) Africa, Asia and Latin America started to experience water pollution in their rivers in 1990. This pollution has become a dilemma that challenges the global community.

NASA’s development of water purification technology continues to benefit the Earth. The 1970 water purification system that used iodine as a replacement for chlorine to destroy the bacteria bears testimony to NASA’s successes. To this day, the success culminated in the space shuttle orbiter using water that passes through a bed of iodinated resin with a microbial check valve. The performance of ongoing experiments resulted in regenerable biocide delivery unit after they discovered that the microbial check valve cartridges had a limited lifespan that needed intervallic replacements. The regenerable biocide delivery unit can create the cartridges without isolating them from the unit. The innovations of space technology in water purification assisted the Earth with persistent needs some of which are hazards from chlorination (Radonic 2020).

Space science and technology can assist in research and development of services, as a monitoring tool, as an evaluation of serious land resources and for better decision making. There are three key priorities identified by the government in space exploration, namely, environmental and resource management, health, safety and security, and innovative and economic development (South Africa, Department of Science and Technology 2018: 4).

South Africa has been purchasing and importing space technology and has started developing its systems to support local industry requirements. A good example of this is the CPUT Satellite Programme. This programme is aligned with the National Space Strategy and receives funds from the DST and the National Research Foundation. Presently, the satellite programme has graduated 60 students in the master's programme. The French South African Institute of Technology and the African Space Innovation Centre jointly host the programme (French South African Institute of Technology 2019).

4.7.2 Array of benefits from space technology

Satellite transmissions have enabled rural schools, colleges, and universities in India to gain access to maths studies through television with the help of EDUSAT's broadcasts (Gottschalk 2017: no page; Pallai 2013: 11-13). EDUSAT covers a vast geographical area and broadcasts in various languages suitable to the various cultures situated in mostly unreachable terrains. The system also functions as a support system for the teaching fraternity (Nair, Shaijumon and Ayyangar 2015: 29; Verma 2021: 181).

E-learning benefits several institutions and has become a fundamental part of face-to-face learning. The institutions which have already developed in-house electronic management systems have made good progress as a result of e-learning initiatives (Khan and Jahan 2018: 4-5). Schools and institutions of higher learning in India use e-learning as a fundamental tool in their education programmes (Mathivanan *et al*. 2021: 3). However, institutions should first assess institutional readiness before making use of the e-learning facilities Kaur and Gothwal (2021: 2).

In 1961 NASA constructed the Hartebeesthoek Radio Astronomy Observatory in Gauteng province, approximately 50 km on the western side of Johannesburg and north of Krugersdorp (Gottschalk 2017: no page; Mbwia 2018: 17). The station was renamed the South African Radio Astronomy Observatory and was declared a national facility in terms of the National Research Foundation Act, No 1988 [Act No.23 of 1998] in 2017 (South Africa, Department of Science and Technology 2017: 171; Mbwia 2018: 17).

The African continent benefits from space technology through real-time EO that is used to observe the progress in the rate of production of natural resources. On the academic side of things, Africa has more than 90 universities, colleges, and regional training centres. These institutions are in 28 countries with businesses in the remote sensing (RS) and geo-Information sciences which operate under 53 national space agencies. The African continent currently has ten receiving and tracking stations in six countries and 17 scientific national associations specialising in geo-information technologies (Woldai 2020:107). This initiative is an outstanding contribution of the African continent to space initiatives.

According to Campbell (2019: 12), the launch of a non-profit making company, ZASpace Inc, in Pretoria, aimed to encourage the growth of the local space industry particularly in the geospatial sector for SA and Africa. The organisation’s focus was skills development and innovative funding for small, medium, and micro-enterprises. During the launch of ZASpace, the chief executive officer, Kamal Ramsingh, announced that the world’s geospatial market was valued at $193 billion in 2013, had risen to $299 billion in 2017, and was anticipated to reach $500 billion by the year 2020. The CEO mentioned the drivers of growth for the geospatial sector worldwide as being “travel and hospitality, disaster management, mapping agencies, banking and financial services and insurance, defence and security, mining and energy, retail and logistics, e-government, utilities, infrastructure and smart cities.” The geospatial information sector has demonstrated the business potential of global satellite navigation systems, geographic information systems and spatial analysis, EO, and three-dimensional scanning.

Campbell (2019: 12, 16) further noted that the US, UK, and the whole of Europe are the leading geospatial markets. However, Africa had the fastest growth with an annual compound economic growth of 16.8 percent, and spatial analysis accounted for 30 percent of the African market. The continental growth comparison between the years 2018 to 2020 for Africa’s geospatial market was 21 percent, Europe’s 11 percent, and the US’s 10 percent. The CEO of ZASpace noted the skills shortage in SA, whereas in other African countries there were no relevant skills.

The SANSA regarded ZASpace as a key role player in the SA space industry. ZASpace will be equal to the geospatial readiness challenge and will strive for improvement. Regarding global geospatial preparedness, SA was ranked 31st. The CEO of SANSA, Dr Val Munsami, announced that the agency was looking at Africa for its growth and that the focus of the National Space Policy was to improve the national space industry. The creation of SANSA through combining previous organisations, the shortage of business models, unpredictable business models, and fragmented business models split amongst the divisions – each with dissimilar operational needs – were some of the drawbacks experienced by SANSA (Campbell, 2019: 12 and 16).

4.7.3 Enhancing innovation in the CoT

The Department of Science and Technology (2018b: 5) noted that there were three programmes that have been developed to make space initiatives a success. These programmes are thematic, functional and support. Thematic programmes are: earth surveillance, navigation, communication, space science and discoveries. Functional programmes are: enabling technologies, mission improvement, space mission manoeuvre, and space mission application. Support programmes are: human capital advancement, infrastructure, and partnering with international communities.

Space technology has been used to solve social challenges in the areas of management, environment, usage of natural assets, growing movement of individuals and products, increase in security threats and the move in the direction of the knowledge economy. Space exploration is going to help solve many present and future challenges faced by SA. The costs associated with space activities are remarkably high, but the returns associated therewith are worthwhile. Job creation, technological advancement, scientific familiarity, and space derivatives are some of the advantages associated with space technology (South Africa, Department of Science and Technology 2018: 5-6). It is for that reason that this study investigated space technology as a tool to help manage WI.

Ojoyi (2016: no page) maintains that many African countries are limited as far as space initiatives are concerned due to inadequate funding. They depend on external donations and for that reason knowledge, infrastructure, tools, and education are unachievable. This technology is necessary for location, imagery, and security for infrastructure under threat of vandalism and other aspects in the CoT and African continent.

Innovation is one of the gaps identified for various municipalities regarding WI. The CoT has been identified as one of the cities that should consider innovation for WI management (Mnguni 2019: 937). It is for that reason therefore that the researcher is pursuing space technology innovation in WI to help the city and the African continent. This technology can be an asset for the CoT considering the theft and vandalism of WI. EO will enable satellites to locate, view and monitor these assets from space at any given distance and time to prevent theft and vandalism. Ojogba *et al.* (2019: 25) noted that satellites as enabling infrastructures also assist in speeding growth leading to economic progress.

The African Union (2017: 5) stated that the African continent occupies 20 percent of the total area of the Earth's surface. This surface area exceeds the USA, China, Europe, and India combined. The expenditure of these four countries totalled over $50 billion on space activities, as compared to Africa's less than $100 million in 2013, 0.2

percent of the 2013 global space budget. South Africa was ranked 23 and was the only African country in the top 30 countries of the world in the 2013 space sector with a space budget of $41 million. Their performance in the scientific production of satellite technology placed them in position 30 translating to 0.87 percent of global publications in this field. These evaluations show underperformance in the African continent's space sector, which restrains the continent from this fast-growing business that can solve their challenges.

One of the major challenges that countries are faced with is the security of the WI, protecting it against destruction by members of the community. Space technology could help to close this gap. Monitoring the activities of infrastructure requires advanced monitoring which is possible with the help of space technology. The following are phases of remote sensing and geospatial technologies as outlined by Kurnaz and Rustamov (2008: 150), namely: detection, preparedness, prevention, protection, and response. Alsdorf, Rodríguez and Lettenmaier (2007: 15) explain that many satellites are used for global observation of Earth from space.

The use of mechanical means such as tractor-loader-backhoe, and excavators, are costly and result in broken pipes and electrical cables. Chang (2015:1-2) proposes that space technology is, therefore, necessary to save time and locate civil infrastructures such as buildings, railways, roads, bridges, dikes, dams, quays, and pipelines. Synthetic aperture radar interferometry is a "precise and efficient technique to monitor deformations on Earth with millimetre precision." This technology therefore could help the CoT with monitoring ageing pipe deformations, and reservoir locations. The use of this technology however requires an advanced degree of knowledge for its application.

4.8 Linking WI to space technology

Regarding WI, detection of underground water sources is one of the advantages offered by space technology. The Israelis have launched freshwater leak detection and prevention technology from outer space through their national WI. They have adopted technology previously used for the detection of water on the planets Mars and Venus.

The technology was invented after an estimated annual worldwide freshwater loss of 32 billion cubic metres in developing countries was reported by the World Bank. Synthetic-aperture radar (SAR) has been adopted by universities and research institutions for the detection of water underground and on other planets. The chief executive officer of Utilis confirmed the technology's usefulness for underground treated water detection in urban settlements (Maccioni 2019).

Synthetic-aperture radar technology is necessary to detect aspects of the WI, especially pipes buried below the surface of the earth. Evagorou *et al*. (2019: 397) highlight that space technology can achieve optical satellite images for bathymetric data to a depth of 30 metres below sea level. Such technology can be used to detect impurities and any other sediments inside dams and reservoirs. Azambuja (2017) notes space technology saves community lives by minimising risks with innovative filtration and purification systems that were developed for the international space station. The partnership of aid organisations and NASA technology demonstrated the effectiveness of space research in response to various global difficulties. This resulted in global collaborative efforts between water security corporations and other organisations using systems with NASA water-processing technology. In the same vein, Giardino *et al*. (2010: 3886) confirm the swiftness of RS and its ability to reproduce spatial and temporal observations of surface water which are impossible to achieve from *in situ* measurements or inspections.

Another benefit of space technology is the remote image sensing of water quality from space using the Hyperspectral Imager for the Coastal Ocean. This technology was invented by the US Naval Research Laboratory for use in coastal ocean water quality assessment. The quality parameters for detection are water clarity, phytoplankton concentrations, light absorption, and the distribution of cyanobacteria. The data generated was used by EPA researchers to develop a smartphone application for the detection of harmful concentrations of pollutants (Azambuja 2017). Greenblatt and Anzaldua (2019) explain that such methodologies enable EO functions like the support of agricultural production; fisheries management, freshwater management; management of forests; and monitoring of detrimental activities.

Among the benefits of space technology applicable to WI is water quality detection in lakes (Malahlela *et al*. 2018: 1), in dams (Giardino *et al*. 2010: 3886), pipeline location

(Chang 2015: 1-2), imagery and remote sensing (Ojoyi 2016: no page), and security and management of natural resources (South Africa, Department of Science and Technology 2018: 5). Malahlela *et al*. (2018:1) cited another example of the remote sensing of water quality assessment and chlorophyll-a (chl-a) with the application of Landsat 8 Operational Land Imager data. The technology has evaluated the red to near-infrared (NIR-red) bands in the Vaal Dam of SA to categorise chl-a concentration. Sekhula (2013: 139) remarked that satellites are not dependent on political decisions and the information they map is unrestricted by borders.

Countries such as Australia have started to implement a ground-based monitoring system working in conjunction with EO satellites. They monitor their river systems and other waterways extensively through real-time updates on waterways. They strive to achieve better water management in their country with the help of research organisations. The space technology alerts the authorities about any accumulation of impurities such as algal blooms that may pollute the drinking water (Xinhua 2020). This methodology is one which the CoT can adopt. Additionally, this could see the creation of job opportunities and the improvement of water quality in the city.

4.8.1 How space science technology can assist in resolving challenges

Space technology can help in addressing some of the challenges municipalities face. This technology has previously been used locally and abroad to address such challenges. NASA (2019: no page) notes that advanced water filtration and purification systems developed for the International Space Station (ISS) are being used in SSA for managing water resources. Another example of the use of such space technology is the space-based technology that assists the global communities with aid and disaster relief programmes. A non-profit organisation, Concern for Kids, sourced funds from NASA to help Iraq, Malaysia and Indonesia with aid and disaster relief programmes with technology adopted from the space station (NASA 2019: no page).

NASA (2019: no page) cited another example of help provided by space technology, namely for the community of Kendala, a Kurdish village in Iraq, who drank dirty, fabric sifted water from the same source as their livestock. They were aided by technology developed by NASA engineers for the provision of clean water. In 2016 satellite images viewed from space detected a 60 percent decrease in the surface area of the Al Massira dam, the second-largest in Morocco. Changes in dam levels in other parts of the world such as Indira Sagar Dam in India, Mosul Dam in Iraq, and Buendia Dam in Spain, have been identified with the help of space technology (Iceland, Luo and Donchyts 2018: no page). This technology could be applied in the CoT for monitoring water levels in reservoirs without having to travel to the reservoirs for physical inspections.

An estimation that more than two billion people globally have no access to safe drinkable water is alarming. Even in developed countries, people are suspicious of the safety of tap water. In the US for example, more than half of the households do not approve of the quality of their water supply, as compared to the 55 percent of Europeans who do approve of the quality of the water from their taps (Moreno 2020).

The challenge being faced by CoT regarding water purification is at the RWWTP because this facility cannot manage the sewage volumes for purification so it is overworked. The facility was visited by Deputy Minister of Water and Sanitation, David Mahlobo, the SAHRC, Tshwane mayor Stevens Mokgalapa, and the mayoral committee. The health of people due to unsafe water supply and the purchase of water were concerns raised by Hammanskraal residents. The team acknowledged that the plant was dilapidated and needed to be fixed. The city manager stated that they were hard at work with other government sectors and the Human Rights Commission to address the problem. The cost of fixing the plant was estimated to be R2 billion however it needed a series of reports first from stakeholders (Mahlokwane 2019). Similar assistance offered by NASA engineers to the Kurdish village of Kendala could be sourced for the Hammanskraal community at CoT.

The developments of space technology at the ISS continues to benefit the Earth. Examples include harvesting water from humidity and the collection of urea which is then sieved and recycled (Moreno 2020). This technology could help in the drought stricken areas to source safe and drinkable water.

4.8.2 Assistance provided to African communities by the US National Aeronautics and Space Administration

Water resources management presents many developmental challenges notably in areas with vast *in situ* monitoring networks which satellite technology could help to overcome Sheffield *et al*. (2018: 9724)

There are hundreds of science experiments that are being performed aboard the SS on a daily basis (Kluger 2020b). These experiments continue to help countries on Earth. Kenya enjoys the assistance of NASA's scientists together with the country's counterparts as they perform satellite manoeuvres to assess suitable agricultural necessities. This is done with the knowledge that the country's 75 percent of the country's means of support and income is obtained from farming. The engagement of NASA's scientists helps the country to prevent the future effects that may arise from drought, locusts, and climate change. Previously agents physically travelled from place to place to search for information about the performance of crops and the availability of financial assistance. The officials realised that it was laborious, and time-wasting and they resorted to the assistance of NASA's EO (Space in Africa 2021).

Data from NASA's satellites have gained relevance for the managers of a Kenya insurance program due to the readily available information available to assist farmers. Information about rainfall, soil moisture, and land use is captured as part of satellite data for the agricultural monitoring programmes. The information is captured with permission granted by the USAID-NASA SERVIR programme to the harvest team and the Regional Centre for Mapping of Resources for Development. Crop condition assessment is performed remotely. Images from the satellites are analysed by computers which point out the exact location where crops grow and the condition of land for the growth of crops. In 2019 Kenya was assisted by the services of Europe's Sentinel-2 satellite data to locate where crops grew (Space in Africa 2021).

The data obtained from satellites assisted the Kenyan Ministry of Agriculture to plan their schedules and finances better. The scientists acquired data from MODIS instruments of NASA's Terra and Aqua satellites at 8 to 16-day intervals for a better assessment of the colour of ground cover. This has profoundly improved efficiency and achieved a saving of 70 percent in costs and time. The number of farmers increased from 30 000 in 2015 to 425 000 farmers in 2019. The new developments by the researchers provided national maps to illustrate places with favourable and unfavourable conditions for crops (Space in Africa 2021).

4.8.3 Remote sensing

Remote sensing is defined as the collection of data using an instrument or sensors which are attached to a satellite, an aircraft, or an unmanned aerial or unmanned ground vehicle that involves an object or a phenomenon that it is not in direct contact with (Weiss, Jacob and Duveiller 2020: 3/ 39). The capacity of space technology in remote sensing to work as a data collector to locate existing buildings and their date of construction (Babayeva and Rustamov 2014: 187) can be applied to WI. The high volume of NRW for various cities in Africa, including the CoT, requires space technology to detect water leaks and other forms of water losses. In the modern world, machines do the work which was previously done by humans.

A study by Adeyemi (2015: 5-7, 16) revealed that despite the deficiency of spatial data, the meteorological stations' *in situ* records have "high temporal resolution" and are covered for longer period of time. Nevertheless, the *in situ* methodology of taking measurements has been shown to be trustworthy, but is expensive and consumes much time. Adeyemi further related the different studies conducted on land surface temperatures (LST) using thermal remote sensing in developed countries. These remote sensing studies excluded the developing nations such as SA and other African countries despite the accessibility of satellite imagery in these nations. The study further implied that the CoT has been using data obtained from *in situ* dimensions to obtain data about LST (Adeyemi 2015: 6-8).

Space technology's RS has been helpful to measure LST for the CoT. Town planners and other role players for the city need environmental assessment information to help plan for the future of a smart city. Remote sensing has been of assistance to track the lower temperatures in the outskirts of CoT compared to the city centre. The observation noted that LST was intensified by increased air pollution and impervious surfaces. As a result, RS showed that LST is higher in non-cropped areas and lower in cropped areas of the CoT (Magidi and Ahmed 2020: 379, 393).

4.8.4 Explanation of remote sensing

Dindar, Kaewunruen and Osman (2017: 2) highlight the use of RS for monitoring a railway system from space using satellites. This technology from space records, observes, and identifies objects from extremely far away without having direct contact. The sun strikes the object on earth and the satellite's optical sensors detect and receive solar reflection, with this information being transmitted to the receiver. Photographs are then taken by camera from space and sent to the earth using satellite dishes. Many remote sensing images can be generated from this system. This technology is a perfect fit for the location of installed WI to monitor against vandalism, theft, and much more. Magidi and Ahmed (2019: 345) support the use of high-resolution satellite remotely sensed data for better identification of land patterns and features.

There are various fields of research as far as space technology is concerned (NASA 2015: 1). The use of space technology for architectural applications and town planning developments is a good demonstration that the system can manage infrastructure projects. Besides, satellites can enable information to be drawn regarding the behaviour of the oceans, the atmosphere, and other features on the ground. Some of the information drawn from GPS can locate places where pipelines intersect roads, railway lines, and rivers. However, the information generated from satellites is not easy to interpret (Babayeva and Rustamov 2014: 187-188). The ability to measure temperature and the use of water as well as how vegetation reacts to stress can be monitored from NASA's ECOsystem Spaceborne Thermal Radiometer Experiment aboard the ISS. The sensor is also capable of obtaining surface temperature from remarkably high altitudes (Sheffield *et al*. 2018: 9735).

Spatial resolution plays a fundamental role in the mapping of data by satellites. Satelites are situated at a remarkably high altitude and are expected to take pictures that are definable to the naked eye. DiBiase and Dutton (2020) refer to spatial resolution as the measure of the texture of a raster grid. Redecker *et al*. (2020: 4, 69) remarked that a raster is displayed by a collection of blocks in the form of squares or rectangles. Lloyd, Sorichetta and Tatem (2017: 3) defined the identification mark of a raster image as the grating of pixels with distinct sizes running in both horizontal and vertical directions. GIS applications make use of raster images to demonstrate the digital appearance of elevated structures and landscapes above the Earth. Belward and Skøien (2015: 118) emphasised that a "high resolution" in this current period would not be the same as it would be in the next 40 years.

As the developments in technology have advanced, RS has been improved with the introduction of high-resolution pictures (< 5.0m) and innovative picture processing methods (Adeyemi 2015: 17). When an image is taken the most important aspect is the distinctiveness of the features that are on that image. Weng (2012: 35) defined spatial resolution as the phenomenon or the degree to which details on an image are recognisable, and the possibility of detecting the smallest feature from an image. Belward and Skøien (2015: 118) suggested five classes of resolution:

- 0.5 m to 4.9 m very high resolution;
- 5.0 m to 9.9 m high resolution;
- 10.0 m to 39.9 m medium resolution;
- 40.0 m to 249.9 m moderate resolution.
- 250 m to 1.5 km low resolution.

4.8.5 Challenges facing remote sensing

One of the most challenging situations that satellites in orbit are faced with is orbital debris. Firstly, it is vital to define what orbital debris is. Space explorers find themselves in a challenging situation of having to deal with and work around space remains. According to NASA (n.d.), orbital debris is defined as any inactive manufactured object that is orbiting the Earth and no longer has a function in space. Orbital debris is formed because of:

- Dilapidated spacecraft and abandoned launch vehicles.
- Transporters of multiple payloads.
- The wreckage caused by the separation of international spacecraft from the

launch vehicle or during mission operations.

- Debris that resulted from spacecraft or upper stage detonations or crashes.
- Spillages from rocket motors.
- Small pieces of paint.

Aglietti (2020:1) and the European Space Agency (2020) estimated that by early February 2020 over 34 000 pieces of debris with a size greater than 10 cm would be present in orbit, and a total of 900 000 particles ranging from 1 to 10 cm in diameter are also predicted to be in the Earth's orbit. Further, a total population exceeding 128 million particles with a size between 1 mm and 1 cm currently orbit the Earth. Aglietti (2020: 1) raised a concern that the enormous speed at which the orbital debris travels may cause a detrimental effect on space assets such as satellites.

According to the NASA (n.d.), the weight of the debris that orbited the Earth exceeded 8 000 tons on the 1 January 2020, and the European Space Agency (2020) recorded 9 100 tons. The US Space Surveillance Network is monitoring all objects with sizes of more than 10 cm by ground-based radars on a routine basis. Most debris orbits within 2000 km of the Earth's surface and the largest amount of debris is in the 750 km to 1000 km range (NASA n.d.). According to Muntoni *et al*. (2021: 01) and Prochazka *et al.* (2014: 755) the debris can be monitored and is traceable.

Since the space era's inception six decades ago approximately 9800 satellites have been launched. There are currently an estimated 3100 satellites in operation as recorded in March 2021, approximately 6 700 satellites still orbit the Earth. However, literature is silent as to whether the remaining satellites are still in controlled orbit, deorbited, or part of the debris (Gleason 2021: 1; Reesman *et al.* 2021: 121).

The European Space Agency (2020) noted that 10 490 satellites have been successfully launched by rocket into orbit around the Earth, with 6 090 still being in space. The agency further outlined that there are 3 300 satellites that are still in good working order. Literature does not point out what happened to the remaining satellites, but the debris, currently in orbit, which resulted from explosions, collisions, break-ups or other abnormal situations is being tracked by the US Space Surveillance Network; this agency tracks 28 290 items of debris which are listed in its register.

4.9 Chapter summary

The chapter provided a brief introduction to the definition of space technology, the custodianship of the space industry, as well as the industry regulations and law enforcement departments. It also gave a brief explanation of how Africa and SA are involved in space-related matters. The cooperation between the first, second, third, and fourth industrial revolutions is explained in the chapter. The meaning of each industrial revolution regarding tools, techniques, and technology has been described. The chapter incorporates a brief discussion of how SA and Africa perceive 4IR.

The chapter described the evolution of the industrial revolutions and the preparation of the workforce for a smooth transition from the third into the fourth era of a global transformation. The barriers to business in the 4IR have been exposed and the diverse ways to overcome the challenges and embrace international trade. Africa's involvement in the 4IR as well as the shortfalls have been pointed out. The number of satellites in orbit by African states, years launched, and the country of ownership have been detailed. The literature discussed the progress and performance made by African states within the space industry to date.

Legislation governing the space industry and the amendments thereof were explained. A detailed outline of how space technology can be of assistance to help address the challenges encountered with WI is provided. Literature pointed out the different African countries, institutions, and countries of the world using space technology. Management and infrastructure are part of the space industry and potential benefits to the CoT have been explained in the study. National and international issues about space technology have been highlighted. Literature has pointed out how the different nationalities experience different issues of WI.

The advanced space technology nations and combined expenditures of the US, China, Europe, and India exceeded $50 billion on space activities in 2013. A brief indication of how Africa began its participation in space technology with an expenditure of $100 million in 2013 was provided. The chapter further explained the importance of using space technology to help resolve some of Africa's problems, for example, monitoring countries' reservoir and dam levels. Finally, the chapter discussed the cost implications related to space technology, and that the technology should be embraced.

The chapter has demonstrated that the following are achievable using space technology,

- Advanced knowledge of science and technology.
- Better agricultural land for crop farming through the application of space technology.
- Multiple experiments performed aboard the ISS (water purification, water sifting; urine sifted and recycled) can lead to helpful WI systems.
- Space technology assisted in infrastructure applications such as architecture, and town planning.
- Monitoring of water levels in reservoirs and the behaviour of oceans.
- Ability to detect water bodies underground and remote sensing of ground temperature.
- Theft and vandalism can be monitored using this technology.
- Space technology has been and continues to be a better management tool.
- Investment in space technology should be upheld in this new era.

The following gaps were identified in the review of the literature: Literature has demonstrated the management of water infrastructure through the application of space technology in other cities of the world but not in the CoT. Furthermore, it has been identified that the CoT has been using space technology in other areas but not in the management of WI for the city. This study will contribute to the body of knowledge on the management of WI for the CoT through space technology which is a gap that has been identified in the literature.

4.10 Conclusion

In conclusion, the chapter has discussed the definition of space technology and outlined the various roles of space technology and its benefits to the CoT, SA, and the African continent. The benefits of space technology for the treatment of water have been demonstrated. The challenges which were previously faced by the municipalities in the countries of the world have been relieved using this technology.

The next chapter discusses the methodology applied to the research project with the outline of data collection methods.

CHAPTER 5: RESEARCH METHODOLOGY

5.1 Introduction

The previous chapter articulated a review of the latest literature concerning the application of space technology to the management of WI. This chapter discusses research methodology. This study was conducted to achieve five objectives. The objectives helped to determine the realities of this study as experienced by the people on the ground.

This chapter aims to demonstrate the route that was followed to collect and analyse the data. In addition, the chapter discusses the approaches of the two methodologies i.e., qualitative and quantitative. A mixed methods research methodology was undertaken to conduct the research process. Such a methodology provides both the depth (qualitative) and breadth (quantitative) of the phenomenon being studied (Dawadi, Shrestha and Giri 2021: 27). There is no single customised research design for all studies Babin and Zikmund (2016: 68), and no research method is superior to another (Watson 2015: 1). The choice of an appropriate research project stems from the researcher using the most appropriate method to answer the research objectives.

The matters of validity and reliability are also presented in this chapter.

This methodology addresses the following research objectives:

Objective 1: To identify the challenges experienced by the municipality during and after the installation of water infrastructure.

Objective 2: To rank the importance of the identified challenges experienced by the municipality.

Objective 3: To explore the root causes of the challenges experienced during the installation of water infrastructure.

Objective 4: To identify how space technology can help with the management of water infrastructure.

Objective 5: To develop a framework of the challenges and their causes.

Objective 6: To explore water management strategies to find possible ways to resolve the challenges.

5.2 Research philosophy adopted

The research paradigm and design are discussed in detail and the reasons for the choices are outlined. The research design is the methods used to select the respondents and the procedures that were followed to obtain and analyse the data.

5.2.1 Research paradigm

Bergman (2010: 172) defines a paradigm as "an organizing framework that contains the concepts, theories, assumptions, beliefs, values, and principles that inform a discipline on how to interpret subject matter of concern". This research study has adopted a philosophy of positivism to collect quantitative information. Highly structured data were gathered to evaluate the quantitative data and were not influenced by the researcher (Saunders and Tosey 2012: 58). This research paradigm was adopted to respond to the research objectives and the research questions of this study.

On the qualitative side of data collection, the researcher applied the philosophy of interpretivism. This philosophy is concerned with collecting in-depth to gain insights into the subjective views of the respondents. The philosophy is suitable for research conducted on people and not on objects so as to understand the world around them and what they make of it from their own perspective. The interpretivist involves the collection and analysis of data from small samples (Saunders and Tosey 2012: 58).

This research is based on the ontology of pragmatism. As a mixed methods study, the research derives its knowledge from a pragmatic base with significance based on the findings. Therefore, the findings of this study were not based on a single point of view, but on multiple points of view that contributed to one bigger picture. According to Goldkuhl (2012: 2) pragmatism involves "action and change" and interaction between knowledge and action. A pragmatic approach makes it more suitable for the researcher to be involved in a real-world situation than observing from an outsider's point of view.

Table 5.1 illustrates the concepts of pragmatism and interpretivism.

Table 5.1: Pragmatism compared to interpretivism

	Pragmatism	**Interpretivism**
Ontology	Symbolic realism	Constructivism
Empirical focus	Actions and changes	Beliefs (socially constructed cognition)
Type of knowledge	Constructive knowledge	Understanding
Role of knowledge	Useful for action	Interesting
Type of investigation	Inquiry	Field of study
Data generation	Data through assessment and intervention	Data through interpretation
Role of researcher	Engaged in change	Engaged in understanding

Source: Goldkuhl (2012: 12)

5.2.2 Ontology

Ontology refers to a theory of the presence of a phenomenon (Marsh and Furlong 2002: 18). The research is based on the researchers' view of the real-world events that unfolded during the research process, and not those that have been created or based on perceptions. World views differ and sometimes may oppose suggestions of what is real about a certain phenomenon. It is worthwhile to note how reality is revealed and the principles and ethics that guide researchers (Wiggins 2011: 45).

This research has taken care to eliminate bias by the researcher and observed the views of the respondents and participants. In other words, the researcher stuck to the content of the collected data and translated data according to real-world observation.

5.2.3 Epistemology

Epistemology refers to the theory of understanding of a phenomenon. Therefore, the epistemological position of this research reflects the researcher's view of what other individuals may know about the world and how others can recognise it (Marsh and Furlong 2002: 18-19). According to Wiggins (2011: 45), epistemology is how the world searches to know the truth about a phenomenon. This research penetrated deeply to get valuable information from the research subjects about the phenomenon researched.

The researcher insisted on probing for more detailed data to uncover the reality of the matter. This is the point at which the researcher analysed and evaluated information collected. Research should be executed within the confine of good axiology (ethical values and morals) (Wiggins 2011: 45). Following the observation of Alharahsheh and Pius (2020: 40), this was the point at which the interpretation of the participant and the world around them was researched and themes were also identified.

5.2.4 Positivism versus interpretivism

The concepts of positivism and interpretivism are intertwined in social studies research. Phaladi (2021: 108) views these two as the opposite sides of the same coin in social science research. In addition, the positivist concept is associated with quantitative research approaches compared to the “rich picture” building of the interpretivist approach (Phaladi 2021: 106, 109).

5.2.4.1 Positivism

Nickerson (2022) defines positivism as a philosophy that depends on the objectivity or facts that emanate from experiments and calculations, to discover the way society operates. Positivism as described by Corbishley (2017: 139) is concerned with the neutral collection of quantitative data. It is based on the philosophy of observable and measurable reality of phenomenon to be able to generalise the results.

5.2.4.2 Interpretivism

The interpretivist approach is concerned with qualitative methodologies. This research applied the interpretivism philosophy to probe for in-depth responses to explore the different views. The resulting rich insights formed an integral part of the qualitative data. Mack (2010: 8) criticises this philosophy as being vulnerable to multiple interpretations that can result in subjective research outcomes.

5.3 Research design

Welman, Kruger and Mitchell (2005: 52) define research design as the plan used by a researcher to gather the eligible respondents to participate in the study and the method of gathering the data. This research pursues mixed methods research. Maree (2007: 268) noted that mixed methods use surveys to check the respondents' attitudes towards the subject matter and continue with in-depth interviews of individuals on the same subject matter. Caruth (2013: 113) stated that mixed methods were established for the use of both qualitative and quantitative designs in the same study after realising the restrictions of using only one method in a study. The reason for using the mixed method is that the researcher can determine the facts from both quantitative and qualitative viewpoints.

Tashakkori and Teddlie (2008: 102) asserted that it is imperative to state the reasons for choosing each type of mixed methodology. The researcher collected the qualitative and quantitative data in parallel. This type of methodology is called convergent parallel design. According to Schoonenboom and Johnson (2017: 117), a convergent parallel design methodology performs both the quantitative and qualitative methods separately and combines the outcomes to complete the interpretation. Creswell and Creswell (2005: 320, 322) referred to this methodology as concurrent triangulation design. The reason for this type of mixed methodology is to conduct the research that provides new outcomes and to prevent the respondents from discussing the research questions with new participants. This convergent parallel design prevents repetitive answers from the respondents of the study.

The primary data was collected in two phases. These phases of research were qualitative and quantitative. The qualitative phase was split into two stages, interviews and focus groups. Data for the interviews were collected through interview schedules with a list of topics for the discussions. Data for the focus groups were collected through a list of discussion topics for each group.

The quantitative phase consisted of a single stage where data was collected through an online survey database. The quantitative research followed a deductive approach and aimed at generating findings that can be generalised to the study area (Kyngäs

2020: 3, 6; Goertzen 2017: 13; Watson 2015: 1; Holton III and Burnett 2005: 30). This study used a cross-sectional survey design to collect data (Watson 2015: 4).
The qualitative and quantitative phases of data collection were conducted in parallel. In other words, no phase of data collection depended on the other. The parallel phases of data collection were appropriate for this research due to the widespread Covid-19 pandemic, with the restrictions of movement. The various lockdown restriction phases would have made it difficult to conduct this research in any other manner than this parallel setup.

This mixed method methodology was selected to obtain in depth information from internal perceptions of those responsible for managing WI development and maintenance (CoT managers' interviews), external perceptions of those responsible for implementing WI development and maintenance activities (contractors' focus groups) and perceptions of the challenges from the outsider's point of view, namely the consumers' views (the survey) with regard to service delivery in the city. The information was then cross checked and triangulated among these categories of respondents for validity.

The reason for using both qualitative data and quantitative was that qualitative research requires a relatively small population and has less costs, whereas quantitative data requires a larger sample which gives the researcher coverage to a wider area and to obtain a variety of responses using statistical techniques to validate the responses. The application of the two methods gives the researcher a greater variety of information. The city managers and the contractors (interviews and focus groups - qualitative) have detailed knowledge which the researcher needs to get an in-depth understanding of the WI problems, whereas the citizens' survey (quantitative) was more about awareness and frequency of problems.

5.4 Respondents

This section deals with the qualitative and quantitative phases of the research in terms of the population, sampling, sampling method, sample size, and justification.

5.4.1 Qualitative phase

The inductive nature of the qualitative phase allowed the researcher to obtain new perspectives and as much in-depth information from the respondents as possible (Kyngäs 2020: 3). The nature of qualitative research is such that the findings cannot be generalised (Kyngäs 2020: 5, 8). This qualitative research was conducted in two phases. The first phase started with the interviews with the managers of the water infrastructure division, and the second phase was conducted with two focus groups of the contractors (Gelling 2015: 145). The contractors' focus groups were split between managers and employees. The reason for adopting two focus group discussions was that single-sided responses tend to skew the results, therefore, the researcher opted for a diverse data collection strategy (Maree 2007: 90).

5.4.1.1 Population researched

Welman, Kruger and Mitchell (2005: 53) define a population as the overall set of subjects that have specific characteristics related to the phenomenon being studied. The population comprised of the CoT employees (managers) of the water infrastructure division, and contractors doing work for the division participated in this study. The total population of the CoT's WI division is illustrated in Table 5.2.

Table 5.2: Population of the CoT WI division

Designation	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
Director	1	1	1	1	1	1	1
Deputy Director	1	1	1	1	1	1	1
Functional Head	1	1	1	1	1	1	0
Engineering Technician	1	1	1	1	0	0	0
Foreman	5	3	4	4	2	4	2
Plumber	13	6	16	10	4	9	7
Senior Process Controller	7						
Electrician	12						

Creswell and Creswell (2005: 46) point out that a sample always has some degree of error because it is not the entire population that is being measured. A sample of the CoT employees was selected from a total population of 132. During the research process the researcher must seek to minimise errors through recording the responses correctly, and consistently phrase the questions to the respondents (Babin and Zikmund 2016: 70; Watson 2015: 2). This researcher avoided in all respects incorrect or selective recording and inconsistent phrasing of the questions.

5.4.1.2 Sampling

A sample refers to a subgroup or a population subset (Babin and Zikmund 2016: 69). Three samples were drawn from the population and comprised 20 CoT water and sanitation managers (interviews), and two focus groups of 14 experts from among the contractors (contractors' managers, and employees). The city managers all attended the interviews successfully. Initially, 15 contractors were scheduled, however, one contractor did not manage to attend the focus group discussions.

A sample of 20 participants for the CoT employees was selected using non-probability purposive sampling. The motive for this sample was to gather information about the challenges in the management of WI and to acquire specific knowledge of the research problem from a management perspective. Similar samples of 20 participants were drawn in the studies conducted by Shava (2018: 16) and Ojo (2018: 15) for the CoT regarding service delivery and water access challenges.

The sample of 14 focus group participants was chosen from the contractor component using non-probability purposive sampling. A group of 14 members split into two focus groups was manageable and avoided the redundancy of other participants. This sample was chosen purposively because participants understood installation issues from the contractors' point of view. Contractors had first-hand information about the community issues and the CoT water division issues (Welman, Kruger and Mitchell 2005: 69). Verification was conducted before any respondent could form part of the sample (Maree 2007: 178). Verification involved checking if the participants belonged to the WI division and whether the designation fell within the managerial level.

Detailed population and sample sizes are shown in Table 5.3.

Table 5.3: Population, sample size, and relation to objectives of qualitative phase

Population	Sample	Why this sample method	Objectives/ research questions	How/why sample answers objectives/questions
City of Tshwane employees (managers)	20 City of Tshwane water/ sanitation managers (interviews).	Non-probability purposive sampling. Relevant information of the challenges possessed. Specific knowledge of the research problem. Familiarity with challenges from a management perspective.	To identify the challenges experienced by the municipality during and after the installation of water infrastructure. To explore the root causes of the challenges experienced during the installation of water infrastructure. To explore water management strategies with the effort of finding possible ways to resolve the challenges. To rank the importance of the identified challenges experienced by the municipality. To develop a framework of the challenges and their causes. To identify how space technology can help with the management of water infrastructure.	Individual interview schedule with a list of topics for discussion/ in-depth knowledge of the subject matter.
Contractors within the city	14 experts (from contractors split into two focus groups).	Non-probability purposive sampling. Manageable sample, avoids participant redundancy, familiarity with WI installation challenges from contractors' perspective.	To identify the challenges experienced by the municipality during and after the installation of water infrastructure. To explore the root causes of the challenges experienced during the installation of water infrastructure. To explore water management strategies with the effort of finding possible ways to resolve the challenges. To rank the importance of the identified challenges experienced by the municipality.	Focus groups/ Group interviews trigger each group member during the discussions.

5.4.1.3 Sampling method

This qualitative research used a non-probability purposive sampling method. The method is appropriate in the sense that there is no determination as to whether a unit or member will form part of the sample, i.e., the probability of inclusion is not equal and cannot be known (Etikan and Bala 2017: 1; Welman, Kruger and Mitchell 2005: 67). Sample population refers to a subgroup or a population subset.

The reason for using this sampling technique is because specific people have specific knowledge about the research problem (Etikan and Bala 2017: 215; Creswell 2007: 125) and because it will give coverage to specific population groups. The selection of focus group members accommodated the aspects of gender, race, and employment status. These categories of participants are illustrated in Table 5.4.

Table 5.4: **Focus groups - race, gender, occupation statuses and date conducted**

Focus group 1 (Contractors' management)			
Race	**Gender**	**Employment status**	**Date conducted**
White	Male	Operations Manager	16 September 2020
Black	Male	Purification plant maintenance and refurbishment	16 September 2020
Black	Male	Operations Manager	16 September 2020
White	Male	Water Infrastructure installations	16 September 2020
White	Male	Control valve engineering	16 September 2020
Indian	Male	Pressure-reducing valve (PRV) maintenance	16 September 2020
White	Male	Chief Executive Officer	16 September 2020
Focus group 2 (Contractor's employees)			
Black	Male	Electrical Engineer	16 September 2020
White	Male	Water infrastructure maintenance	16 September 2020
White	Female	Sewer plants maintenance	16 September 2020
White	Male	Electrician	16 September 2020
Black	Male	PRV servicer	16 September 2020
Black	Male	Telemetry supplier	16 September 2020
Black	Male	Fitter and Turner	16 September 2020

5.4.1.4 Sample size and justification

It is impossible for a researcher to select a sample that perfectly matches the population, no matter how much effort they put in. It is appropriate to use purposive sampling based on their experience, creativity, and previous study findings to draw a sample for analysis as an appropriate representation of the population (Welman, Kruger and Mitchell, 2005: 67-69, 74). Samples of 20 CoT water and sanitation managers and 14 other experts (divided into two focus groups comprised of seven members in each) from contractors were adequate for the qualitative section of the study (see Table 5.3). The reason for choosing these subjects was that they had specific knowledge to provide meaningful responses to the study.

The criteria for the purposive selection of the 20 CoT water and sanitation managers, such as engineers, directors, process controllers, foremen, and artisans, was that they had first-hand information of challenges experienced at their level of operation. Each of the designations was well represented during the interviews. The challenges that managers experienced cut across communities, employees, and contractors. The reason for the selection of 20 participants was to achieve coverage of various managerial positions, gender, race, departments, and other various aspects. The sample was enough to represent this study qualitatively.

The 14 experts (contractors) were purposively selected and two focus groups of seven members each were formed. They had first-hand information on installations of pipes, repairs, maintenance, management, and various issues from the community. One of the contractors declined the appointment a day before the meeting. These categories of participants' selection criteria were arranged with the assistance of the CoT employee assigned to manage the contractors. The contractors who were contracted to work within the boundaries of the CoT for the city were recruited for this purpose. The first focus group consisted of seven members (to break the even numbers monotony) and the second focus group also consisted of seven members. The reason for the two focus groups is that Maree (2007: 90) suggested that two focus groups could present alternative points of view.

5.4.2 Quantitative phase

The quantitative phase consisted of an online survey that lasted for 14 days, from 08 September 2020 to 21 September 2020. A professional firm with a convenient database helped the researcher to administer the survey (Corbishley 2017: 27). The company had a database of the citizens of the CoT. The survey recruitment was professionally administered through emails that were sent to the respondents. The emails which were sent to the respondents contained an introduction to the researcher, the qualification being studied, the qualifying respondents, the title of the study, the aim of the study, the supervisor's contacts, the ethics administrator's contacts, and a link to connect to the survey questionnaire.

There was no remuneration of any kind to participate in the survey and the respondents were made aware that participation was voluntary. The respondents were also notified that they could freely withdraw from participating in the survey if they wanted to and that there would be no adverse effects because of their withdrawal. The survey received a total response of 693 respondents, but only 402 responses were eligible for the analysis.

5.4.2.1 Population researched

The targeted population for the survey was the citizens of the CoT. The population had experiences or perceptions about the performance of the WI and how it was being managed from the citizens' perspective.

5.4.2.2 Sampling method

This quantitative research used a non-probability convenience sampling method for the citizens' survey. Table 5.5 illustrates the type of population and sample size in relation to the research objectives

Table 5.5: Population, sample size, and relation to objectives

Population	Sample	Why this sample method	Objectives/ research questions	How/why sample answers objectives/ questions
Citizens of Tshwane	402 citizens of Tshwane	Quantitative responses on Likert scale questions	To explore the root causes of the challenges experienced during the installation of water infrastructure. To identify the challenges experienced by the municipality during and after the installation of water infrastructure.	Questionnaire/ survey as responses do not require elaboration - they are closed-ended Likert questions.

5.4.2.3 Sample size and justification

According to the Raosoft (2004) sample calculator, the sample size of CoT citizens required to be valid was 384. This sample was calculated from a population of 2.9 million (Peres, du Plessis and Landman 2017: 691), although, according to the latest figures, the population is 3.1 million (Ariyan 2020: 17; CoT 2019b: 22). The researcher chose a non-probability sampling method, namely convenience sampling, for the citizens' survey. Maree (2007: 177) suggested that convenience sampling is useful when the researcher requires quicker and easily obtainable participants. The reason the researcher chose convenience sampling is that it saved time and the cost was reasonable. Brynard, Hanekom and Brynard (2014: 56) noted that a sample simplifies the research process, reduces the costs, is efficient, and represents the population. The reason a manageable sample was selected and not the entire population was to eliminate undesirable costs for this study (Creswell and Creswell 2005: 46).

Sekaran and Bougie (2013: 268) recommend a sample size of at least 384 participants for a population of a million or more. To allow for unusable or incomplete responses, a sample of 400 was aimed for. The survey received 693 responses, of which 402 (58 percent response rate) questionnaires were completely answered, and the remaining 291 questionnaires were incomplete.

5.5 Data collection

This section covers both the qualitative and quantitative research data collection instruments, derivation of the instruments, design and testing of the instruments, the pretest for the quantitative instrument and administration of the instruments.

5.5.1 Qualitative phase instruments

Questions for the interviews and focus groups were drafted in English. The interviewees were made aware of the language of choice for the interview and that participation was voluntary. The structure of the interview schedule started with the introduction of the researcher, title, aim, and objectives of the study. The preambles of the measuring instrument resonate with that of a study conducted by Jain (2021: 545).

Wiid and Diggines (2009: 31) define data as all the measurements, views, evidence, and likelihoods that are within our accessibility. The researcher collected primary (raw/new data) data from the CoT employees (managers), and external sources such as contractors (experts). A digital voice/audio recorder was used to record the interviews and the focus group discussions (Jain 2021: 547; Pawi, Putit and Buncuan 2010: 4). The motive for using a digital tape/audio recorder rather than taking notes was that recorders provide a more accurate record of the content of the discussions (Bailey 2008: 130). The semi-structured interview schedules, the focus groups discussion schedules, and the recordings remained with the researcher after each session was completed. There were no questions that triggered the respondent’s personal feelings in the interviews and the focus group discussions.

Welman, Kruger and Mitchell (2005: 134) and Wiid and Diggines (2009: 34) further noted that the different methods of collecting data have their rewards and shortcomings. Data was collected through qualitative research methods by applying exploratory research principles. The semi-structured interview schedule with a list of topics (Appendix B) and the focus groups' discussion topics (Appendix C and Appendix D) are attached to this thesis as appendices. The questions for the interviews and focus groups were derived from the previous studies cited in chapters 2, 3, and 4 of this study. A few of these studies are described in this quantitative derivation of the instrument section of this chapter.

The researcher visited the CoT's premises where the eligible participants were located. Participants were invited to participate through telephone calls, emails, or text messages (WhatsApp). The interviews were conducted with the CoT managers (20) at various workplaces, homes, and other venues. The two focus groups (14 participants split into two equal groups) who were experts within Tshwane (water and sanitation contractors) were conducted in a suitable boardroom provided by the CoT. The interviews occurred over a period of four days, that is, from 14 September 2020 to 17 September 2020 as illustrated in Table 5.7 (depending on the respondents' availability), and the focus group discussions were conducted on 16 September 2020 as reflected in Table 5.7.

Each focus group consisted of seven members. The focus groups were made up of people with experience in management, maintenance, installation, repair, and other various aspects of water infrastructure. The focus groups comprised contractors who were contracted to the water and sanitation divisions of the CoT. Permission for recording was obtained from each focus group at the beginning of each session. A letter granting permission (a gatekeeper's letter Appendix E) to the researcher was obtained from the CoT.

Focus groups benefit from the services of an effective moderator (Wangsom, Kongvattananon and Somprasert 2018: 145), with good listening and effective communication skills (Muijeen, Kongvattananon and Somprasert 2020: 362). In this study the focus groups were conducted by a moderator with experience of collecting data for research purposes in a university context. The moderator made sure that no single member of the focus groups became dominant in the discussions (Dawson 2009: 29-30), and that the proceedings were conducted smoothly and professionally. Each member who formed part of the interviews and the focus groups signed a consent form before each session. An example of a consent form signed by each of the study respondents is attached as Appendix K. Table 5.6 illustrates the method with which each category of respondents/ focus groups was conducted according to the dates and number of participants.

Table 5.6: Schedule of participants, dates, and the number of participants

Type of participants	**Date interviewed/ discussed**	**Number of participants**
Interviews	14 September 2020	9
Interviews	15 September 2020	7
Interviews	16 September 2020	2
Focus group	16 September 2020	1 Focus group (7 respondents)
Focus group	16 September 2020	1 Focus group (7 respondents)
Interviews	17 September 2020	2

5.5.1.1 Derivation of the qualitative instruments

The researcher formulated the interview schedules and discussion schedules/topics. The schedules and questions were derived from studying the research title, research problem, the aim of the research, research objectives, and research reasons in conjunction with the direction of the literature. They were not extracted directly from literature, but literature played a pivotal role in the formation of the discussion questions/topics.

A few studies that informed the questionnaires, interview schedules and discussion topics were as follows: suitable personnel who understand the WI systems (Kloosterman and van der Hoek 2020: 2); endemic political factional battles (Mello 2020: 83-84); improved service delivery standards and improved client satisfaction through WDN management (Bello *et al*. 2019: 2-3); insufficient water supply, poor water quality, vandalism and theft of electrical cables in SA and in the CoT (CoT 2019b: 128); political interference (Soppe, Janson and Piantini 2018: xii-xiii); improved water management strategies (Urich *et al.* 2013: 301); the CoT budget strain that led to poor service delivery (Masolane 2019: 54) ; the CoT experienced revenue collection difficulties (Dludla 2020); extensive protests in SA municipalities due to poor quality of service (Hamer *et al*. 2018: 1, Alexander *et al.* 2018: 27, Pooe, Worku and Van Rooyen 2016: 24, Mofolo 2016: 230-232), elimination of communities from decision-making processes (Mofolo 2016: 243). Many more citations from which the questions were derived are in the literature chapters namely, Chapters 2, 3, and 4.

The measurements used in this thesis are general experience in the CoT as a contractor, installation challenges, maintenance challenges, challenges caused by the contractors, the root causes of the challenges, ranking of the challenges, gaps that fail the city, intervention by management, strategic advice, comparison of the CoT with other SA cities in terms of managing WI, adherence to contractual obligations, management of contracts and the state of readiness for space science technology. These issues were identified as important from the literature, and some were included due to the frequency of their mention, and their importance as stressed by participants in the interviews and focus groups.

5.5.1.2 Design and testing of the qualitative instruments

The interview schedule had four main sections, and each section had a few bullets as sub-schedules for the interviews. These four main sections were related to challenges that affect the municipality during and after the installation of WI, assistance given by the municipality to the contractors, the capacity of management to execute the work, and the available or new strategies to adapt to innovative technology such as space technology. The schedule was checked with this study's supervisor to eliminate any ambiguities in the instrument before it was administered.

The structure of the measuring instrument for the discussion topics (focus groups) starts with the introduction of the researcher, title, aim, and objectives of the study. The topics are divided into three main sections/ topics with several bullets under each section as sub-topics. These main sections are the challenges experienced by the municipality during and after the installation of WI, interventions done by the city's management after the challenges, and adherence of the contractors to the obligations. The supervisor and a part-time lecturer were consulted to check and eliminate any ambiguity in the instrument before it was used.

5.5.2 Quantitative phase instrument

Primary data is gathered by the researcher and not from secondary sources Brynard, Hanekom and Brynard (2014: 38). Data was collected through a survey questionnaire (Appendix A) with closed-ended descriptive questions. Consent to participate in the survey was obtained from the participants. The rights of participants to form or not to form part of the survey were explained. The CoT was notified through an email when the survey started and when the survey ended. This exercise was necessary to guard against malpractices of continuation of emails that may have pretended to be a real survey of this study. Similar to the study by Corbishley (2017: 27, 156), a professional research firm with a database of the citizens of Tshwane was contracted to distribute the questionnaire through emails to the respondents.

The survey email introduced the researcher, the title and aim of the study, the definition of water infrastructure, the right to withdraw from the study, a no remuneration clause, confidentiality, the study supervisor’s contacts, complaints office contacts, and the link to the survey. Some respondents contacted the researcher to verify the authenticity of the survey and asserted their right not to participate.

There were 693 responses to the survey. Only 402 completed responses were eligible for analysis i.e., 292 responses were spoilt or incomplete and did not qualify for analysis. During the administration of the survey, a few respondents complained, and some congratulated the researcher for the study.

The data collection instrument was a structured questionnaire of five-point closed-ended Likert scale questions. The data collection instrument was designed to accommodate the aspects of appearance, order of questions, wording, and the classifications of responses (Maree and Pietersen 2007: 158-159). The five-point Likert scale responses were, strongly disagree (1), disagree (2), neither disagree nor agree (3), agree (4), and strongly agree (5).

5.5.2.1 Derivation of the quantitative instrument

According to Mason (2004: 274), a “questionnaire” helps to give direction to the data collection process. The questionnaire was derived from the previous studies cited in the literature review in Chapters 2, 3, and 4 of this study. The questions were derived in the same way as described in the previous derivation of the instrument section of the qualitative phase

The questionnaire was well presented and should not take more than 20 minutes to be answered by a respondent (Maree and Pietersen 2007: 158-159). The instrument setup was such that the simple questions came first, and the more demanding questions were placed later. The instrument consisted of one section only and had an introductory instruction for the respondents to answer by marking a cross in the appropriate corresponding number. The researcher took care that the instrument generated relevant information (Dawson 2009: 89).

5.5.2.2 Design and testing of the quantitative instrument

The survey instrument had 14 questions, each with response categories numbered one to five and a tick box next to the Likert scale appropriate numbers. The instrument consisted of the following categories of questions i.e. installation challenges, maintenance challenges, challenges caused by the contractors, challenges caused by the municipality, political interference, community challenges, strikes by the contractors, ownership of the contracted companies, the technical and management capacity of the city’s employees, adherence to the health and safety standards, delays in the project’s execution, vandalism of the projects, management strategies for the projects, and enhancement of the projects by the politicians. All these questions were closed-ended and did not allow the respondents to comment further after making a tick.

The reason the researcher used this type of instrument is that it is easy to administer, is attractive, has quick responses, and is easily recorded by the researcher (Dawson: 2009: 90). The instrument was self-administered by the respondents. The researcher used simple words, no insults, no bias, and avoided ambiguous questions when constructing the instrument (Dawson 2009: 90-91). Secondary or historical data aided the researcher in terms of identifying the type of data to be collected. The researcher conducted a pretest of the instrument before it was rolled out to the respondents.

5.5.2.3 Pretest study

A pretest study was conducted to identify and remove any ambiguity from the instrument and was conducted despite time being limited (O'Sullivan *et al.* 2017: 244). The purpose of pretesting is to detect and eliminate any weaknesses in a questionnaire to be used in undertaking a research project. In this study pretesting was conducted by selecting a sample of respondents to check if the questionnaire was understood and doable. The aspects of language, sequence of the questions, and skip pattern were also checked and were acceptable (Sekaran and Bougie 2016: 155; In 2017: 601). If the questionnaire does not convey a clear message to the respondents, then questions need to be adjusted. According to the observations of Mashamaite (2021: 151), pretesting a questionnaire helps to avoid misunderstandings by the respondents, to identify the response time required, and to ensure that the questionnaire contains the required information.

A pretest is defined as an experimental test of specific-small scale respondents or participants to quantify a dependent variable before exposure to the full measurement (Sharma 2022: 123, Sekaran and Bougie 2016: 395). It evaluates if there are any errors or ambiguity in a questionnaire with an objective to improve the questionnaire. The pretest questionnaire was administered by the researcher from start to finish. The pretest questionnaire contained similar information as that of the main study. The responses help to evaluate the relevance of the questions and to show early warnings of whether the research is feasible (Majid *et al*. 2017: 1076).

This research applied a pilot study which is a miniature form of a complete study that encompasses pretest research instruments including a questionnaire or an interview schedule (Van Teijlingen and Hundley (2001). A snowball sample (obtained through referrals by other study respondents/citizens) was applied to select the pilot study respondents (Creswell 2007: 127, Welman, Kruger and Mitchell 2005: 69). A pilot study is highly recommended (Moloantoa 2015: 69) in a quantitative study, and it improves the validity of the study (Abd Gani, Rathakrishnan and Krishnasamy 2020: 140).

This pilot study was conducted on ten respondents who reside in the CoT. Recruitment was done through Google Forms with a link to connect the recruited respondents to the pilot study questionnaire. The pilot study did not identify any weakness in the questionnaire. The pilot study responses were not included in the final analysis of this study.

5.5.3 Administration of the instruments

The qualitative phase of the interviews was conducted by the researcher with the participants. All the interviews were direct face-to-face.

5.5.3.1 Qualitative study

The interviews (CoT's managers) were conducted by the researcher face-to-face with the participants at the different interview venues selected by the participants.

The moderator managed the discussion topics lists face-to-face with the focus groups which were held in a boardroom venue at the CoT offices.

a) The interviews

This qualitative phase of the research was conducted to gather in-depth knowledge (Lester, Cho and Lochmiller 2020: 95), from the employees' point of view. The first phase of collecting the primary data was accomplished through a semi-structured interview schedule. The interviews were conducted at various times that were scheduled with these employees. The interviewees consisted of 20 CoT employees (directors, deputy directors, managers, artisans, engineers, engineering technicians, process controllers, and foremen). These positions had managerial capacities in the form of junior management, middle management, and senior management responsibilities. One of the interviewees opted to stop the interview and no longer proceeded after a few minutes, another employee opted to not even start to participate. The researcher managed to get replacements for these two.

The participants contributed their perspective to this study regarding the management issues and the different behaviours that they experienced from the junior employees, the residents, politicians, and the executives. The researcher had requested the appointments with the respondents at their suitable places, that is, at their work premises, homes, and other suitable places, and it took four days to conduct the interviews.

The interviews were recorded with their consent for recording obtained from each participant before the start of the interview. Participation in the interviews was voluntary and there was no stipend, nor any form of remuneration given to the participants. Data were collected until a saturation point was reached when it became apparent that no new responses were being generated – in other words, the answers became repetitive (Kyngäs 2020: 8). The aspects of the participants' statuses, the number of participants, gender, race, and the interview dates are presented in Table 5.7.

Table 5.7: Interviewees' race, gender, and employment status

Race	Gender	Employment status	Date of interview
White	Male	Functional Head	14 September 2020
Black	Male	Acting Foreman	14 September 2020
Black	Female	Foreman	14 September 2020
Black	Male	Engineering Technician	14 September 2020
Black	Male	Artisan	14 September 2020
White	Male	Artisan	14 September 2020
Black	Male	Engineering Technician	14 September 2020
White	Male	Foreman	14 September 2020
Black	Male	Deputy Director	14 September 2020
Black	Female	Civil Engineering Technician	15 September 2020
Black	Male	Engineering Technician	15 September 2020
Black	Female	Deputy Director	15 September 2020
Black	Male	Deputy Director	15 September 2020
Black	Male	Foreman	15 September 2020
Black	Female	Senior Process Controller	15 September 2020
Black	Male	Director	15 September 2020
Black	Male	Deputy Director	16 September 2020
Black	Female	Plumber	16 September 2020
Black	Male	Director	17 September 2020
Black	Male	Deputy Director	17 September 2020

b) The focus groups

The task of organising the focus groups to come together was not easy (Pawi, Putit and Buncuan 2010: 1) as the respondents kept postponing and changing the dates. Finally, the city's senior employees responsible for the contractors were asked to organise the focus group appointments well in advance (Muijeen, Kongvattananon and Somprasert 2020: 362). The focus group discussions were conducted in one day in a boardroom provided free by the CoT water division. The venue was suitable for conducting focus groups – it was accessible, spacious, welcoming, comfortable, with sufficient chairs, no disruptions, and had free parking space (Dawson 2009: 84; Muijeen, Kongvattananon and Somprasert 2020: 366; Wangsom, Kongvattananon and Somprasert (2018: 149).

The researcher and the moderator introduced themselves to the focus groups. The moderator outlined the purpose of the study, the title of the study and the level of the study, the ground rules, and requested the group members to introduce themselves, provide an overview of their experiences, and outline their likes and dislikes about the phenomenon being studied (Muijeen, Kongvattananon and Somprasert 2020: 367).

The first focus group (contractor managers) discussion took one hour and seven minutes, and the second focus group (contractor employees) lasted for one hour and four minutes. One and half hours (Dawson 2009: 79), or between one to two hours (Wangsom, Kongvattananon and Somprasert 2018: 149; Muijeen, Kongvattananon and Somprasert 2020: 365-366) are recommended for a focus group meeting. Wangsom, Kongvattananon and Somprasert (2018: 149) disapprove of a focus group meeting conducted under 45 minutes. The authors fear that a focus group conducted under 45 minutes may generate incomplete data as this period is regarded as the start of a warm-up. The researcher engaged a research assistant to moderate the proceedings in the presence of the researcher.

The moderation process was conducted professionally without dominance by any member of the focus groups. Dominance by certain focus group members generates poor data and results in insufficient outcomes (Pawi, Putit and Buncuan 2010: 2; Dawson 2009: 29-30; Mare (2007: 202). The researcher noted the discussions and made follow-up questions for detailed explanations. Name tags were written with a marker on a piece of paper and placed in front of each focus group member (Wangsom, Kongvattananon and Somprasert 2018: 149).

A digital audio recorder was used to record the discussions (Maree 2007: 92; Dawson 2009: 30), and consent was obtained from the participants. According to Dawson (2009: 149), the researcher may provide “something in return” to the participants for sacrificing their time for the study. At the end of the discussions, the researcher thanked the respondents and provided a flash disc as a gift – “something in return” – to every respondent. Lunch and soft drinks were provided to the respondents because the sessions proceeded until lunchtime (Dawson 2009: 85). The researcher thanked the respondents and thanked them for their presence and for contributing information to this study.

5.5.3.2 Quantitative study

The survey instrument was sent to the respondents (CoT citizens) by email with a link to open the questionnaire. The questionnaire had check boxes for the respondents to click in the appropriate box of the corresponding answer. The end of the questionnaire had a ‘submit’ box for the respondents to click for the final submission.

A professional research firm with a CoT database was contracted to manage the mailing exercise. The firm sent multiple emails to the respondents and 693 responses were received. The responses from the survey respondents were obtained on various days. The researcher can confirm that there were lots of mailing exercises to and from the respondents on each day of the survey period. The researcher’s interest was more in the number of responses than the number of emails that were sent to the respondents. The responses that were eligible for analysis were 402. There was no personal or physical contact with the survey respondents.

5.6 Data analysis

Data analysis is the process of arranging new data to be prepared for analysis to provide information to make informed decisions (Karaca and Cattani 2018: 1). The results of analysis are reliable performance indicators of whether a certain proposed idea is supported or rejected. During the data analysis process the researcher revealed the various relationship patterns and made sense of the meanings of the substance from the data collection, and the relevance thereof (Albers 2017: 18). As the research process unfolded, the researcher noticed the patterns and the real meanings which were extracted from the discussions. Analysis of the qualitative data produced charts, themes, tables, word frequencies, word counts, word clouds, word clusters, and words tree map analyses.

Analysis of the quantitative data revealed various patterns reflecting the views of the respondents. These patterns were presented in the form of presentations, charts, means and standard deviations, survey response table, reliability statistics, exploratory factor analysis (EFA), descriptive statistics and reliability, constructs and, Cronbach's alpha. Data was captured and entered in an Excel spreadsheet, stored, and imported into the Statistical Package for the Social Sciences (SPSS Version 27) software for final analysis. A master copy of the data has been safely stored for cross-checking should the need arise or in case of imminent discrepancies (Watson 2015: 4).

5.6.1 Qualitative analysis

This section covers editing/cleaning and capturing, and qualitative analysis techniques. Seers (2012: 2) suggested to qualitative researchers to be vigilant and to not drown in data during the data analysis process.

5.6.1.1 Editing/cleaning, data capture/entry

This sections discusses data editing, cleaning, capture, entry and the use of words.

- **Data editing/cleaning**

The researcher replayed the recordings and cross-checked with the field notes and the transcriptions. Editing was done, and spelling mistakes and other typo errors were corrected.

- **Data capture/entry**

Data was then refined and captured on Microsoft (MS) Word documents. Data was then fed into NVivo computer software for analysis. Transcribing of data needs a well-trained person to listen and type the responses – this is the beginning of the data analysis process (Bailey 2008: 129). A professional typist was engaged to listen and capture the recorded data for both the focus group discussions and the interviews.

The researcher listened to the recordings to check if the transcriptions were correctly captured; the cross-check process was the beginning of data analysis from the research point of view. According to Bailey (2008: 130), the job of data transcription involves interpretive knowledge and does not necessarily require technical expertise. The transcription of the contractors' first focus group (managers) was 11 pages and the second contractors' focus group was 12 pages. The average number of pages for the 20 individual interviews was six.

- **Word usage**

A list of important words from the interviews and focus group transcripts were identified and analysed by NVivo software. The software generated a word cloud, tree map, and cluster analysis each with 50 words with an exact match (see Appendix L). The word frequencies and word counts were generated and recorded in tables and charts and are presented in Chapter 6.

5.6.1.2 Qualitative analysis techniques

Mezmir (2020: 15) defines data analysis as the arrangement and interpretation of verbal or visual data to report on hidden and exposed matters and to make meaning about the material and what it represents. It creates how participants make sense of a particular aspect by examining their opinions, approaches, understanding, awareness, principles, emotional state, and experiences in an endeavour to estimate the creation of a phenomenon.

Qualitative data were analysed through NVivo, Excel graphs, pie charts, and tables. Tables and charts help to arrange, analyse, display, and present qualitative data and are better means of presenting qualitative findings (Cloutier and Ravasi 2021: 127; Camões 2016: 91-92). Every line of the transcribed data was read and then allocated into significant analytical items that generated word clouds, word count, statement frequencies, themes, and other in-depth analyses. The content analysis of the collected data helped to deconstruct and reconstruct the data (Lee 1999), to produce the themes and other meaningful concepts as discussed in Chapter 6.

5.6.2 Quantitative analysis

Quantitative data cleaning is necessary to improve the quality from that of raw data (Prokoshyna *et al*. 2015: 300). Data cleaning prepares the data for the analysis process and eliminates distortion.

5.6.2.1 Data cleaning and capture

Data were cleaned by revisiting the database of the responses which were migrated into an Excel spreadsheet. Data were checked and rechecked to make sure no information was corrupted during the migration process. Data cleaning was done for errors such as missing values, nonresponses, incomplete questionnaires, and other migration inaccuracies (De Waal, Pannekoek, and Scholtus (2011: ix). The researcher captured data that were complete and without skip patterns. Incomplete responses were not captured and did not form part of the final analysis.

5.6.2.2 Quantitative analysis techniques

The Statistical Package for the Social Sciences (SPSS Version 27) was used to analyse the Likert scale survey responses.

The following tests were conducted to analyse the quantitative data:

- Descriptive statistics which are presented in graphs and tables.
- Means and standard deviations which are presented in tables and charts.
- Frequencies which are presented in tables and charts.
- Cronbach's alpha is a reliability measure, which measures the extent to which the items on a measurement scale or test produce consistent results. Chronbach's alpha was used to measure the reliability of each of the four research constructs.
- The Anova test was used to test the relationship between two or more groups and the resultant significance.
- The Kaiser-Meyer-Olkin (KMO) index values test was conducted to check the adequacy of a chosen sample.

- Bartlett's test of sphericity was conducted to check the adequacy of the analysed data. A p value should be significant.
- Analysis according to constructs.

The techniques used to analyse the data was EFA, descriptive statistics, and reliability check. The EFA technique was performed by applying the principal components analysis procedure to check the factor structure of all research constructs. The reason for choosing this type of analysis was to check the factorability of the data thereby applying the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity. The sample chosen for the quantitative phase of this study was found to be adequate. Eisenhardt (2021: 151) concurred that constructs are a vital part of the theory and can be measured.

5.7 Validity and reliability

The mixed methods methodology demands intensive understanding and validity (Schoonenboom and Johnson 2017: 111). Reliability and validity are key concepts in quantitative research and depend on a suitable instrument for data collection (Sürücü and Maslakçi 2020: 2695-2696; Punch 2014: 245; Maree 2007: 80).

5.7.1 Validity and reliability / trustworthiness of the qualitative research

Validity refers to the degree to which a tool measures what it is expected to measure (Sylvia 2018: 92; Watson 2015: 2; Maree 2007: 216). Reliability refers to the research findings from one researcher being similar to another researcher using the same methodology (Watson 2015: 2). Maree (2007: 80) noted that reliability for qualitative research can be ensured by checking the credibility and trustworthiness of the research project and that the study achieved its intended aim.

The researcher is the instrument for gathering data in a qualitative study (Maree 2007: 80). The key concerns regarding trustworthiness have been pointed out by Guba (1981: 79-80) namely, truth value, applicability, consistency, and neutrality. Guba (1981: 79-81) further identified methods that can be used to remedy the concerns as illustrated in Table 5.8. Polit and Beck (2004: 27) and Guba (1981: 88) proposed that the key ingredients of trustworthiness are: dependability, credibility, transferability, and confirmability to examine how trustworthy a qualitative study is.

Dependability- refers to the extent to which two researchers assessing the same scenario with the same evidence at various times arrive at the same conclusions (Bhattacherjee 2012: 110). The credibility of this study suggests that it is dependable and that the results are available for audit purposes and are available on request. The results of this study have been triangulated amongst the interviews, focus groups, field notes, and other diarised information for common themes (Maree 2007: 305).

Credibility- refers to the believability of a study when its inferences are evaluated and found to be credible by other readers (Bhattacherjee 2012: 110). This study has used triangulation and lengthy engagement to find the themes of the gathered information.

Transferability- is described as the extent to which the study's findings are generalisable to the other settings (Bhattacherjee 2012: 111, Tobin and Begley 2004: 392). The findings of this quantitative study may be generalised to the study's general population; however, the qualitative findings of this study may not be generalised. If the researcher generalises the qualitative findings care should be exercised to evaluate the transferability. This possibility has been improved by gathering rich data through carefully selected non-probability purposive sampling (Mason 2004: 289).

Confirmability- refers to the findings of the study arriving at the same results as the participants of other studies following the same research design (Bhattacherjee 2012: 110). A study conducted by Mason (2004: 289) recommended that audio records, transcripts, "data collection instruments", "deconstructed and reconstructed" materials, documents, and field data should form part of the appendices. This study can confirm that the findings of this study are the true reflection of the responses of the participants and are not orientated to the researcher's perceptions. The instruments used in this study to gather data appear in the appendices, as per the study conducted by Mason (2004: 289).

Table 5.8 lays out the various aspects of trustworthiness and ways of ensuring their implementation. An important tool for establishing trustworthiness of a qualitative study is an audit trail. For the purposes of openness of this study the results (that is, interview transcripts, focus group transcripts, peer-reviewed and published journal, peer-reviewed and published chapter, and presentation) are available upon request from the researcher (Seers: 2012: 2). The email address of the researcher is 21143673@dut4life.ac.za or mokgobul72@gmail.com. The conditions under which to send the required information shall be treated in terms of the Durban University of Technology Faculty Research and Ethics Committees' code of conduct.

Table 5.8: Ways and means of ensuring trustworthiness

Aspect	Naturalistic Term	Means
Truth value	Credibility	Member checks. Triangulation. Use prolonged engagements and persistent observation. Quantitative data is included.
Applicability	Transferability	Collection of thick data with thick descriptions.
Consistency	Dependability	Data steadiness. Do repetitive audits. Checks on researcher's own insights.
Neutrality	Confirmability	Triangulate the information. Eliminate bias.

Source: Guba (1981: 80-87)

5.7.2 Validity and reliability of the quantitative research

This section describes the qualities that an instrument must possess to measure what it is intended to measure, namely, validity and reliability (Sürücü and Maslakçi 2020: 2695; Phaladi 2021:155).

5.7.2.1 Validity

Validity refers to the degree to which the collected data measures the aspects that the research is intended to measure (Mertens, Pugliese and Recker 2017: 50; Punch 2014: 245; Polit and Beck 2004: 443). The measuring instrument was checked for content validity. This means that the aspects required for the content validity were all scrutinised in the questionnaire. Content validity, according to de Barros Ahrens, da Silva Lirani and de Francisco (2020: 3), is the starting point of validating the measuring instrument for language, suitability, and theoretical fitness.

Face validity has also been checked – this measure evaluates the questionnaire for any ambiguities. Face validity is, according to Taherdoost (2016: 29) and Polit and Beck (2004: 443), the degree to which "non-expert" examiners judge that a measure is related to a specific construct. Taherdoost (2016) further stated that validity assesses if the questionnaire is feasible, legible, and has consistent style, is well-formatted, and has understandable language. Face validity and content validity for the measuring instruments were assessed by the researcher with the help of the research supervisor. The ethics clearance committee verified the instrument before it was rolled out. A statistician also verified the data collection instrument as valid and reliable, and the Cronbach's alpha test performed above the minimum threshold. A pilot test as discussed earlier in this chapter was conducted for this study and yielded positive results with a good response rate without complaints**.**

5.7.2.2 Reliability

Reliability refers to the degree to which one or more variables demonstrate consistency of measurement (Sürücü and Maslakçi 2020: 2695; Mertens, Pugliese and Recker 2017: 50-51; Polit and Beck 2004: 443). The degree of reliability of the questionnaire has been measured statistically using Cronbach’s alpha coefficient. Cronbach’s alpha coefficient is the most widely used test for reliability. In terms of Cronbach’s alpha coefficient, the acceptable reliability values are 0.90 (high reliability), 0.80 (moderate reliability), and 0.70 (low reliability). A value less than 0.60 is not acceptable (Maree 2007: 216). The four research constructs that were evaluated were community challenges, contractor’s challenges, municipal and political challenges, and maintenance and political support. A Cronbach’s alpha coefficient test was applied to the four research constructs of this study with results between 0.596 and 0.782. A detailed summary of Cronbach’s alpha test for each of the four research constructs is illustrated in Table 6.3 in Chapter 6 of this research.

5.8 Research ethics

It is a mandatory requirement that a research project should have full ethics approval before the project starts (Simelane-Mnisi 2018: 1). Ethics is the ability to determine between right and wrong actions. Rani (2022: 328) defines ethics as whatever adds value to an individual and the community and determines the type of activities that individuals owe themselves and other people. Institutional research is receiving heightened attention in South African higher education to ensure the ethical practice of the researchers (Webber, Muller and Botha 2016: 361) and to guard against research malpractices.

Ethical behaviour must be observed at every step of the research process. This behaviour includes the form of addressing the respondents, recruitment, the dress code, access to the research area, and avoiding harm. The researcher exercised the highest conduct of ethical behaviour during the execution of this study. The conditions of approval as laid out by the DUT's Faculty Research Ethics Committee (FREC), the gatekeepers' letter, and the confidentiality agreement were adhered to. The researcher obtained an approved gatekeepers' letter (Appendix E and approval from the FREC Committee to conduct this research. Ethics approval from FREC was approved prior to commencing data collection (see Appendix H). The researcher adhered to the conditions of the gatekeepers' letter and the FREC. Furthermore, the researcher discussed the following ethical considerations with the participants: voluntary participation, confidentiality of the information, anonymity, and voluntary withdrawal from the study.

According to Cumyn *et al*. (2018: 1-2), it is expected that the researcher must manifest ethical behaviour in all stages of research. The researcher has abstained from any form of bias by reporting the information supplied by the respondents of this study. The bias aspect of ethics has been avoided by applying a well-structured research design, data analysis, and data interpretation. The analysis tools such as SPSS, NVivo, tables, charts/graphs, word clouds, and word frequencies have assisted the researcher to arrive at informed decisions derived from the collected data. This study has devoted much attention to ethical conduct because the research subjects were humans.

Another aspect that the researcher undertook was to obtain a gatekeeper's approval letter from CoT to conduct the research. According to Singh and Wassenaar (2016: 42), the researcher shall obtain a gatekeeper's approval letter and the Research and Ethics Committees' approval prior to conducting research within the premises of an organisation. However, this is not a requirement for research conducted in the public domain such as in the streets or taxi ranks. In other words, the success of a study rests solely on the approved gatekeepers' letter and the approval of the Research and Ethics Committee. More specific aspects of research ethics are now discussed.

5.8.1 Voluntary participation by respondents

Respondents were informed of their voluntary participation in the study and that anyone could withdraw anytime without adverse repercussions. Information about the purpose of this study, the rights to participation, risk exposures, processes to be followed, and the benefits of the study were discussed with the participants (Manti and Licari 2018: 145, 146; Nijhawan *et al*. 2013: 134).

5.8.2 Informed consent

To comply with the legal framework and ethical conduct, the point of entry to a study involving humans requires informed consent from the participants (Nijhawan *et al*. 2013: 134; Smith-Tyler 2007: 189). The researcher defined all aspects of the risks and discomforts and the benefits of this study and requested informed consent from each participant (Manti and Licari 2018: 146). This requirement aimed at making sure each participant took part in the study voluntarily and without prejudice.

The consent documents were signed and dated by the participants (Nijhawan *et al.* 2013: 134) and form part of this study's appendices (Appendix K. The researcher is not permitted to force the participants to take part in a study to achieve self-interest, and participants are under no obligation to participate in any study (Nijhawan *et al*. 2013: 134). The decision to participate suggests that the participant has studied and understood the contents of the informed consent form (Biros 2018: 2).

5.8.3 Anonymity and confidentiality

The researcher-maintained anonymity and confidentiality by excluding the names of the respondents in this final study (Smith-Tyler 2007: 189). Measures to protect anonymity and confidentiality were managed in terms of the Durban University of Technology ethics policy. Additional measures to protect the identity and confidentiality of the respondents, the recordings, the transcripts, and the survey data will be kept in a locked cupboard for a period of 15 years and be destroyed afterwards (Moloantoa 2015: 70).

The researcher has taken reasonable measures to comply with Sections 18 and 19 of the Protection of Personal Information Act, 2013 (POPIA) [Act No. 4 of 2013]. In terms of Section 18 of POPIA, 2013 [Act No. 4 of 2013] it is the responsibility of the data collector to explain the reasons for the collection of personal data to the subject from which it is obtained. Section 19 of POPIA, 2013 [Act No. 4 of 2013] outlines that such data collector shall take reasonable steps to protect personal information from unauthorised access and to safeguard the integrity and confidentiality of such information (South Africa, The Presidency 2013: 30-32).

The researcher has signed confidentiality and consent agreements with the CoT and the participants, examples of which are given in Appendices G and K. The signed agreements are available on request for inspection at the researcher's affiliated institution (DUT). The information given by the participants is confidential and remains with the researcher, the supervisor, and the researchers' affiliated institution only. At the beginning of data collection, anonymity was guaranteed to the study participants and that information is confidential and may not be divulged. The names of the participants have not been revealed due to the necessary anonymity, confidentiality, and ethical requirements.

5.8.4 Violation of privacy

The researcher provided the contact details of the researcher, the supervisor, and the DUT Institutional Research and Ethics Committee administrator to participants in case any queries or adverse effects occurred because of this study. The contacts were available for use by any study participant who may have detected any violation of privacy during the research process. The researcher signed for the inclusion of the contact details as part of the conditions of approval of the study to take place. The conditions of approval were in the participant information letter of the DUT Institutional Research and Ethics Committee.

In terms of Section 14 of the Constitution of the Republic of South Africa Act, 1996 [Act No. 108 of 1996], every person has the right to privacy and the right to non-interference with their communication (South Africa, Department of Justice and Constitutional Development 1996: 1249). No personal data was requested in the survey questionnaire and focus group discussions; however, the use of names was important in the interviews for transcription purposes only and not for publication. No names were used in the final report of this study.

5.9 Chapter summary

This chapter discussed the various methodological approaches that were relevant to successfully undertake this study. The quantitative and qualitative (mixed methods) research processes were explained in detail. This chapter discussed the research design, population, sampling methods, phases of research, data collection, measuring instruments, data capturing, data analysis, validity and reliability, and ethical considerations, as the components of the methodological tools used to conduct the research.

5.10 Conclusion

This chapter has shown that a mixed methods methodology was an appropriate approach to providing answers to the research objectives and questions of this study. This study considered the requirements of undertaking the mixed methods approach and applied the relevant theories with arguments throughout the research process. In conclusion, this chapter addressed the issues of validity and reliability, and ethical considerations as vital to this study.

The next chapter, Chapter 6, presents the data and analysis of the collected data.

CHAPTER 6: PRESENTATION AND ANALYSIS OF RESULTS

6.1 Introduction

This chapter presents analysis and interpretation of the collected data. The data were collected through a survey, interviews and focus groups. The data collection was administered according to the following categories: the survey covered the CoT residents, the interviews were conducted with the city employees, and focus groups with contractors who were contracted to the city. The quantitative and qualitative data form the discussions of this chapter. The reason for using both research methods is that quantitative method has closed-ended questions while qualitative method allows the respondents to expand and express their points of view. The method applied to collect quantitative data was questionnaires. The questionnaires were distributed to the residents of the CoT through emails that contained a link to connect to the survey questions. The presentation starts with the quantitative data and concludes with the qualitative data.

6.2 The results of the CoT residents' survey

Table 6.1 presents the mean for each question of the survey. The questions that were rated three were at the midpoint. Means above three indicate a higher agreement with the statements, while means below three indicate a disagreement with the statements. There are Nine questions that have performed above the midpoint. The most highly rated issues range between means 3.12 and 4.0 and therefore need the most attention. The survey results are illustrated in Table 6.1 and Figures 6.1 to 6.16. The means and standard deviations are illustrated in Table 6.1.

Table 6.1: Means and standard deviations of respondents on CoT's WI challenges

Questions/ statements	N	Mean	Std Dev
Political interference plays role in the award of jobs to contractors	397	4.00	0.999
Unbarricaded trenches, inaccessible streets due to inst & maintnc	401	3.76	1.175
Striking contractors affect the smooth running of WI inst & maintnc	399	3.76	1.184
Delays arising from the contractors doing WI inst and maintnce	400	3.63	1.002
Politicians own the companies doing the WI inst and maintnce	401	3.47	1.824
Challenges from the municipality regarding WI installations	397	3.46	0.162
Challenges during maintenance of WI in township	397	3.39	1.200
Challenges arising from contractors doing the installations of WI	400	3.26	1.122
Challenges during installation of WI in township/ suburb	397	3.12	1.142
Contractors doing inst and maintnce adhere to the min H/S stds	401	2.97	0.919
The public disturb the contractor's work by vandalising projects	402	2.88	1.130
Managers of the CoT have enough technicl and mngmnt capacity	401	2.73	1.096
The CoT managers have a better strategy for managing projects	401	2.64	0.906
Politicians enhance projects, work closely with mun, citzns & contr	402	2.43	1.027

Detailed responses to the survey are outlined as follows: Figure 6.1 rates the overall satisfaction level of the respondents.

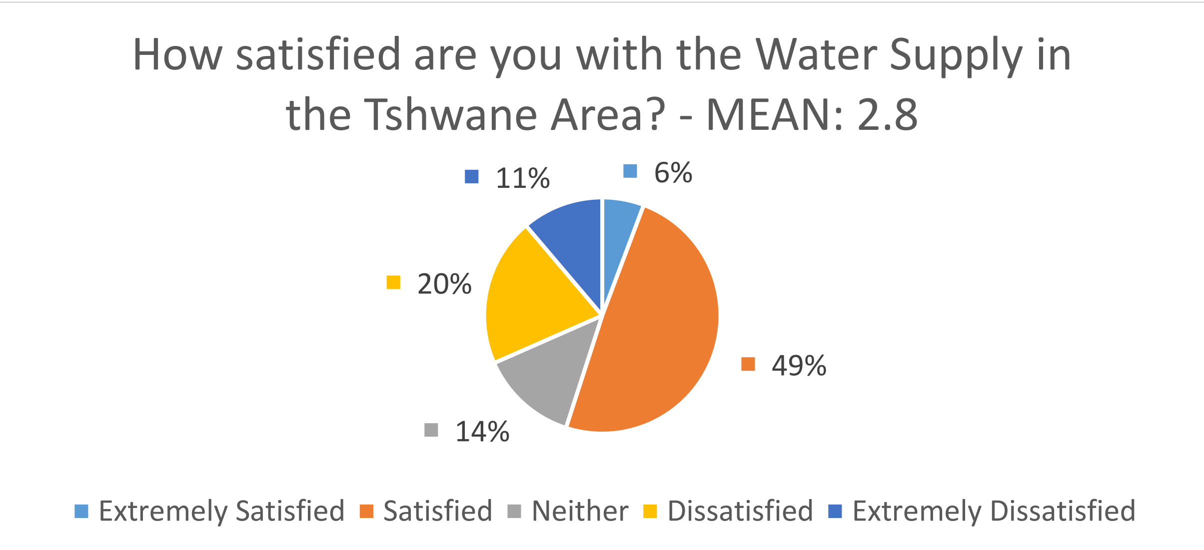

Figure 6.1: Rating level of respondents' satisfaction with water supply

Figure 6.1 rates the overall performance of the CoT on the matter of water supply as a whole. Its purpose was to rate the satisfaction level of the respondents who were CoT residents in terms of the water supply services in the city. The mean of 2.8 illustrated in Figure 6.1 means that the overall result was just slightly less than the midpoint (3). Overall respondents could be described as neither satisfied nor dissatisfied. According to the graph, 55 percent of respondents of the CoT are satisfied with the CoT water supply services, however, there is 31 percent dissatisfaction.

Figure 6.2 presents the challenges experienced by respondents during the installation of WI.

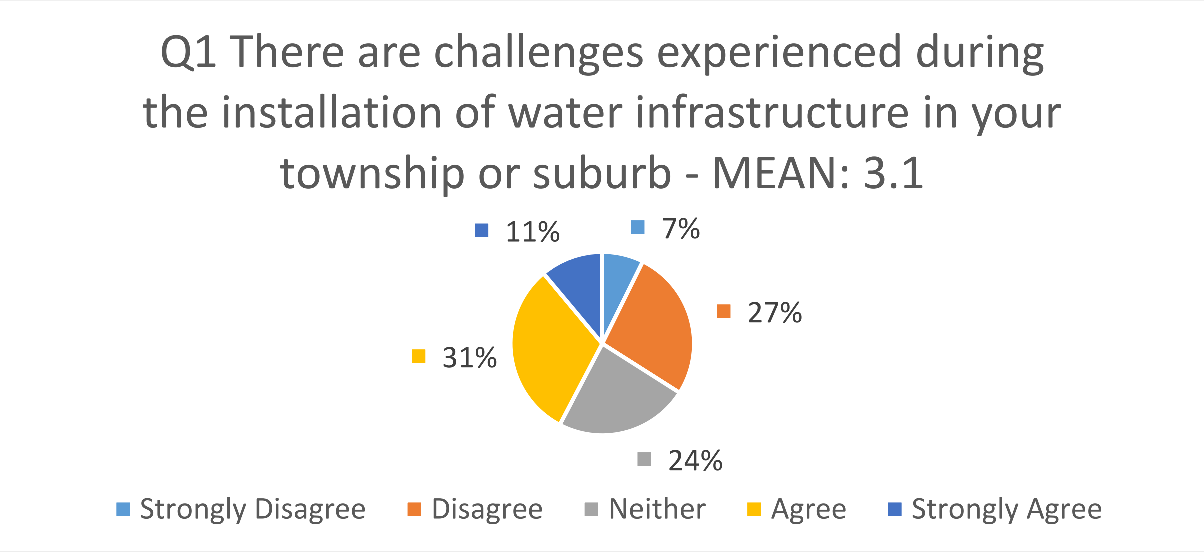

Figure 6.2: Challenges experienced by respondents during installation of WI

Figure 6.2 shows the respondents' experiences regarding the installation of WI in their suburbs. The mean of 3.1 illustrated in Figure 6.2 means that 42 percent of the respondents agreed with the statement that there are challenges experienced during the installation of water infrastructure in the townships or suburbs. It is unacceptable that more than two out of every five respondents had experienced problems with the installations. Figure 6.3 rates the challenges experienced during the maintenance of WI.

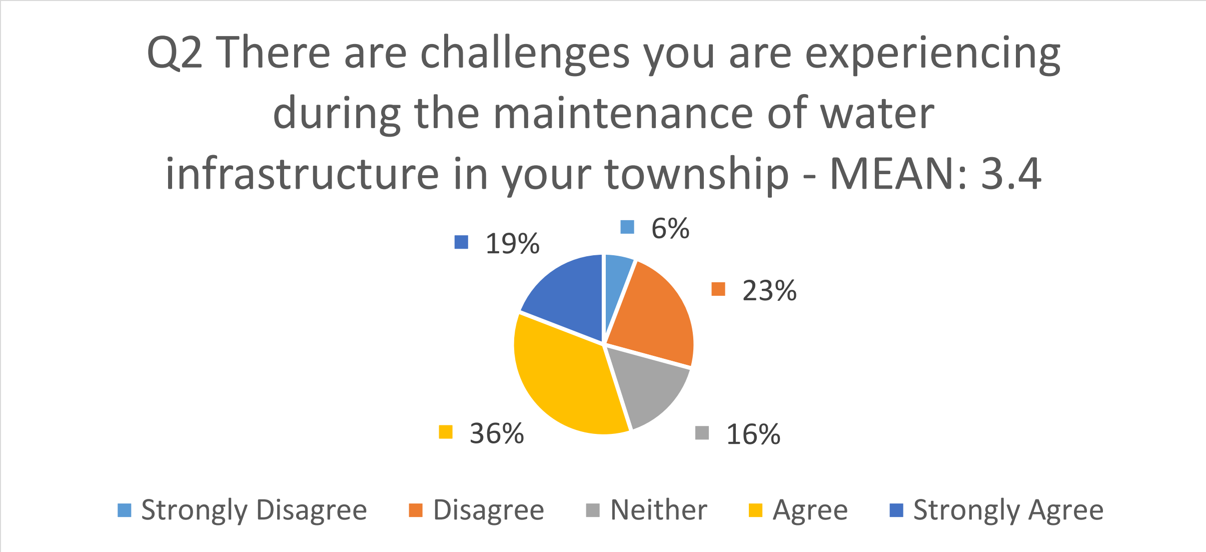

Figure 6.3: Challenges experienced during maintenance of WI

Figure 6.3 presents the experiences of the respondents when maintenance of WI is undertaken in their townships. Summarising the findings shown in Figure 6.3, 55 percent of respondents tended to agree that they are experiencing challenges, while only 29 percent tended to disagree that there were challenges. This highlights that most CoT respondents had experienced difficulties with the maintenance of the water supply.

Figure 6.4 shows the challenges arising from the contractors.

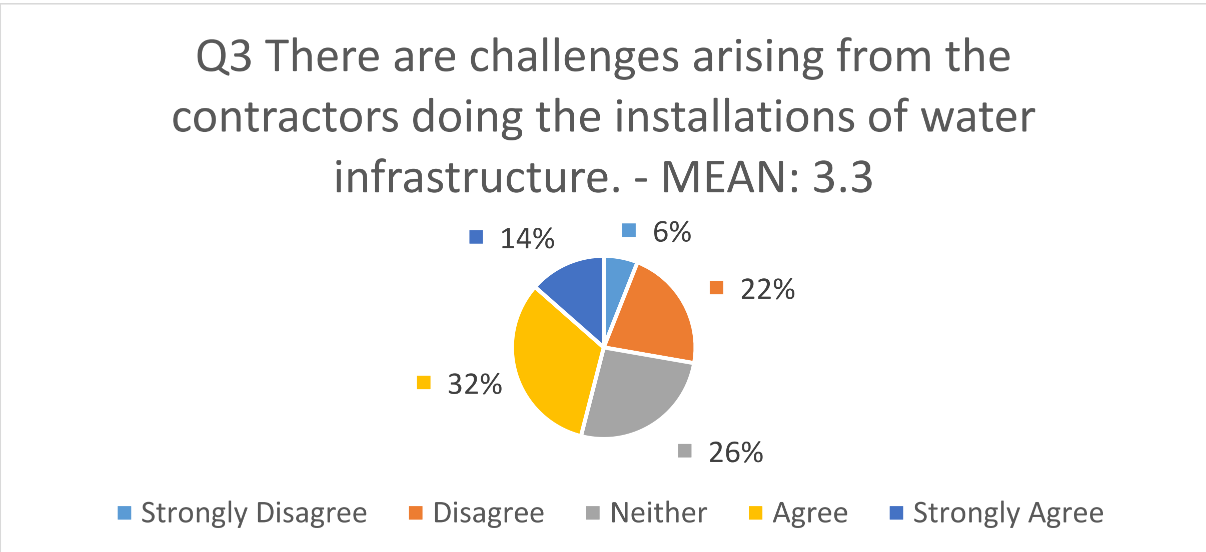

Figure 6.4: Level of challenges arising from contractors installing WI

Figure 6.4 illustrates the level of challenges the respondents experienced with the installation contractors. The mean of 3.3 in Figure 6.4 shows that was a tendency towards agreement. In this category, 46 percent of the respondents agreed compared to 28 percent of disagreements.

Figure 6.5 assesses the challenges arising because of the municipality regarding WI installations.

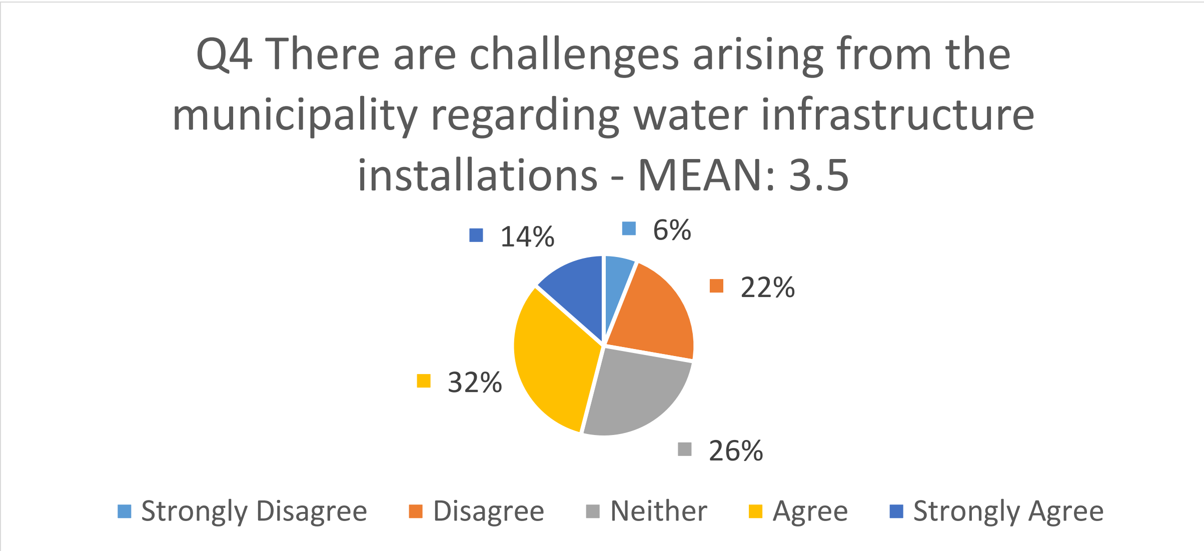

Figure 6.5: Challenges arising from municipality regarding installation of WI

Figure 6.5 illustrates the challenges perceived by respondents relating to the municipality. The mean of 3.5 illustrated in Figure 6.5 means that there is a slight level of agreement with the statement. A summary of the responses indicated that 46 percent agreed and 28 percent disagreed with the statement.

Figure 6.6 assesses political interference.

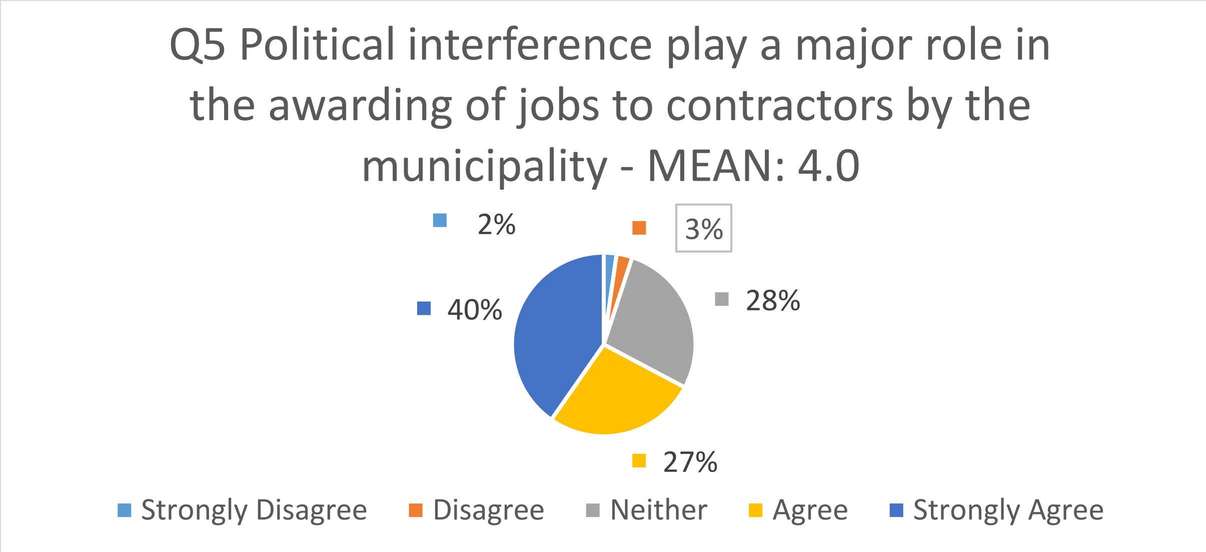

Figure 6.6: Political interference in awarding of jobs to contractors

Figure 6.6 illustrates perceived political meddling when the jobs are given to the contractors.

With a mean of 4.0, Figure 6.6 shows that the majority of respondents agree with the statement. A summary of the results shows that 67 percent agreement as opposed to 5 percent disagreement.

Figure 6.7 evaluates safety during installation and maintenance.

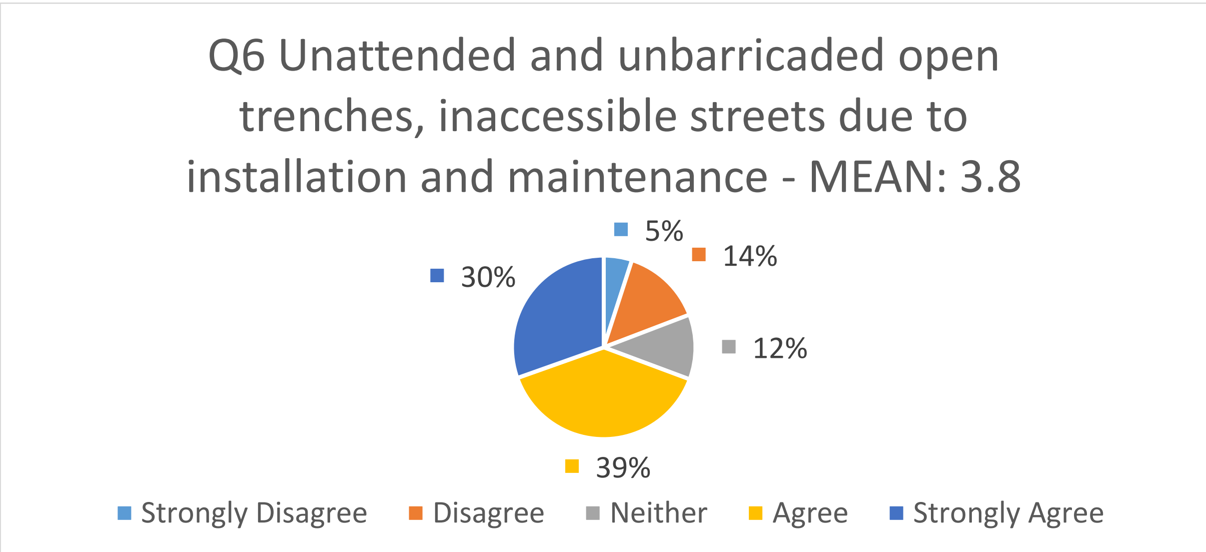

Figure 6.7: Trench safety/ street accessibility during installation and maintenance

Figure 6.7 shows the results for the safety of the trenches and street accessibility when installation and maintenance are in progress. With a mean of 3.8, Figure 6.7 shows that the responses support the statement. Summarising the findings shown in Figure 6.7, 69 percent of respondents tended to agree that the trenches in the CoT are unattended with no barricades. This indicates a very real potential danger for citizens.

Figure 6.8 assesses the impact of strikes by the contractors.

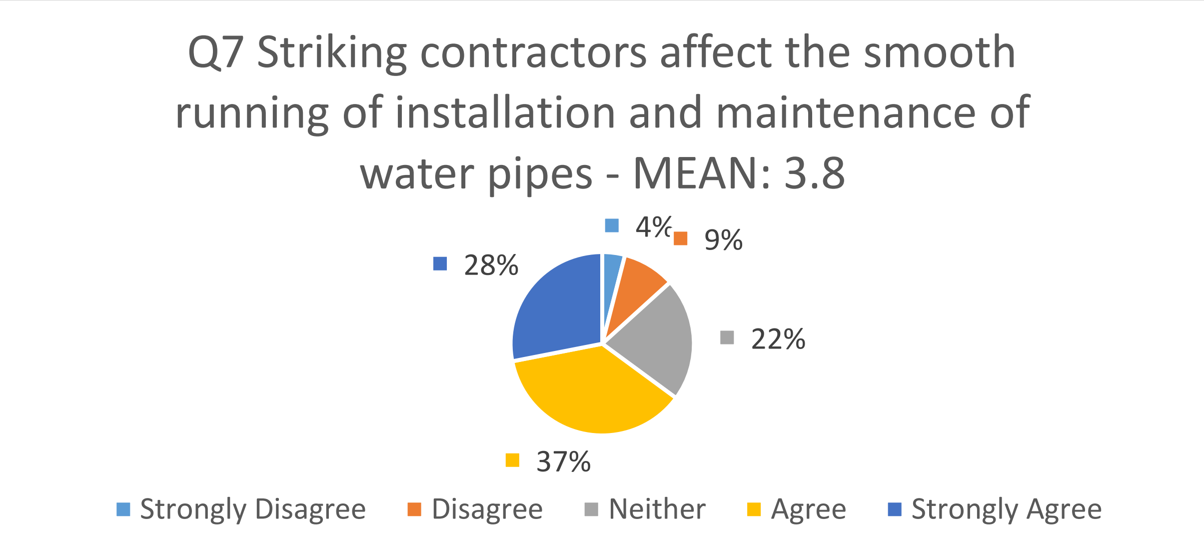

Figure 6.8: Perceived effect of striking contractors

With a mean of 3.8, Figure 6.8 shows that more than half of the respondents agree with the statement.

Summarising the findings shown in Figure 6.8, 65 percent of respondents agreed that striking contractors affect the work, while only 13 percent disagreed. This highlights that most respondents had experienced difficulties when contractors go on strike.

Figure 6.9 evaluates the perceived ownership of companies.

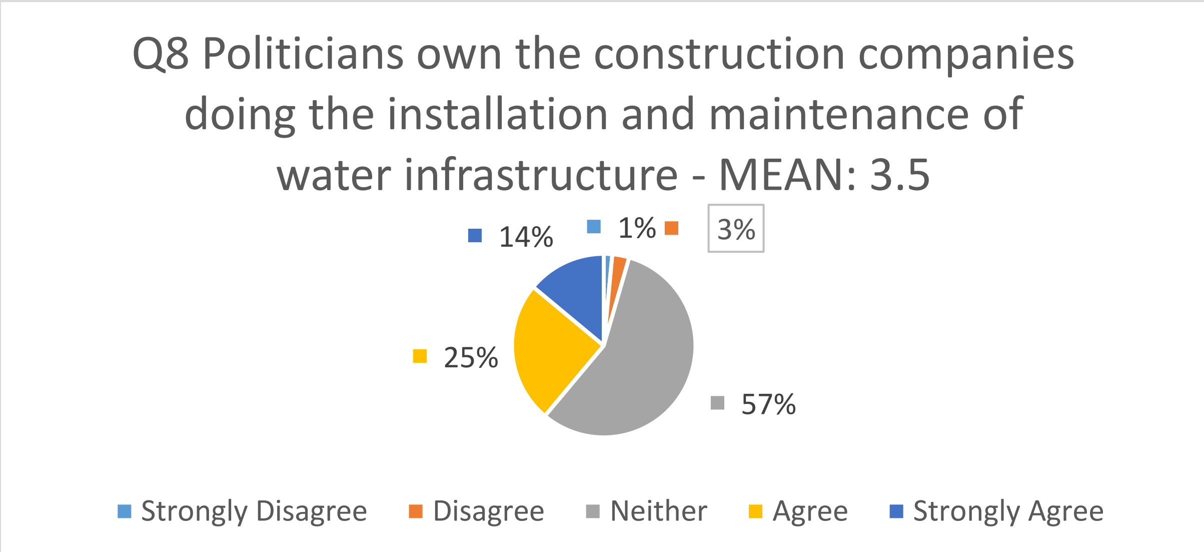

Figure 6.9: Perceived ownership of construction companies by politicians

Figure 6.9 demonstrates the percentage of politicians perceived to be owning the companies contracted to CoT. The mean of 3.5 illustrated in Figure 6.9 shows that there is a high level of agreement and a neutral position compared to the rest of the categories. Summarising the findings shown in Figure 6.9, 39 percent of respondents agreed that politicians own the companies contracted to the city, while only 4 percent disagreed, however, 57 percent were undecided.

Figure 6.10 evaluates the technical and management capacity of staff.

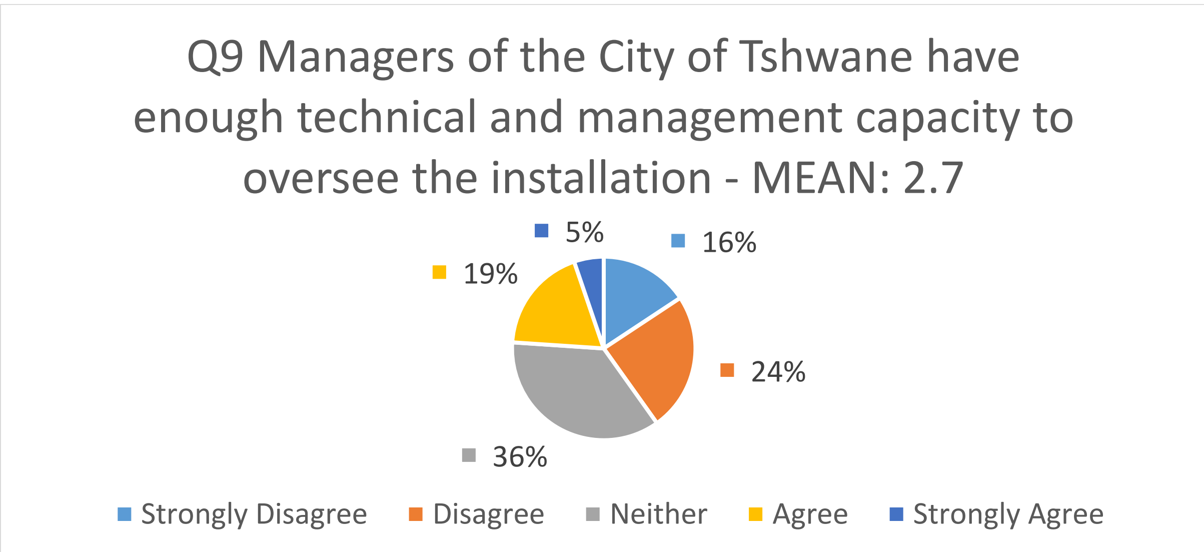

Figure 6.10: Managers' technical and management capacity

Figure 6.10 illustrates the results of CoT management and technical capacity in the management of WI installations. With a mean of 2.7, Figure 6.10 shows that most respondents do not support the statement. Summarising the findings shown in Figure 6.10, 40 percent of respondents tended to disagree that CoT management has enough technical and management capacity to run the installations, while only 24 percent tended to agree, however, there 36 percent undecided respondents. This highlights that most CoT residents perceive the management of CoT as incapable of taking care of WI installations.

Figure 6.11 assesses if contractors conform with minimum health and safety standards.

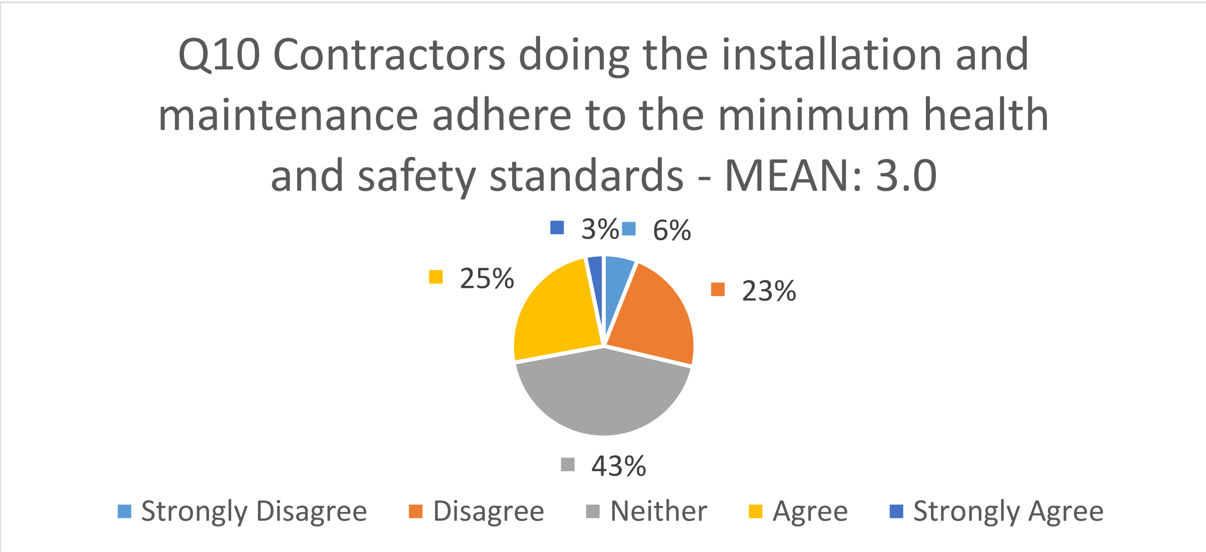

Figure 6.11: Contractors' adherence to health and safety standards

Figure 6.11: describes the results of the contractors' conformance to the set health and safety standards.

With a mean of 3.0, Figure 6.11 shows that most respondents do not support the statement. Summarising the findings shown in Figure 6.11, it is apparent that 29 percent of respondents tended to disagree that the contractors conform to the set standards, while only 28 percent tended to agree that contractors do comply, however, there were 43 percent undecided respondents. This highlights that most respondents perceived the contractors as not adhering to the health and safety standards.

Figure 6.12 evaluates the possibility of delays from the contractors.

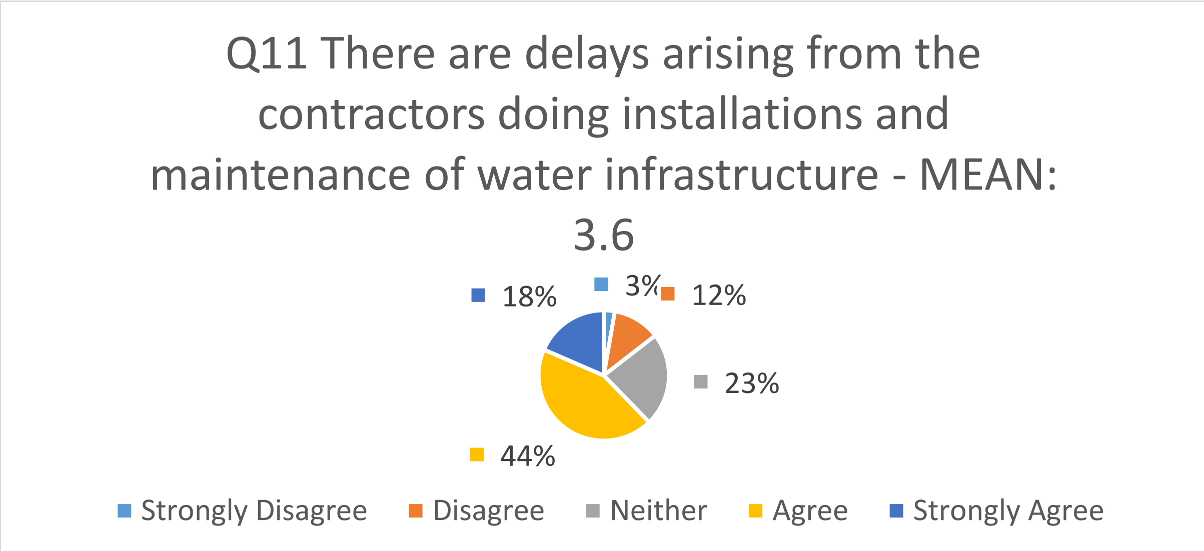

Figure 6.12: Perceived delays from contractors that install and maintain WI

Figure 6.12 describes the results for the possibility of delays from the contractors doing the work for the municipality. A mean of 3.6 in Figure 6.12 shows that most respondents support the statement. Summarising the findings shown in Figure 6.12, it is apparent that 62 percent of respondents tended to agree that the contractors cause the delays to the installation and maintenance work, while only 15 percent tended to disagree, however, 23 percent were undecided. This highlights that most respondents perceived that contractors do cause some delays when doing the work.

Figure 6.13 assesses the possibility of public disturbance of the contractors' work.

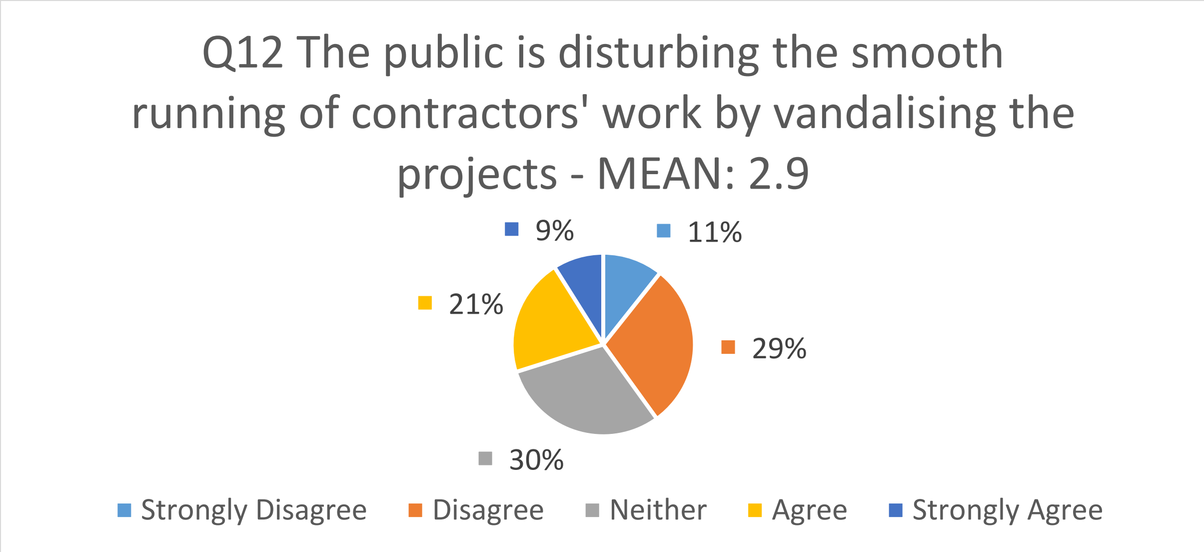

Figure 6.13: Vandalism of contractors' work by the public

Figure 6.13 describes the results regarding vandalism of projects by members of the public. A mean of 2.9 in Figure 6.13 shows that most respondents do not support the statement. The findings shown in Figure 6.13, demonstrate that 40 percent of respondents tended to disagree that the public vandalise the projects, while 30 percent tended to agree, however, 30 percent were undecided. This highlights that most CoT residents perceive that the public do not vandalise the projects.

Figure 6.14 evaluates the availability of strategy from the city managers.

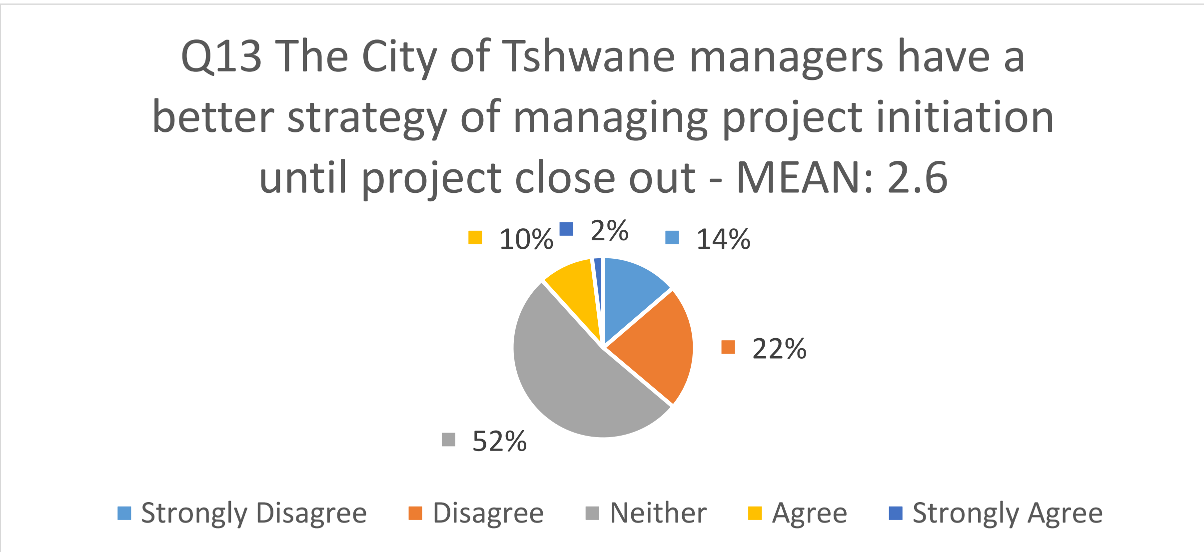

Figure 6.14: Managers' better strategies to manage project life cycle

Figure 6.14: describes the results for the strategic management of projects by the CoT managers. A mean of 2.6 in Figure 6.14 shows that a large block of respondents does not support the statement. The findings shown in Figure 6.14, demonstrate that 52 percent of respondents neither agreed nor disagreed that there is the strategic management of projects, while 36 percent tended to disagree, and 12 percent of respondents agreed. This highlights that most CoT respondents were neutral about the strategic management of the projects, although a high level of disagreement was recorded.

Figure 6.15 assesses the political support for the projects.

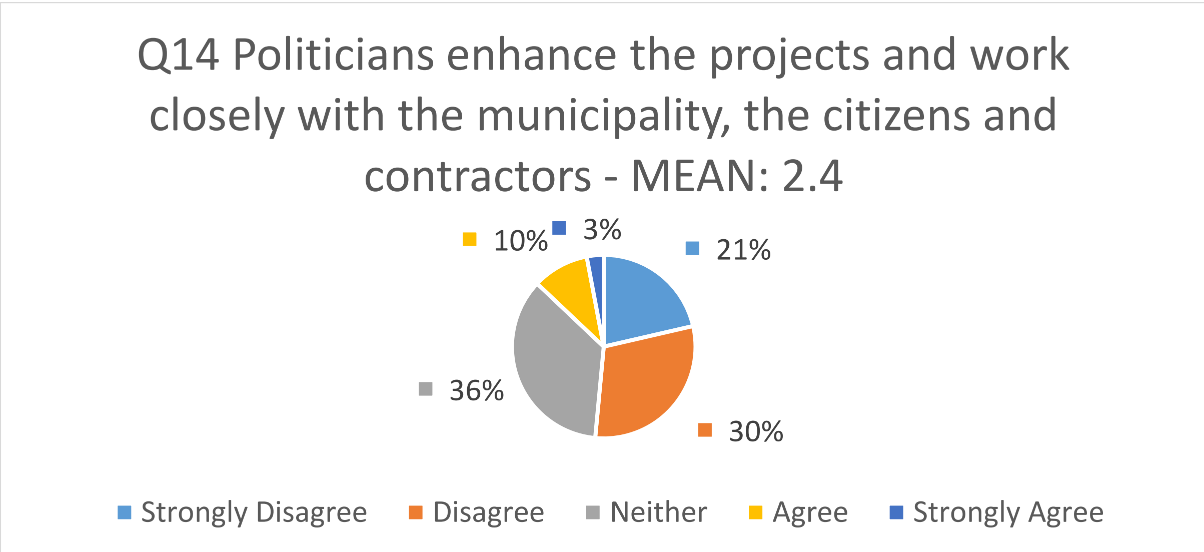

Figure 6.15: Perceived political support for projects and cooperation

Figure 6.15 describes the results for the political enhancement of the projects. A mean of 2.4 shows that the respondents did not agree with the statement. The findings demonstrate that 51 percent of respondents disagreed that politicians enhance the projects, while 36 percent were neutral, while 13 percent of respondents agreed. This highlights that most respondents observe no political support for projects or cooperation.

Figure 6.16 illustrates a summarised version of the means for all the survey questions.

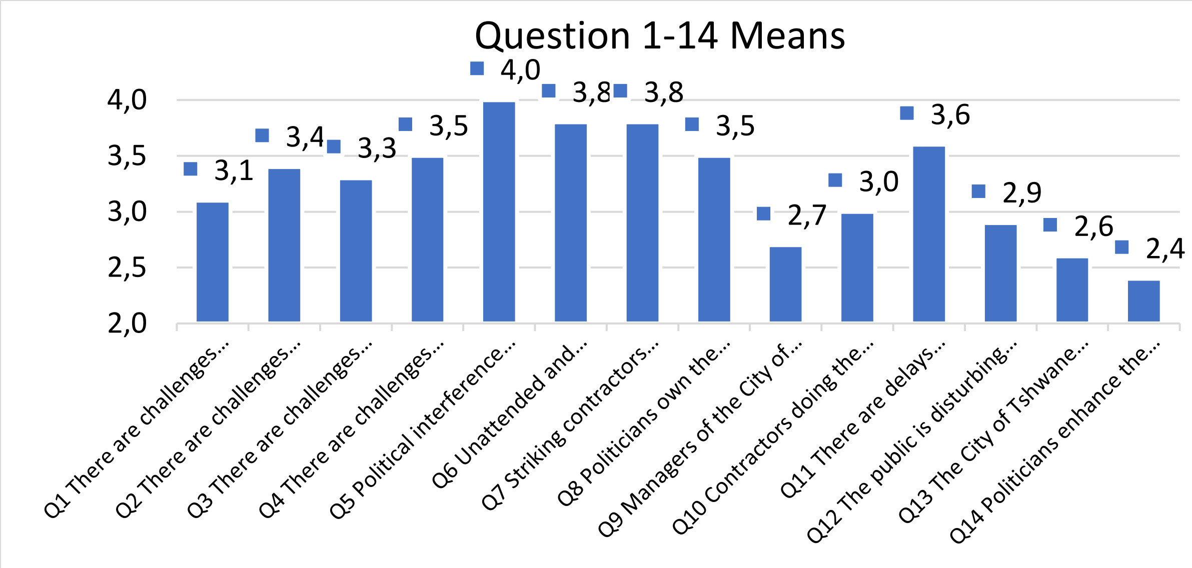

Figure 6.16: Means for survey questions

Figure 6.16 illustrates the means as presented, with the higher the mean the greater the level of interest shown by the respondents to the question. The means with scores above three show a more positive response, while the means below three show a more negative response. There are four scores below three and this is an indication of negative responses.

A summary of the responses from the CoT resident respondents in terms of the survey is tabulated in Table 6.2. The figures in the table represent the percentages of the responses to each question or statement.

Table 6.2: Analysis of CoT resident respondent's survey responses

Item No	Statements	Strongly disagree	Dis-agree	Neither agree nor disagree	Agree	Strongly agree	Total
Q1	There are challenges experienced during the installation of water infrastructure in your township or suburb.	7%	26%	23%	31%	11%	100%
Q2	There are challenges experienced during the maintenance of water infrastructure in your township or suburb.	6%	23%	16%	35%	19%	100%
Q3	There are challenges arising from the contractors doing the installations of water infrastructure.	6%	22%	26%	32%	13%	100%
Q4	There are challenges arising from the municipality regarding water infrastructure installations.	6%	19%	17%	39%	18%	100%
Q5	Political interferences play a major role in the awarding of jobs to contractors by the municipality.	2%	3%	27%	27%	40%	100%
Q6	Unattended and unbarricaded open trenches, inaccessible streets due to installation and maintenance of water pipes, materials lying around for a long time, unnoticed water cut-offs, etc. are a few challenges experienced by the citizens.	5%	14%	11%	39%	30%	100%
Q7	Striking contractors affect the smooth running of the installation and maintenance of water pipes.	4%	9%	22%	36%	28%	100%
Q8	Politicians own the construction companies doing the installation and maintenance of water infrastructure.	1%	3%	56%	25%	14%	100%
Q9	Managers of the City of Tshwane have enough technical and management capacity to oversee the installation and maintenance of the contractor's work.	16%	24%	36%	19%	5%	100%
Q10	Contractors doing the installation and maintenance adhere to the minimum health and safety standards.	6%	23%	43%	25%	3%	100%
Q11	There are delays arising from the contractors doing installations and maintenance of water infrastructure.	3%	12%	23%	43%	18%	100%
Q12	The public is disturbing the smooth running of contractors' work by vandalising the projects.	11%	29%	30%	21%	9%	100%
Q13	The City of Tshwane's managers have a better strategy of managing project initiation until the project closeout by contractors.	14%	22%	52%	10%	2%	100%
Q14	Politicians enhance the projects and work closely with the municipality, the citizens, and contractors for project success.	21%	30%	35%	10%	3%	100%

6.3 Reliability statistics

6.3.1 Cronbach's alpha

Several statistical indexes may be applied to evaluate internal consistency. Examples include the average inter-item correlation, average item total correlation, and split-half reliability, but Wells and Wollack (2003: 4) recommend the Cronbach's alpha. This study adopted Cronbach’s alpha as the measure of internal consistency for the survey measurement scale. According to Wells and Wollack (2003:4), Cronbach’s alpha measures the extent to which the items on a measurement scale or test produces consistent results. Cronbach’s alpha is often considered a measure of item homogeneity. Where the values of alpha are larger, the implication is that items tap a common domain.

The scale in Cronbach’s reliability test ranges from 0 to 1. Scores that are close to 1 indicate that the instrument has high reliability, while scores close to 0 indicate that the reliability of the instrument is low (Wells and Wollack, 2003:4). Most researchers require the reliability of at least 0.7 in order to use the instrument.

In this study, the Statistical Package for the Social Sciences (SPSS Version 27) was used to assess the reliability of the measuring instrument. This test provided a summary of inter-correlations that existed among the items on the challenges of managing WI in a selected SA municipality**.** These values are presented in Table 6.3.

Table 6.3: Reliability statistics

Constructs	Number of items	Sample size (n)	Cronbach's Alpha (α)
Community challenges	3	402	.782
Contractor's challenges	5	402	.656
Municipal and Political challenges	3	402	.650
Managerial and political support	3	402	.596
Overall	14	402	.730

Source: Researcher

The 14 associated questions were combined to form four research constructs shown in Table 6.3. Cronbach's alpha reliability tests were performed on each of the four research constructs to ensure the scale's reliability. One construct had a Cronbach's Alpha of 0.782, while the other three ranged between 0.596 and 0.656. Khare and Rakesh (2010: 213) maintain that a Cronbach’s alpha value of 0.600 is acceptable for a newly developed construct, which is applicable in this situation. Since three of the constructs score above 0.6 and the fourth was only marginally below the 0.6 requirement for a newly constructed instrument, the instrument can be accepted as reliable. Furthermore, as shown in Table 6.3, the overall Cronbach's alpha value in the study was greater than the minimum threshold of 0.7, further indicating that the scale was reliable.

6.3.2 Exploratory factor analysis

Exploratory factor analysis using the principal components analysis procedure was performed to check the factor structure of all research constructs. To determine the factorability of the data, a Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity were computed. The smallest KMO value attained was 0.875 (Table 6.4), which is above the minimum cut-off value of 0.5 (KMO > 0.5) and all results for Bartlett's test were significant at 0.000 (p value sig < 0.05). The values therefore warrant a further factor analysis of the data (Madanchian *et al*. 2018: 971; Yap, Komalasari and Hadiansah 2018: 142; Napitupulu, Kadar, and Jati 2017: 700, 702; Field 2013: 687, 695).

Communalities for all items were acceptable as they ranged between 0.376 and 0.838, which were above the recommended minimum threshold value of 0.3 (Jokwiro *et al*. 2022: 5; de Souza *et al*. 2014: 3249). Only those factors with eigenvalues greater than 1 (Mahmoudi *et al*. 2021: 2; Napitupulu, Kadar, and Jati 2017: 701), and items with factor loadings higher than 0.5 were retained (de Souza *et al*. 2014: 3246), in line with the original recommendation by Kaiser (1960: 145). The EFA procedure revealed that each of the 14 items had a one-dimensional structure. The results of the EFA, including the Cronbach's alpha, mean scores, standard deviations, and tests for normality are presented in Table 6.4. Table 6.4 reveals that the factor loadings derived from the EFA for all four research constructs were high, surpassing the 0.5 minimum cut-off value and reflect strong and significant results (Napitupulu, Kadar, and Jati 2017: 701).

Eigenvalues were above the lowest prescribed cut-off value of 1.0 and ranged from a minimum of 2.604 (SCI) to a maximum of 3.976 (SCP). In terms of the cumulative percentage of variance explained, all four research constructs scored less than the recommended minimum of 60 percent (Hair *et al*. 2014). The range for the overall mean scores for the scales (2.46 to 4.00) signified an inclination towards the 'agree' and 'strongly agree' positions on the Likert scale. This result is in agreement with the questions on each measurement scale. Thus, respondents perceived that all four research constructs were valid measurements for the perceived challenges of managing water infrastructure in a selected South African municipality.

As indicated in Table 6.4, KMO scores for all scales were above the recommended minimum threshold of 0.5, and Bartlett's test results for all scales were significant (sig.000). These results confirmed that the sample size was sufficient for EFA, and that the data were factorable. Therefore, no items were discarded from any of the four scales as all recommended thresholds were met (factor loadings > 0.5; eigenvalues > 1.0; communalities > 0.4). Additionally, percentages of variances for all five scales were higher than the 60 percent minimum cut-off value recommended by Hair *et al*. (2010). Therefore, all four scales had one-dimensional factor structures adopted and applied in the further analyses of the data. Comprehensive data for the tests is illustrated in Table 6.4.

Table 6.4: Exploratory factor analysis, descriptive statistics, and reliability

Research construct	Item code	Factor loadings	Commu-nalities	Eigen-values	% of variance	Mean	Std. dev	KMO	Bartlett's test
Community challenges	Q1	.743	.713	5.090	36.358	3.10	1.155	.663	Approx. Chi Sq. 371.798 df 3 sig .000
	Q2	.783	.795	1.747	12.478	3.38	1.214		
	Q6	.721	.536	.716	5.117	3.75	1.178		
Contractors' challenges	Q3	.827	.798	1.332	9.516	3.24	1.138	.718	Approx. Chi Sq. 283.977 df 10 sig .000
	Q7	.639	.527	.622	4.444	3.75	1.084		
	Q11	.686	.525	.445	3.176	3.63	1.003		
	Q12	.198	.390	.323	2.309	2.88	1.133		
	Q10	.322	.376	.474	3.389	2.96	.911		
Municipal challenges and political challenges	Q4	.839	.838	.989	7.063	3.45	1.177	.621	Approx. Chi Sq. 182.514 df 3 sig .000
	Q5	.623	.549	.764	5.456	4.00	1.005		
	Q8	.498	.557	.574	4.102	3.47	.832		
Managerial and political support	Q9	.384	.404	5.29	3.776	2.73	1.103	.616	Approx. Chi Sq. 132.294 df 3 sig .000
	Q13	.327	.619	.232	1.654	2.63	.903		
	Q14	.325	.542	.163	1.161	2.46	1.029		

Source: Compiled by researcher

6.3.3 Analysis of variance

The Anova test was applied to evaluate the relationship between two or more groups and the resultant significance was 0.000. This test is performed to check if the variability of means between the groups of people are larger than what has been observed within these groups. The result indicates that there was a statistically significant relationship between people and within people who were assessed. The results of the Anova are illustrated in Table 6.5.

Table 6.5: Analysis of variance

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig
Between People		1328.596	375	3.543		
Within People	Between Items	1067.230	13	82.095	85.909	.000
	Residual	4658.556	4875	.956		
	Total	5725.786	4888	1.171		
Total		7054.381	5263	1.340		
Grand Mean = 3.25						

6.4 Qualitative data presentation and analysis as per the research objectives

This study used a survey, focus groups, and interviews to find the information and to provide answers to the research objectives and the research questions. Some of the questions, the answers, and the figures are relevant to more than one research objective. Nevertheless, the figures applicable to more than one objective have been shown in the first objective and referred to in the subsequent objectives. Analysis from the CoT managers' interviews according to the research objectives follow.

6.4.1 Objective 1: To identify the challenges experienced by the municipality during and after installations of water infrastructure

This objective has been answered by questions 1.1, 1.2, 1.4, and 2.1. The reason for the questions was to obtain information such as:

- Question 1.1: What would you say are the challenges experienced by the municipality that affect the community during installations of water infrastructure?
- Question 1.2: Are there any challenges the municipality experiences which affect the community during the maintenance of water infrastructure?
- Question 1.4: How serious are the challenges experienced in the division?

- Question 2.1: Are there challenges experienced by the contractors in the execution of projects?

6.4.1.1 Challenges of the municipality affecting the community during installation of WI

Osman, Ammar and El-Said (2017: 29) noted issues such as the failure of infrastructure resulting in traffic jams, and the lack of specific models to repair repetitive pipe breakages even in emergencies. This study provides an analysis of the issues to see if there may be better solutions to the challenges. Analysis of these challenges of the municipality during installations is detailed in Figure 6.17.

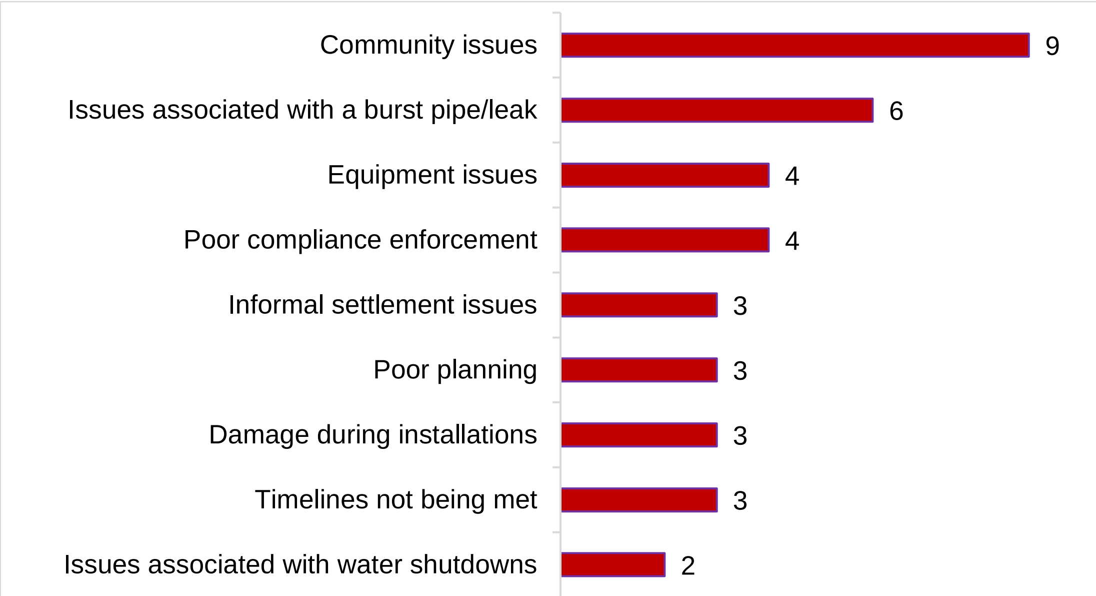

Figure 6.17: Challenges experienced by municipality during installations of WI

Figure 6.17 illustrates the results of the CoT manager respondents' perceived views of challenges experienced by the municipality during the installations of WI. Each bar is titled (for example, community issues) and shows the frequency of the issues associated therewith. The most frequently mentioned issues concerned the community, burst pipes, equipment, and poor compliance enforcement. The issues that concerned the communities dominated the discussions.

6.4.1.2 Challenges of the municipality that affected the community during maintenance of WI

Literature from Mahlalela *et al*. (2020: 2743) has pointed out that SA is disadvantaged by a lack of proper planning and inappropriately managed water resources. The CoT (2019b: 108-109) reported that the major complaints are the response time for maintenance and repairs of leaks, vandalism of the infrastructure, and lack of enforcement of the byelaws. The challenges during maintenance are presented in Figure 6.18.

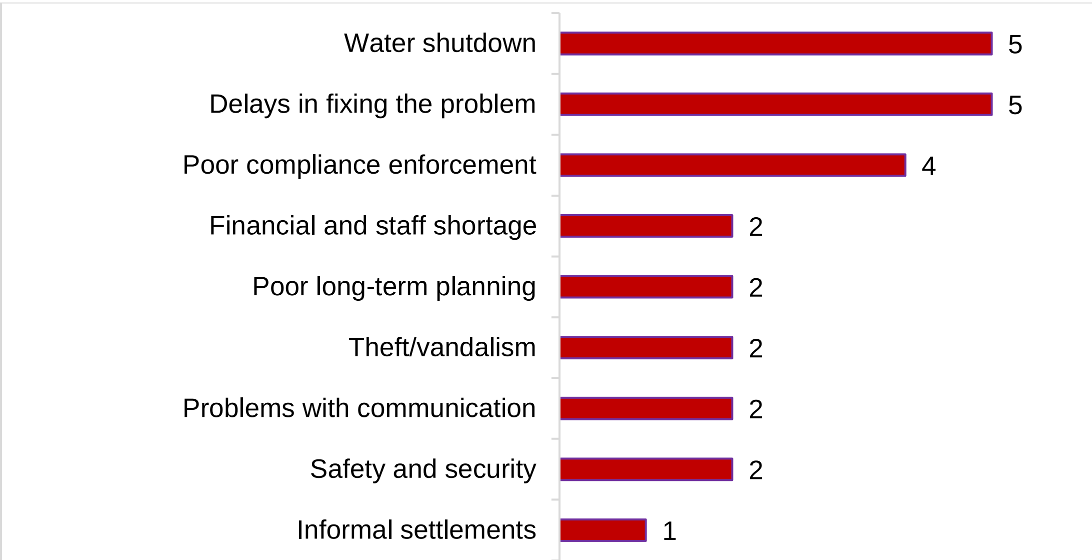

Figure 6.18: Challenges experienced by municipality during maintenance of WI

Figure 6.18 illustrates the respondents' perceived views of challenges experienced by the municipality during the maintenance of WI. The aspects that were frequently mentioned mainly covered the issues associated with the water shutdowns, delays to fixing the problems, and poor compliance enforcement.

6.4.1.3 The seriousness of the challenges in the WI division

Operating with insufficient funds to maintain the infrastructure posed a serious challenge to the effective management of the water resources in SA (Chauke 2017: 79; Ochieng 2016: 22). The sewer reticulation systems at the CoT are inadequately maintained and the infrastructure is dilapidated (Ochieng 2016: 12). The serious challenges are listed in Figure 6.19.

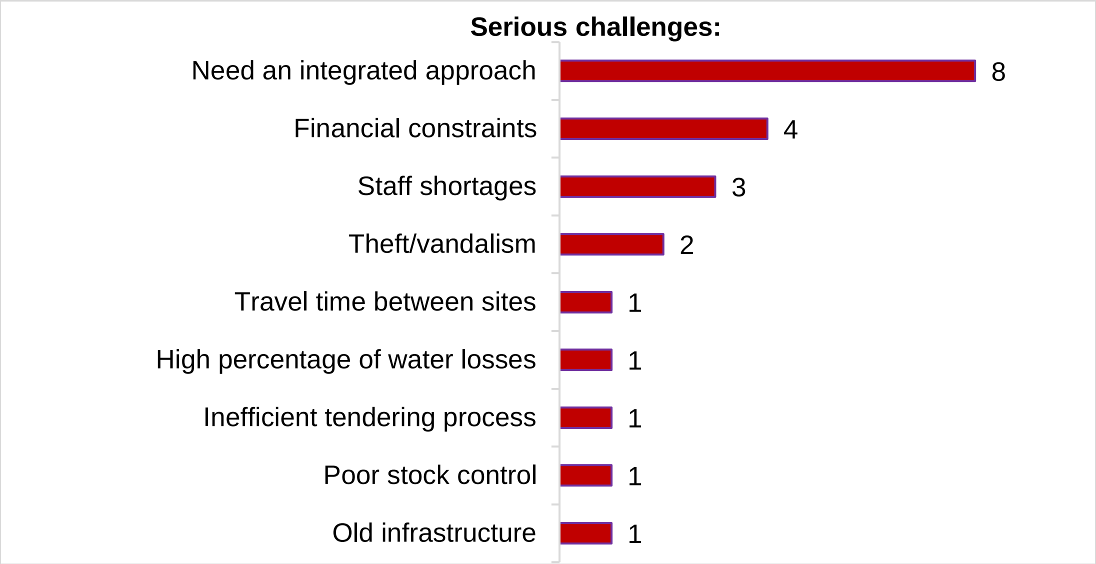

Figure 6.19: Perception of seriousness of challenges

Figure 6.19 illustrates the findings of the seriousness of the challenges experienced in the WI division. The findings indicated that the challenges needed an integrated approach to get the division running effectively. Various issues dominated the findings concerning the integrated approach and financial issues. The frequencies of both the serious and less serious challenges are indicated in Figure 6.20.

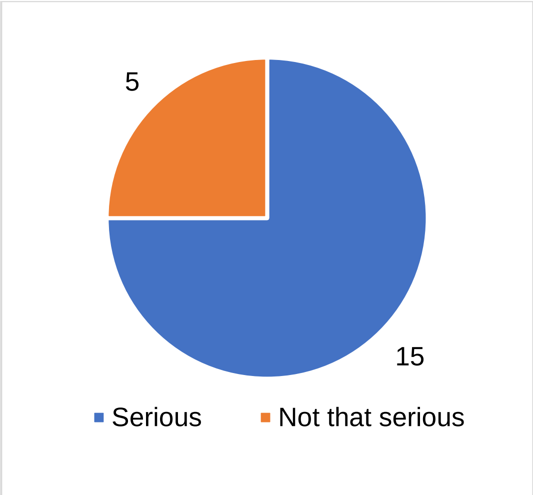

Figure 6.20: Frequency chart indicating seriousness of challenges

Figure 6.20 illustrates the frequency of the findings, indicating that 15 (75 percent) responses were about serious challenges and 5 (25 percent) responses were about challenges that were not that serious. The less serious challenges are expanded on in Figure 6.21.

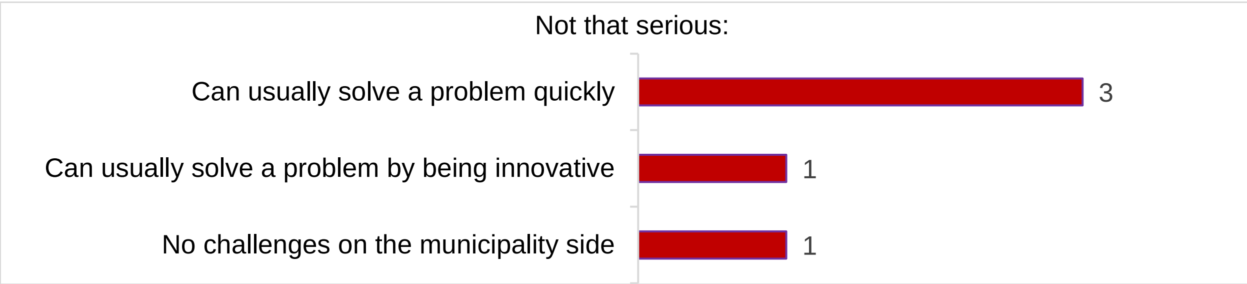

Figure 6.21: Frequency of unserious challenges

Figure 6.21 demonstrates that less serious challenges as pointed out by the findings were quickly solvable. The phrase 'quickly solvable problems' was more frequently mentioned than any other statement in the figure. Figures 6.19, 6.20, and 6.21 complement each other on the findings of the seriousness or less seriousness of the challenges in the WI division.

6.4.1.4 Challenges experienced by the contractors in the execution of projects

The challenges that SA faces include escalating skills shortages, infrastructure and service delivery bottlenecks, and political volatility (Chikowore and Willemse 2017: 87). Details regarding the challenges are in Figure 6.22.

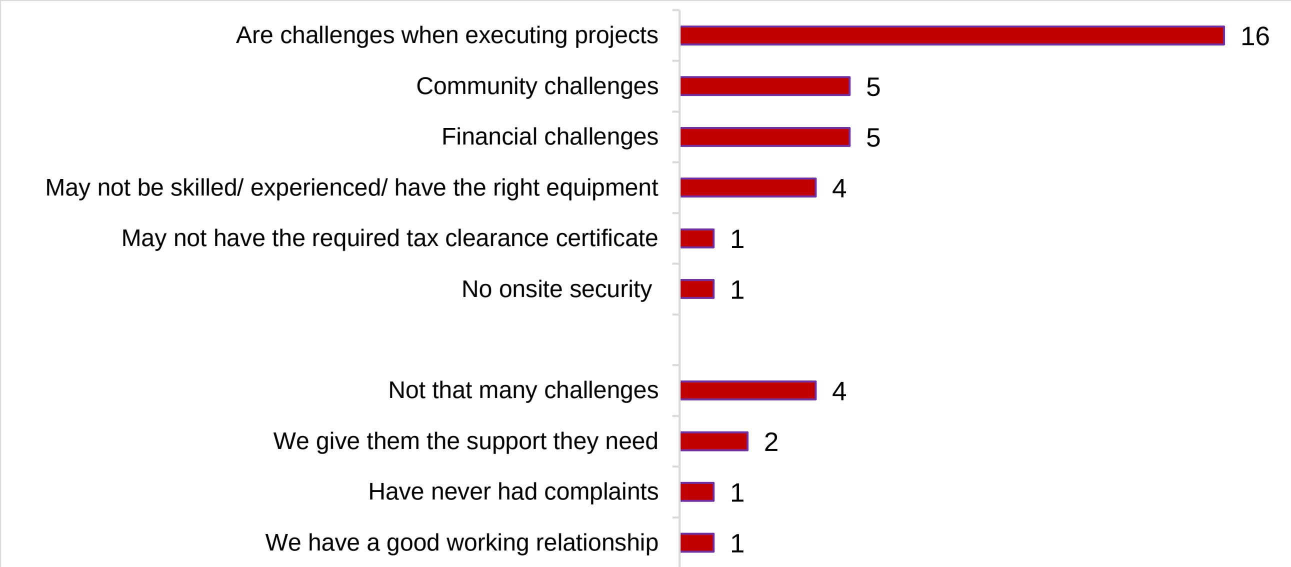

Figure 6.22: Contractors' challenges when executing projects

Figure 6.22 illustrates that there are several challenges experienced by contractors. The findings indicated that the challenges during the execution of projects were dominant, and the next categories with high frequencies were community challenges and financial challenges as indicated in Figure 6.22. The next categories with high frequencies were a shortage of skills or experience, and lack of the right equipment.

6.4.1.5 Conclusion re: Objective 1

This objective has identified that the CoT is facing multiple challenges regarding WI. The respondents indicated that community issues such as burst pipes / leaks, damage to pipes during the installations are some of the challenges faced by the city. The respondents further identified the lack of equipment, poor enforcement of the municipal bylaws, poor planning, and lack of finance as contributors to the underperformance of the WI division. These factors were most frequently mentioned by the respondents in various aspects of this study.

6.4.2 Objective 2: To rank the importance of the identified challenges experienced by the municipality

Literature from the Portfolio Committee Human Settlement, Water and Sanitation (2019) has provided a framework for the dissatisfactions pointed out by the residents of the CoT.

6.4.2.1 Question 1.5: Can a framework of challenges and causes be recommended to city?

This objective has been answered by question 1.5. The reason for the question was to obtain the views of the respondents whether a framework of the challenges and causes had to be recommended to the city or otherwise.

The results of the recommendations are in Figure 6.23.

Figure 6.23: Recommendations of a framework of challenges and causes

Figure 6.23 indicates that the findings on the question about the recommendation of a framework favoured a framework to be presented to the city officials. The most common phrases mentioned were “a better way of doing things”, and “a more integrated approach”. Respondents commented on the fact that previously concerns have been raised but no changes have come about. The results of the frequency of the responses are outlined in Figure 6.24.

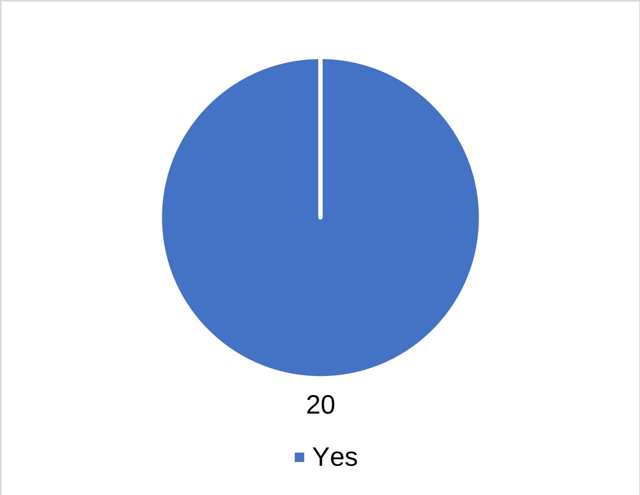

Figure 6.24: Responses in favour of recommendation of a framework to city

Figure 6.24 illustrates that the findings pointed out 100 percent of the responses supported the framework to be made known to the officials of the city. Figures 6.23 and 6.24 complement each other and must be read together.

6.4.2.2 Conclusion re: Objective 2

According to Objective 2, the majority of the respondents proposed that the framework of the challenges should be presented to the executives of the city. In addition, the respondents expressed the hope that the proposal could bring advanced changes, bring about a more integrated approach, and help in the research inputs. The respondents were all in favour of the framework.

6.4.3 Objective 3: To explore the root causes of challenges during installation of water infrastructure

While technology is viewed as one of the challenges, the New Zealand Controller and Auditor-General (2017: 11, 13) pointed out that technology has a major role to play in managing the water services. Technology can assist in the efficient use of water and ease water pollution. The Department of Cooperative Governance (2018: 28) noted one of the root causes of the challenges as being under expenditure of the allocated funds for the improvement of projects.

6.4.3.1 Question 1.3: What are the root causes of the challenges during installation of WI?

This objective has been answered by question 1.3. The reason for this question was to find out the origin of the challenges outlined in this study.

The results are outlined in Figure 6.25.

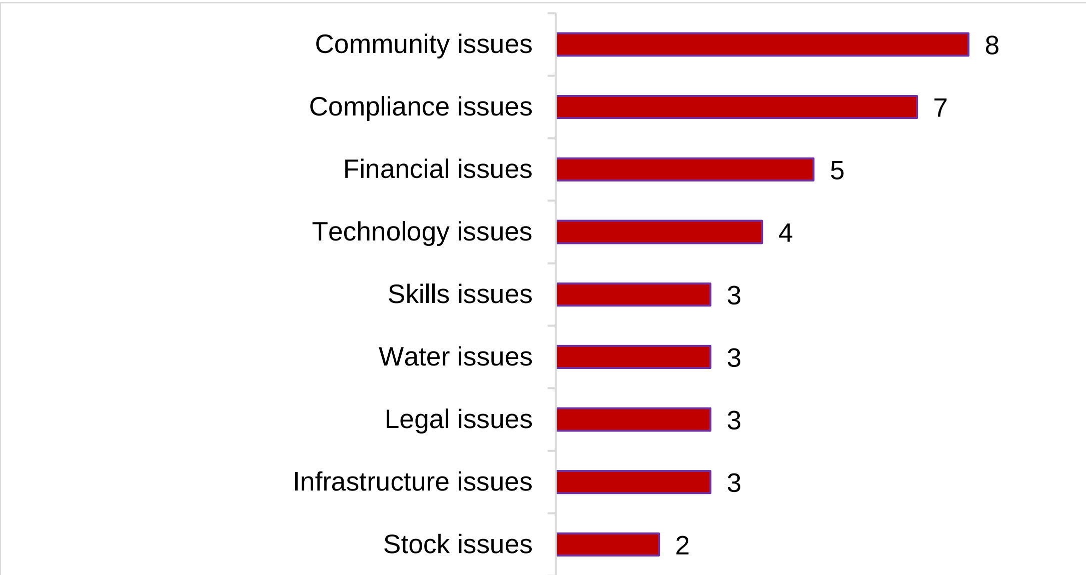

Figure 6.25: The root causes of challenges during installations of WI

Figure 6.25 depicts the results of the CoT managers' perceived views of the root causes as having much to do with community, compliance, finances, and technology issues. There are however other multiple causes as presented in the graph which are below frequency level 4.

6.4.3.2 Conclusion re: Objective 3

In terms of Objective 3, the root causes of the challenges centred around the community dissatisfactions, lack of enforcement of compliance by the city, inadequate finance, skills shortage, and employees' lack of skills to apply technology to mention a few. These issues came high in the deliberations with the respondents.

6.4.4 Objective 4: To identify how space technology can help with the management of water infrastructure

In line with this objective, the CoT has been identified as one of the cities that should consider innovation for the management of WI (Mnguni 2019: 937). Literature from Marshall (2017) has pointed out that space technology can observe water levels in reservoirs and can detect and provide quick information about the declining levels to the customers. Space technology enables android smartphones to monitor the water flow inside pipes and transfer the information to the water utility's portal (Suresh, Muthukumar and Chandapillai 2017: 1).

6.4.4.1 Question 4.3: How ready is the CoT to use space science technology?

The findings in this objective have been obtained from question 4.3. The purpose of the question was to establish if the CoT was ready to participate in the activities of space technology for WI.

In terms of the city's state of readiness, an outline is presented in Figure 6.26.

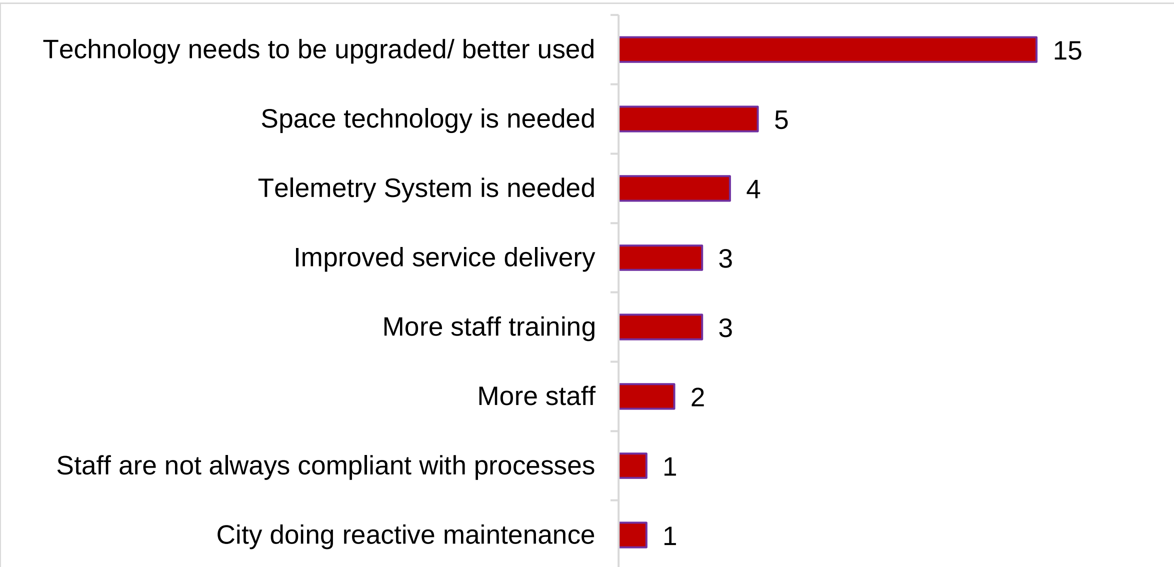

Figure 6.26: Perceptions of CoT's state of readiness to use space technology

Figure 6.26 illustrates that 44 percent of the findings indicated an upgrade of technology, 15.71 percent the need for space technology, and 11.76 percent the need for a telemetry system. The other five findings scored 8.8 percent and below.

6.4.4.2 Conclusion re: Objective 4

This objective has established that the city has to upgrade the available technology to enhance the much-needed space technology. In addition, the respondents articulated that telemetries are required to enhance service delivery. The operation of these resources requires additional staff with an advanced level of training. The conclusion of this objective implies that the city is not yet ready for the application of space technologies.

6.4.5 Objective 5: To develop a framework of the challenges and their causes

Literature demonstrated the challenges from the residents of the CoT in the form of a framework as per Table 2.1 (Portfolio Committee Human Settlement, Water and Sanitation 2019). In addition, the National Council of Provinces Finance (2017) has another framework of the challenges as per Table 3.4.

6.4.5.1 Question 1.5: Can the framework of the challenges and the causes be recommended to the city?

Question 1.5 was relevant to generate the answers to this objective. The purpose of this question was to draft a framework of the challenges and the causes.

The analysis of this question was already explained in Figure 6.23 and Figure 6.24 where the findings were similar, therefore that analysis is not repeated here for this question, except to say that 100 percent of the respondents agreed that a framework of the challenges and causes is required. Table 6.6 shows a framework of the challenges and the causes as developed by the researcher arising from the data provided by the respondents.

Table 6.6: Framework of challenges and possible causes

Challenges	Potential cause
Political interference	Subcontracting by the politicians
Community interference	Must employ within the community
Limited budget	Misuse of funds
Ineffective procurement system (tenders)	Unable to process the tender documents
Top management indecisive	Politically driven decisions
Lack of planning	Planned for reactionary maintenance
Unsafe sites	No maintenance to sites/ no security
Reluctance to upgrade the WI	No funds to do the upgrades
Vandalism/ theft	Sale of spares
Poor/ lack of maintenance	No plan for maintenance/ reactive maintenance
Shortage of staff	Lack of funding for new recruitments
Inexperienced municipal employees	Nepotism
Policies and systems are not in place	Misalignment of policies and processes
Inefficient communication	Little or no communication of messages
Lack of government involvement	Limited communication
Subjective allocation of work to contractors	Work is allocated to friends with conditions

6.4.5.2 Conclusion re: Objective 5

This objective required a framework of the challenges, which is depicted in Table 6.6. The key challenges were articulated by the respondents of this study. These are not just a list but the basis from which the city must direct the available resources to resolve the challenges.

6.4.6 Objective 6: To explore water management strategies to find possible ways to resolve the challenges

Kopung (2017: 195) asserted that the lengthy process to finalise the appointment of the successful tenders impacted on the CoT's project output. These delays affect the strategy of the municipality to serve the community.

6.4.6.1 The strategies and innovation

The findings of this objective were generated from questions 4.1 and 4.2. The purpose of the questions was as follows:

- Question 4.1: are there any gaps that open for failures in the WI division?
- Question 4.2: are there any new management strategies that you can suggest for the development of the division?

The details about the frequency of the comments from the respondents are presented in Figure 6.27.

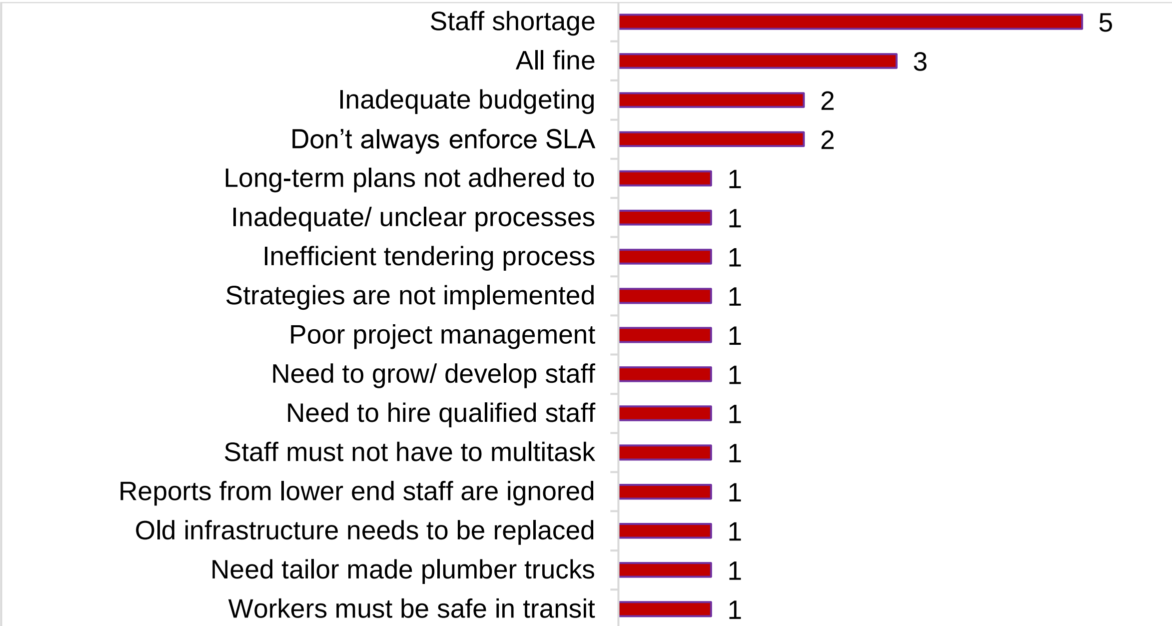

Figure 6.27: Perceptions of gaps that fail WI division

Figure 6.27 demonstrates the findings of the gaps that cause the underperformance of the division. Staff shortage as a gap came out top as the most frequent comment, followed by the “All fine” comment. Two comments tied for third most common comment, namely “Inadequate budgeting” and “Don’t aways enforce SLA [service level agreement]”. All other findings had a similar weight. The new management strategies proposed by respondents are outlined in Figure 6.28.

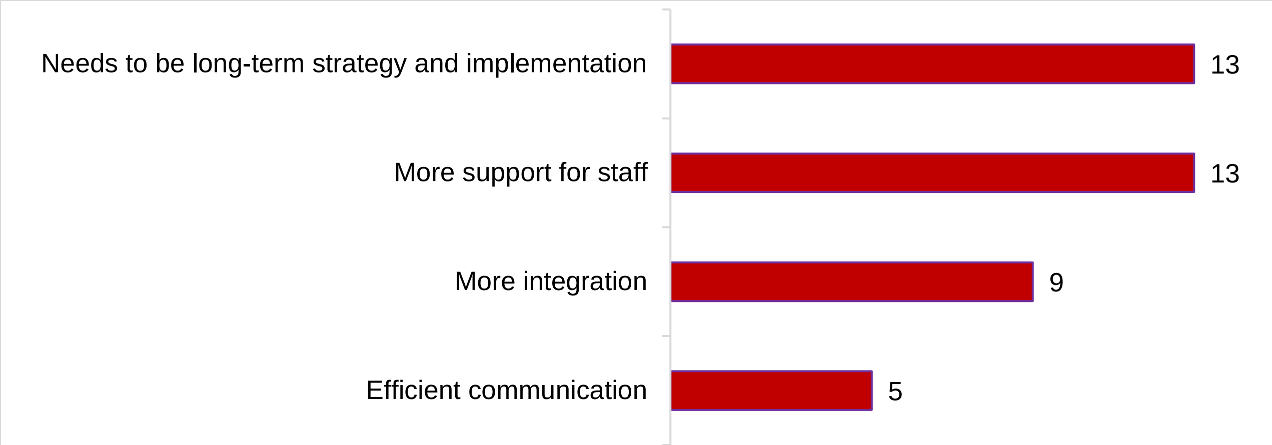

Figure 6.28: Perceptions of strategies suggested for management.

Figure 6.28 illustrates the findings of the suggested strategies which indicated four pillars. The strategies have been shown as frequencies in the figure and have been converted into percentages. The two main strategies each received 32.5 percent in the deliberations, and the remaining strategies obtained 22.5 percent and 12.5 percent respectively. The majority of respondents mentioned the need for a long-term strategy and more staff support, followed by more integration and efficient communication.

6.4.6.2 Conclusion re: Objective 6

This objective raised issues of staff shortages, inadequate budget, and ignorance of SLA. The respondents proposed strategies that stressed more support staff, efficient communication, and a long-term strategy.

6.4.7 Assistance to the contractors and management capacity

According to Sershen *et al*. (2016: 458), service delivery inequalities and the challenges faced by the municipalities have triggered the SA countrywide service delivery protests. Communities have experienced dissatisfactions such as incapable decision-makers, shortage of skills in the water sector, unreliable political undertakings, and deteriorated infrastructure. These issues indicate that there is not enough assistance from the side of management.

6.4.7.1 Assistance given to the contractors by the municipality

The purpose of the questions was to establish if the contractors had challenges in their projects, and/or whether they abided by the rules of the municipality. However, on the other side of the issues, the CoT had a low level of productivity, and irregular expenditure of R1 684 million in the 2017/18 fiscal year (Olivier 2021: 284-285). The contractors may struggle for assistance as a result.

Question 2.1: Are there challenges experienced by contractors in the execution of projects?

This question sought to answer Objective 1 in Figure 6.22 due to the answers overlapping more than one question. Therefore, Figure 6.27 has not been repeated in this section, and is only referred to. The most common responses acknowledged that there were indeed challenges in the city, however, the community challenges and financial challenges earned the second-highest responses. Other findings questioned the level of skills of the contractors.

Question 2.2: Are the contractors abiding by their contractual obligations in this municipality?

The results for this are shown in Figure 6.29.

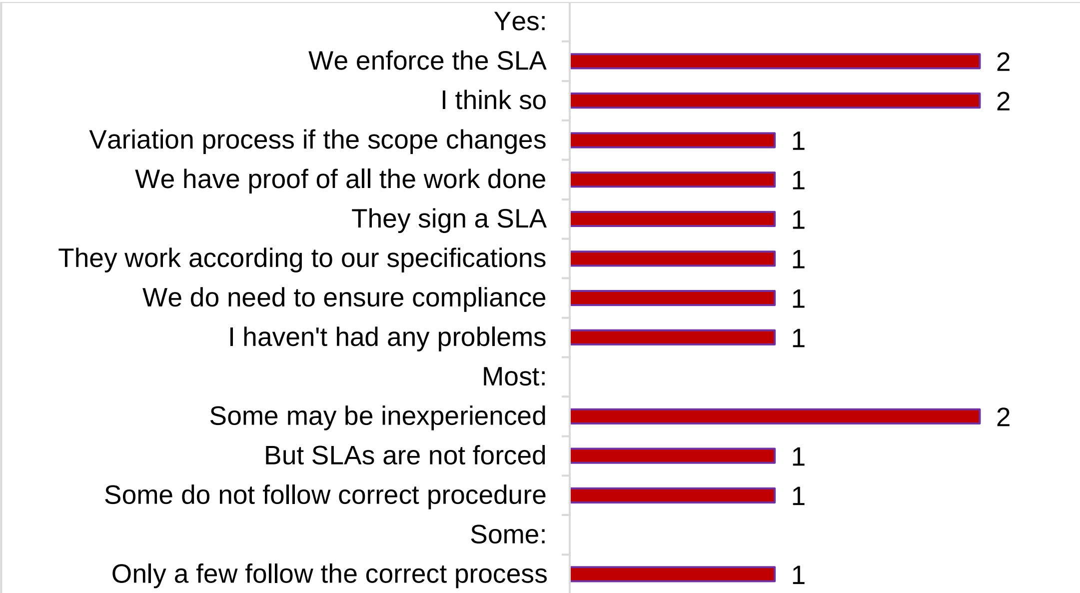

Figure 6.29: Perceptions regarding adherence to contractual obligations

Figure 6.29 demonstrates the findings of whether the contractors adhere to the obligations. The general outcome was that all the responses are positive, in other words, the findings are that the majority of contractors adhere to the rules. The findings are outlined in Figure 6.30.

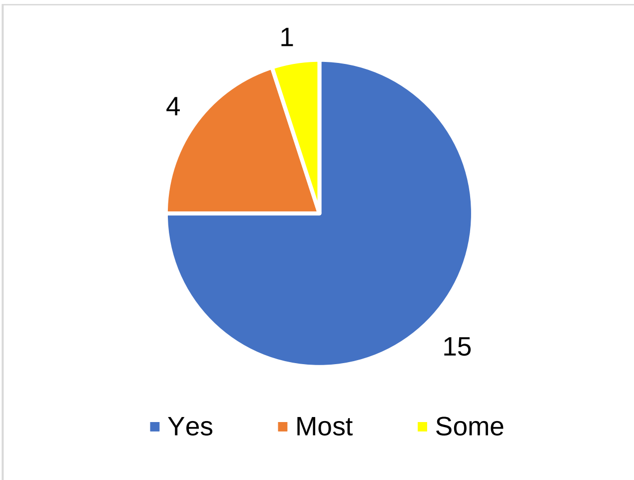

Figure 6.30: Frequencies of adherence to contractual obligations

Figure 6.30 shows that 75 percent of the comments agree that the contractors do comply, 20 percent agree that most do comply and 5 percent agree that some do comply. The responses were shown in frequencies and converted to percentages. Figures 6.29 and 6.30 complement each other in terms of the statements and the frequencies.

6.4.7.2 Management capacity in the execution of work

The purpose of these questions was to check the management capacity in terms of staff component, staff competency, and turnaround time to deal with the complaints.

- Question 3.1: Is the division having enough staff component to do the work?
- Question 3.2: What would you say about the staff competence in the division?
- Question 3.3: What is the turnaround time in response to the installation and maintenance complaints?

Dludla (2020) stated that mismanagement and irregular expenditure drove the CoT into administration. The National Council of Provinces Finance (2017) further deliberated that management of the CoT ignored the loopholes in the organisational structure and reported the matters to the law enforcement agencies at a snail's pace. The findings are illustrated in Figures 6.31, 6.32, 6.33, and 6.34.

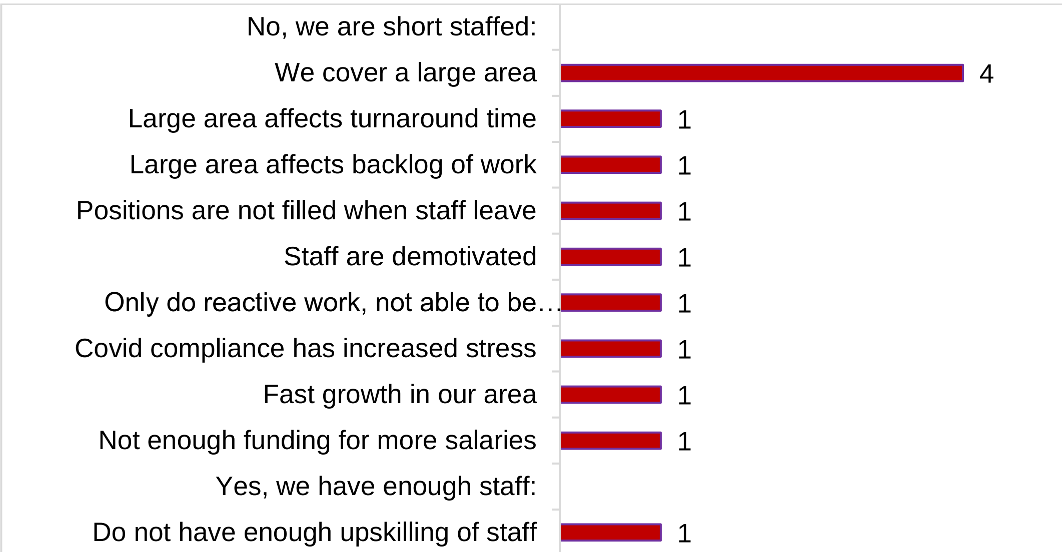

Figure 6.31: Perceptions on sufficient staff to do the work

Figure 6.31 illustrates the findings that there are not enough staff. The extent of the area that has to be covered is large and this dominated the comments by 31 percent as compared to all other statements with 8 percent frequency of comment.

The frequency of whether there was sufficient staff available to do the work is outlined in Figure 6.32.

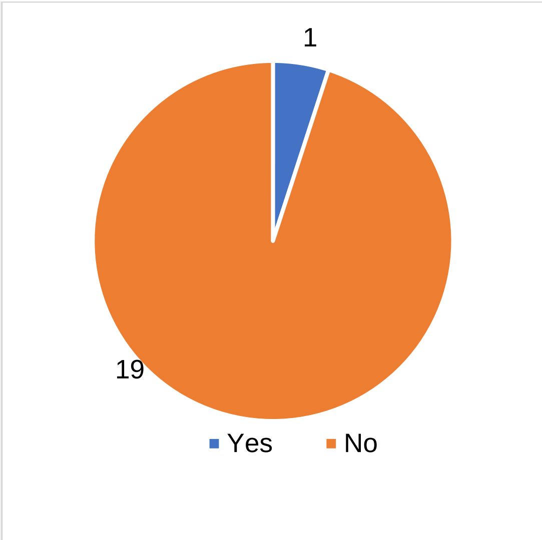

Figure 6.32: Frequency of perceptions on sufficient staff

Figure 6.32 demonstrates the perception that there was not enough staff to do the work in the WI division by 95 percent of the respondents as compared to 5 percent who felt there is enough staff.

Staff competency is presented in Figure 6.33.

Figure 6.33: Views on the staff competence for WI division

Figure 6.33 shows the finding that training of the staff has been mentioned by 36.4 percent of respondents. Three statements were each mentioned by 9.1 percent and the remaining eight statements by 4.5 percent each. The findings indicate a need for specific competency and outlined that older staff do not adapt to technology.

The findings of the turnaround time are discussed in Figure 6.34.

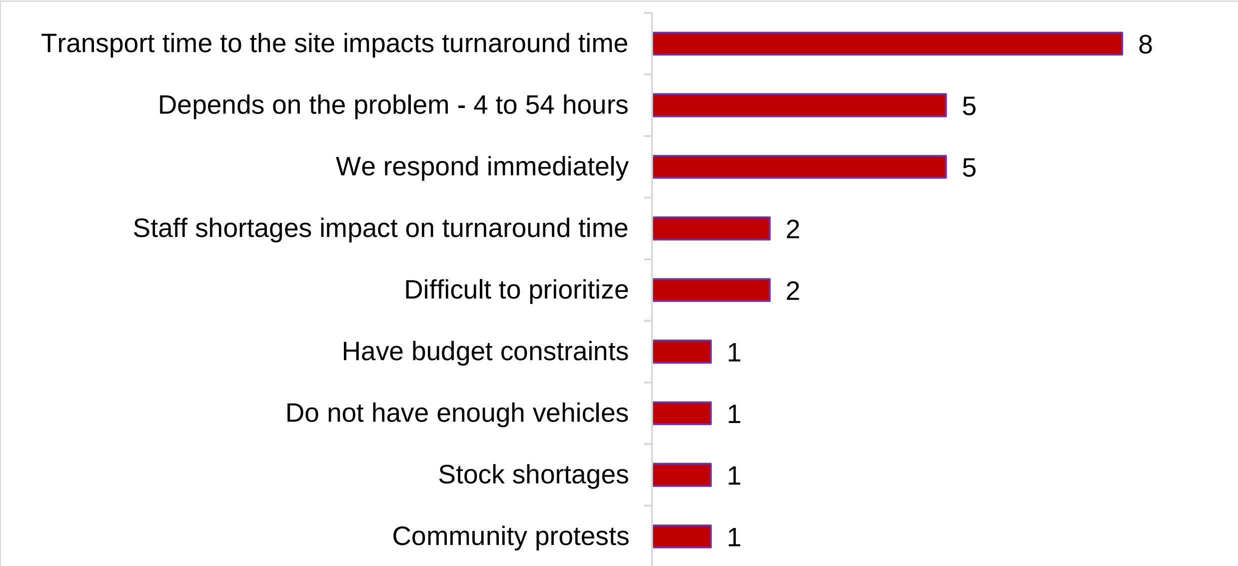

Figure 6.34: Turnaround time for installation and maintenance complaints

Figure 6.34 demonstrates that 31 percent of the respondents agreed that travelling to the sites impacts turnaround time. The next two categories scored 19.2 percent each, the next two 7.7 percent each, and the last four 3.8 percent each. The findings indicate that it takes between 4 and 54 hours to sort out a problem. The issue of shortage of staff appears in many responses – such shortages result in difficulties with allocation of work.

6.4.7.3 Conclusion to assistance to the contractors and management capacity

Management has not paid attention to equipping the water division with enough staff. There has been an outcry from the respondents about the issue of the understaffed water division. The perception of respondents was that management does not consider the large geographical extent that the overstretched employees have to cover. There is no training offered to the employees, as a result, the respondents were demotivated. The elderly staff is challenged by technology. Certain jobs needed specific competencies that needed management to initiate staff development, but management did not pay attention to that aspect. Management is not capable of running the water division effectively and efficiently.

6.5 The results of the focus groups

The results in this section cover both focus groups, namely, the contractor managers and the contractor employees. It is important to mention that some of the findings appear in more than one objective, and some appear in more than one question.

6.5.1 Objective 1: To identify the challenges experienced by the municipality during and after installation of WI

According to the literature most challenges for the CoT arose after the infrastructure had been installed. The biggest challenge that the city faces is the failure to collect the revenue (Dludla; 2020). According to Masolane (2019: 53-55), large immigration numbers into the city have placed the budget under severe strain and overwhelmed the delivery of services. As a result, the Department of Cooperative Governance (2018: 28) outlined challenges which are that staff have inadequate expertise to manage the infrastructure projects, examine the tender documents, and consult with the stakeholders. According to Olivier (2021: 285), the procurement processes of the CoT are characterised by irregularities, resulting in the “worst” financial health and position which requires rescue.

6.5.1.1 Challenges experienced by the municipality during and after installations of WI

The results for this objective were obtained from questions 1.2 and 1.4.

- Question 1.2: What is your experience regarding the installation of water infrastructure in this municipality?
- Question 1.4: What would you say are the biggest challenges that the municipality is experiencing regarding installation of water infrastructure?

The findings for this objective are illustrated in Figures 6.35 and 6.36.

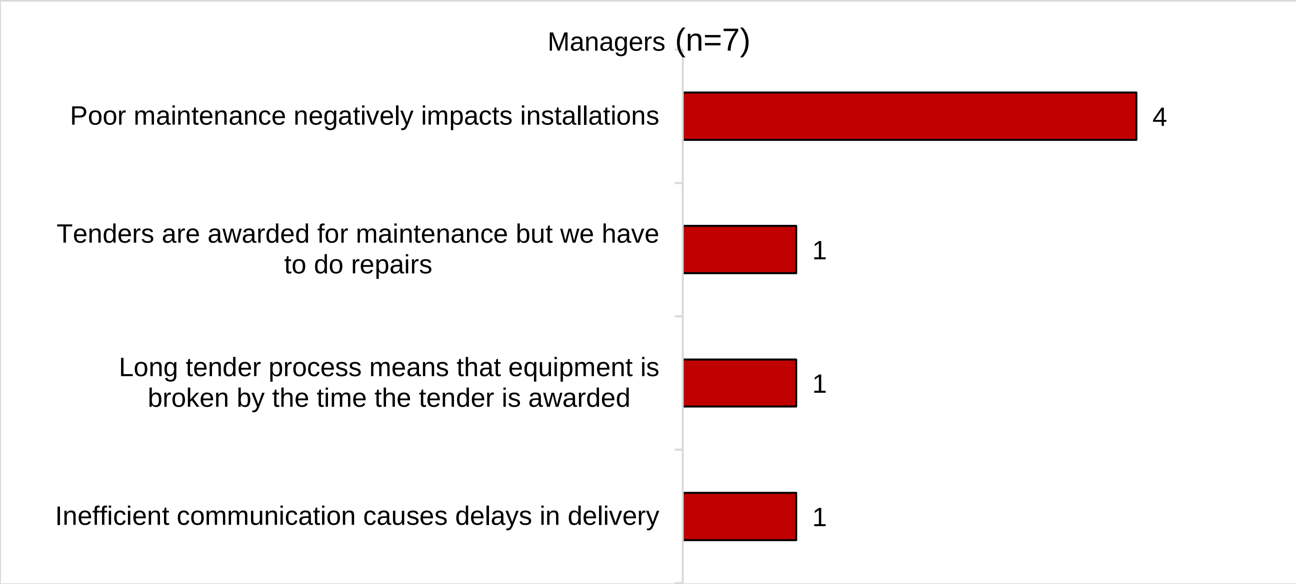

Figure 6.35: Perceptions of experiences/ challenges by contractor managers

Figure 6.35 illustrates that the findings from the managers are that they mentioned poor maintenance more frequently than any other aspect. The other three aspects of the challenges were mentioned at the same frequency. The managers also queried the tender processes and inefficient communication.

The challenges of the employees are shown in Figure 6.36.

Figure 6.36: Perceptions of challenges by contractor employees

Figure 6.36 shows that the findings from the employees most frequently mentioned the safety aspect on site followed by aspects of strikes or community unrest. The employees further mentioned that the challenges were experienced during, rather than after, the installations.

6.5.1.2 Conclusion re: Objective 1

The procurement system of tenders had many delays and handicapped the water division. Poor maintenance of the WI impacted the installations negatively. The communication in the water division was inefficient and delayed the work of contractors. The employees’ safety on the maintenance sites was not guaranteed because of overgrown grass and the absence of security officers. Community strikes delayed or halted the progress of contractors.

6.5.2 Objective 2: To rank the importance of the identified challenges experienced by the municipality

Leburu (2017: 9) pointed out that if the perceived high level of corruption and defective maintenance of the infrastructure were not responded to, the situation could exacerbate. The challenges identified in the literature are important to the survival of the city. Miya and Grobbelaar (2015: 941) identified the most frequent challenges that most local authorities experience in SA.

6.5.2.1 Question 1.7: Rank the challenges from the most to least severe?

Question 1.7 provided the findings related to this objective. The reason for the question was to obtain information about the severity of the challenges. The challenges are rated in Figures 6.37 and 6.38.

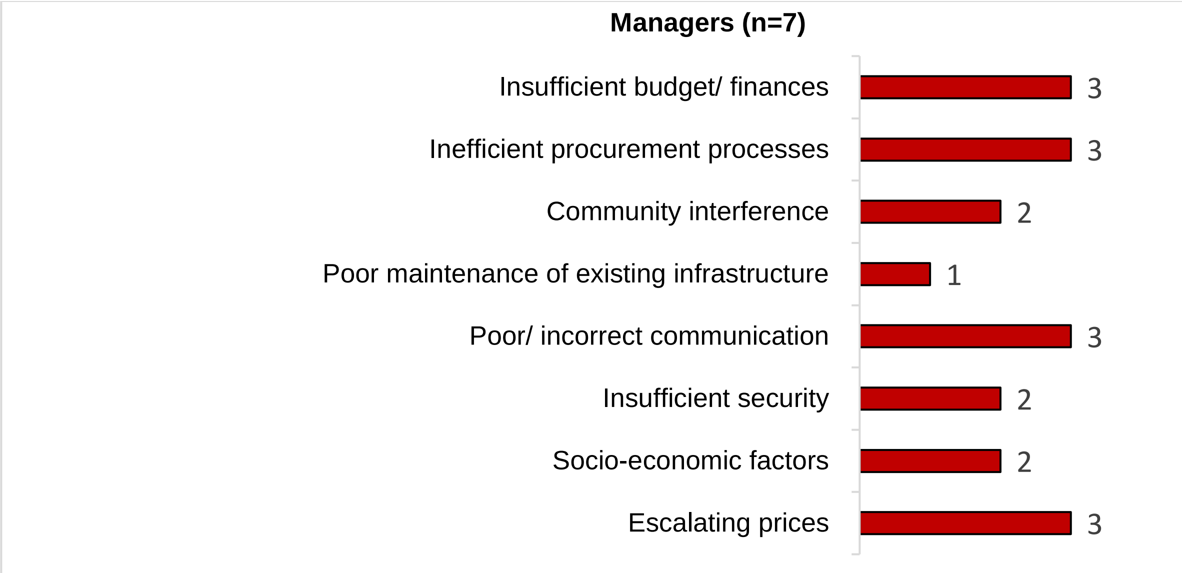

Figure 6.37: Ranking of challenges by contractor managers

Figure 6.37 demonstrates the findings from the managers rated from 1-3. A finding with rating one would be the least severe while rating three appeared the most severe to the managers. Four challenges were rated as three, three challenges were rated as two and one challenge was rated as one. The most burning issues for the managers were budget, procurement, communication, and price escalations. The employees' challenges are shown in Figure 6.38.

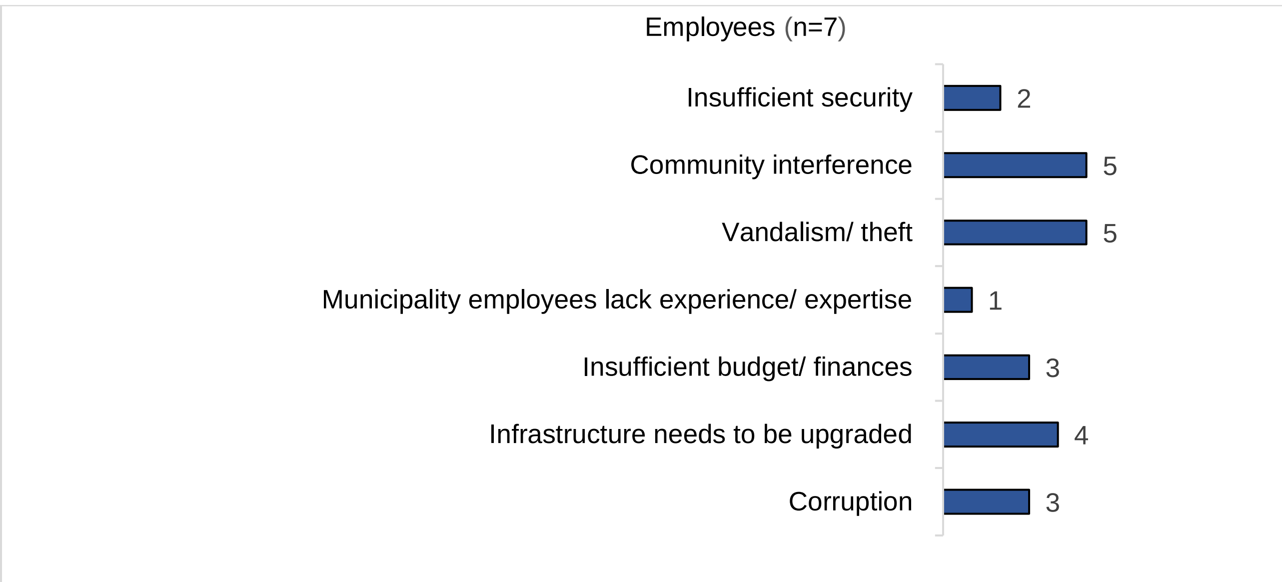

Figure 6.38: Ranking of challenges by contractor employees

Figure 6.38 demonstrates the findings with a rank of one as the least severe while a ranking of five appeared to be the most severe to the employees. The employees were mostly concerned about interference from the community, vandalism, and theft. The perceived root causes of the challenges follow in the next objective.

6.5.2.2 Conclusion re: Objective 2

This objective unveiled the shortfalls of insufficient budget, poorly maintained WI, vandalism, theft, and interference from members of the community. The municipal WI faced collapse due to poor maintenance by the inexperienced municipal employees, under the management of perceived corrupt officials.

6.5.3 Objective 3: To explore the root causes of the challenges during the installation of water infrastructure

Mbandlwa, Dorasamy and Fagbadebo (2020: 1642-1643) noted that the main causes of the challenges are poor and unethical leadership in the local government system. Chikowore and Willemse (2017: 87) noted that the challenges that SA faces are corruption and increasing skills shortage. In addition, the main contributors of underperformance in the CoT are political interference, skills shortage, and lack of training (Pooe, Worku and Van Rooyen 2016: 24, 28).

6.5.3.1 Question 1.6: Thinking deeply what could be the root causes of the challenges?

The findings to Objective 3 were obtained from Question 1.6. The reason for the question was to obtain the source of the challenges. Figures 6.39 and 6.40 illustrate the foundation of the challenges.

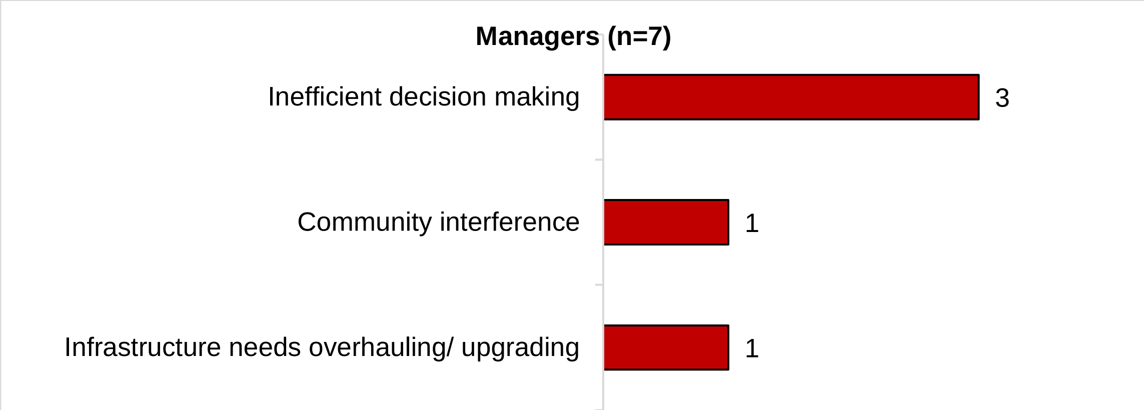

Figure 6.39: Contractor managers' perceptions of root causes of challenges

Figure 6.39 reveals that the managers viewed inefficient decision-making as the greatest contributor to the root causes of the challenges. The other two aspects such as interference by the community and the overhaul/ upgrade of infrastructure were on the same level of frequency of the findings. The views of the employees are shown in Figure 6.40.

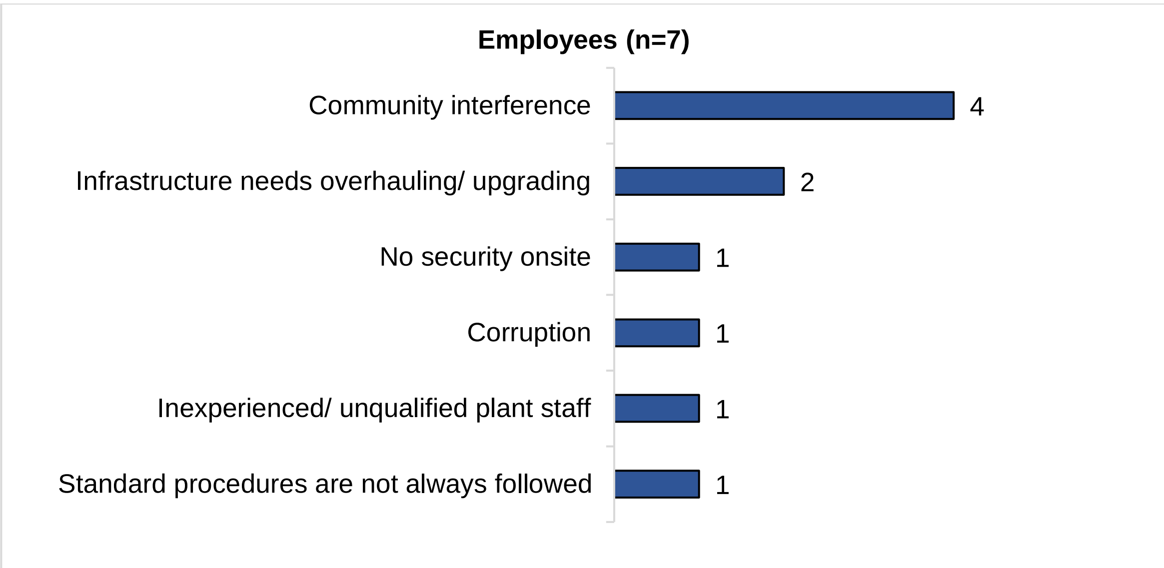

Figure 6.40: Contractor employees' perceptions of root causes of challenges

Figure 6.40 shows that community interference was perceived as the highest contributor to the root causes of the challenges. The need to overhaul the infrastructure appeared second in the findings followed by the remaining four on the same level.

6.5.3.2 Conclusion re: Objective 3

Objective 3 has uncovered that most of the challenges emanate from inefficient decisions that the managers take, infrastructure that requires a complete overhaul or upgrade, disregard of the standard operating procedures, and that communities interfere with the operations of the contractors. The aspect of corruption has been mentioned in multiple objectives and needs attention.

6.5.4 Objective 4: To identify how space technology can help with management of water infrastructure

Mnguni (2019: 937) noted that the CoT had been earmarked as one of the chosen cities for implementation of innovation. Space technology may assist cities to assess the quality of water using RS (Malahlela *et al*. 2018: 1). According to Campbell (2018), SANSA can assist with data for EO and imagery, vegetation, land use, urban development, water bodies (quality, growth, and decline), and cloud cover to mention a few. The developments of space technology would help to fight water pollution in the rivers. According to World Water Assessment Programme-UN Water (2018: 3) water pollution in rivers started in 1990 and is projected to worsen the water quality in Africa, Asia, and Latin America for decades.

6.5.4.1 Discussion of the objective

The reason for this objective was to establish a way to manage WI with the use of space technology.

The questions regarding space technology were not on the list of the focus group discussions. However, a follow-up was made with some members of the focus groups immediately after the completion of the discussions. The researcher discovered that there was no need to conduct any discussions about space technology with the focus groups. The reason was that members of the focus group did not have any ideas about, or knowledge of, space technology. The discussions about space technology were only held during the interviews with the CoT employees as illustrated in Figure

6.26. Therefore, there would not have been any significant data contribution from the focus groups.

6.5.4.2 Conclusion re: Objective 4

This objective has articulated through secondary data the possibility to apply the space technologies to the WI. Various towns and cities have experienced the benefits of space technology ranging from water purification, RS of water bodies (quality, growth, and decline), RS of water leaks and levels in reservoirs, EO, locate pipelines, and imagery to mention a few.

6.5.5 Objective 5: To develop a framework of the challenges and their causes

The various challenges from the literature have been arranged in the form of frameworks obtained from Table 2.1 (Portfolio Committee Human Settlement, Water and Sanitation 2019) and Table 3.4 (National Council of Provinces Finance 2017). These two frameworks provided a base for the focus groups and the CoT employees' framework illustrated in Table 6.6.

6.5.5.1 Questions that generated a framework of the challenges and the causes

Questions 1.1, 1.2, 1.3, 1.4, and 1.6 were relevant to generate the answers to this objective.

- Question 1.1: What has been your general experience working as a contractor in this municipality?
- Question 1.2: What is your experience regarding the installation of water infrastructure in this municipality?
- Question 1.3: What are the things you like (and or dislike) about the installation of water infrastructure in this municipality? (Please state why).
- Question 1.4: What would you say are the biggest challenges that the municipality is experiencing regarding installation of water infrastructure?
- Question 1.6: Thinking deeply what could be the root causes of the challenges?

In this objective only questions 1.1 and 1.3 will be discussed in detail through visual presentation/graphs. The following visual presentations have been thoroughly discussed (Question 1.2 Figure 6.35 in Objective 1; Question 1.4 Figure 6.36 in Objective 1; and Question 1.6 Figure 6.39 and Figure 6.40 in Objective 3) and will be omitted in this section to avoid repetition. The aim of question 1.1 was to measure the level of experience obtained by the contractors with the maintenance and installation of WI. The aim of question 1.3 was to check what the contractors enjoy and do not enjoy with their work. The two questions resulted in the findings generating the challenges. A framework has been developed from the findings obtained from all the questions in section 6.5.5.1. The results about the experiences of the contractors are shown in Figures 6.41 and 6.42.

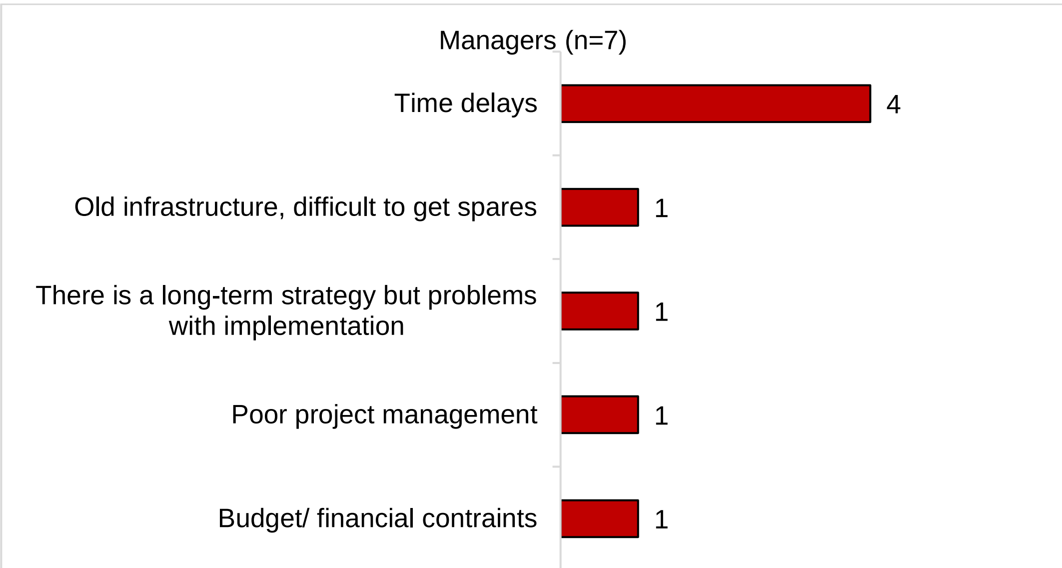

Figure 6.41: Experiences of contractor managers

Figure 6.41 reveals that the managers perceived time delays as being the biggest challenge or experience in the municipality. The other four aspects of their experiences were on the same frequency level. These aspects were old infrastructure, unimplemented strategy, poor project management, and financial constraints. The experiences of the employees are shown in Figure 6.42.

Figure 6.42: Experiences of contractor employees

Figure 6.42 demonstrates only two findings, which were the employees' ability to do decent work, and exposure to the work – both were mentioned only once each by respondents.

6.5.5.2 Conclusion re: Objective 5

This objective has uncovered the frequent delays due to the old models of the installed infrastructure which means that manufacturers may no longer carry spares. The projects experienced severe underperformance because of poor project management and financial constraints. Despite the various underperformances experienced, the contractors were able to make use of the limited resources to proceed with the work. A framework of the challenges and the causes as required by this objective is illustrated in section 6.4.5.1 Table 6.6, so it has not been shown here to avoid repetition.

6.5.6 Objective 6: To explore water management strategies with the effort of finding possible ways to resolve the challenges

Pooe, Worku and Van Rooyen (2016: 29) suggested customised skills training for the employees of the CoT as a strategy to overcome the challenges. South African local authorities have started to rework their policies in order to address the challenges of climate change (Madonsela *et al*. 2019: 2). Armitage *et al*. (2014: vi) proposed management strategies such as policy improvement, organisational structures, community involvement, construction of the infrastructure, and operation and maintenance, as better transitions towards water-sensitive settlements.

6.5.6.1 Question 2.2: What would you advise management to do to improve their strategies?

Question 2.2 answers Objective 6. The purpose of this question was to feed the city's management with information to improve their strategy.

Laitinen *et al*. (2020: 10) advised that water services could acquire a full and functional status if managers apply innovative training and motivation methods, equip employees with technical skills and socio-economic necessities, and provide education about climate change and political conditions.

Advice offered by contractor management and contractor employees are given in Figures 6.43 and 6.44 respectively.

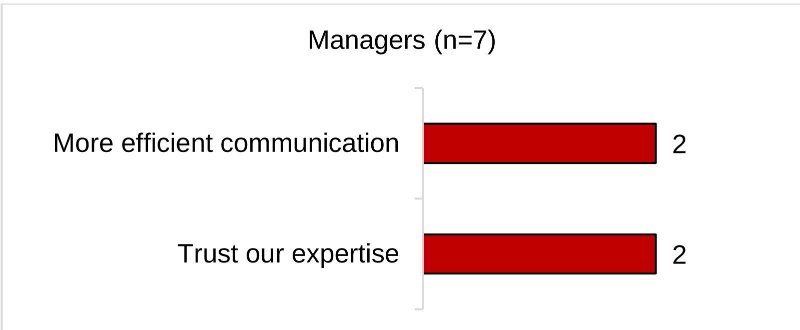

Figure 6.43: Contractor managers' advice on how to improve strategy

Figure 6.43 shows that the advice was to improve communication strategy and to trust the expertise of contractors. These two aspects of strategic advice were mentioned by the managers at the same level of frequency. The employees' advice is shown in Figure 6.44.

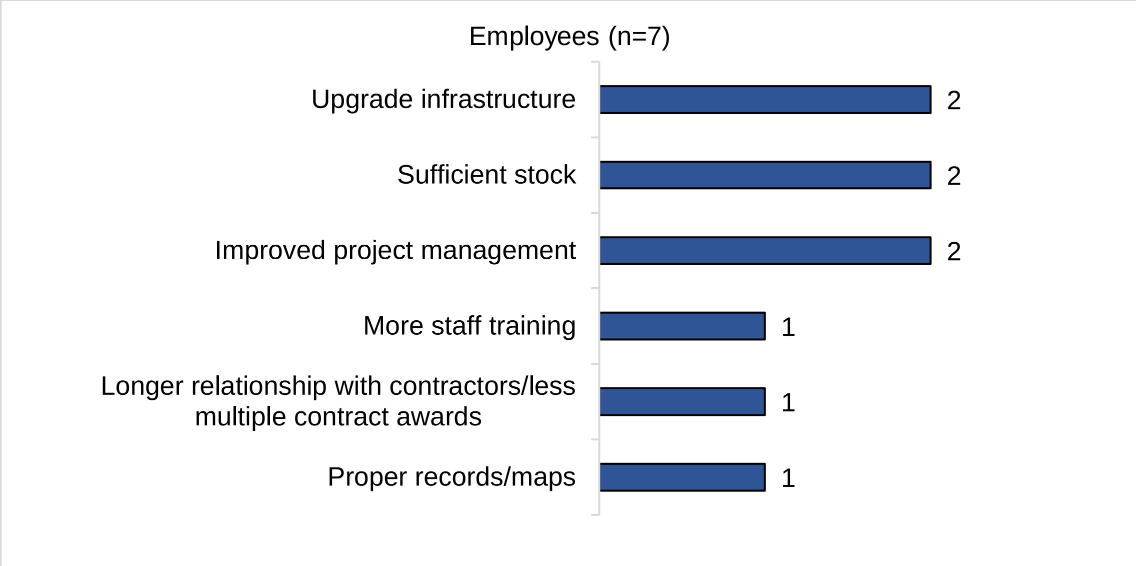

Figure 6.44: Contractor employees' advice on how to improve strategy

Figure 6.44 illustrates the six findings, the first three mentioned twice and the remaining three once. The employees gave more suggestions about strategy compared to their superiors. The employees proposed the upgrade of infrastructure, sufficient stock, and improved project management on the highest strategic list.

6.5.6.2 Conclusion re Objective 6

This objective sought to advance better performance and suggested that the following strategies should be applied by the city: improve communication, create relationships and trust between stakeholders, upgrade the dilapidated infrastructure, replace worn-out spares and accessories, and improve project management.

6.5.7 Interventions by the management of the city

The National Council of Provinces Finance (2017) unveiled the CoT's management shortfalls such as unlawful awarding of contracts, individualising the matters that needed the attention of other stakeholders for success, unattended loopholes in the organisational structure, slow pace to report matters to the law enforcement agencies, disregard for the water and sanitation standards, and misalignment with other departments.

6.5.7.1 Question 2.1: Was there any intervention by management to the challenges which were encountered

The purpose of this question is to establish if there were any interventions by CoT management to resolve the challenges in the city. The results are presented in Figures 6.45 and 6.46.

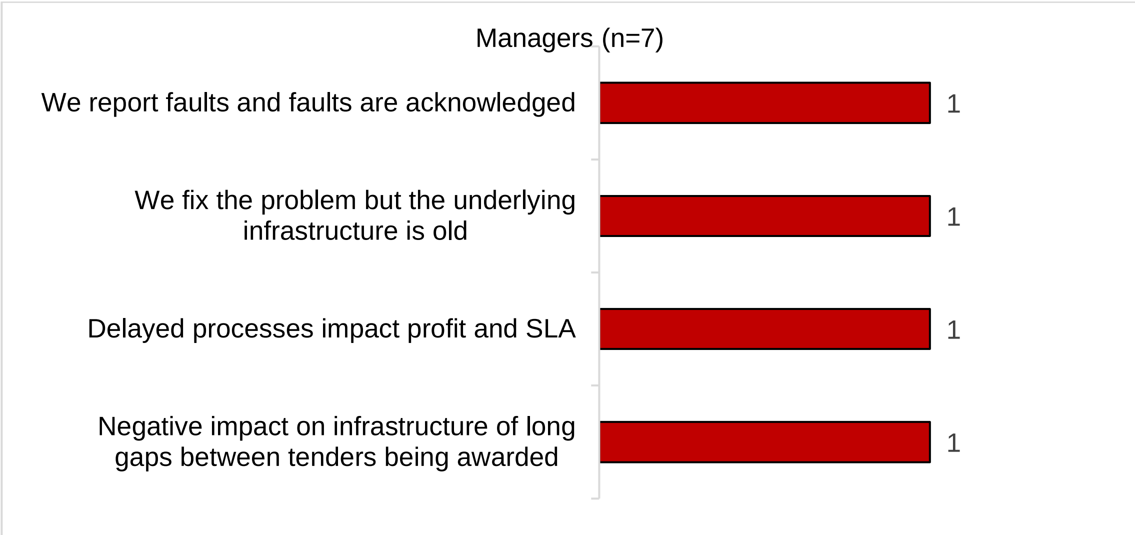

Figure 6.45: Contractor managers' views of interventions by the city

Figure 6.45 outlines four findings from the contractor managers. The managers complained about issues related to a lack of acknowledgement of the reports by the city, old infrastructure, delayed processes of SLA, and tendering. Instead, the managers still complained about the challenges, in other words there were no interventions. The challenges mentioned by the employees are outlined in Figure 6.46.

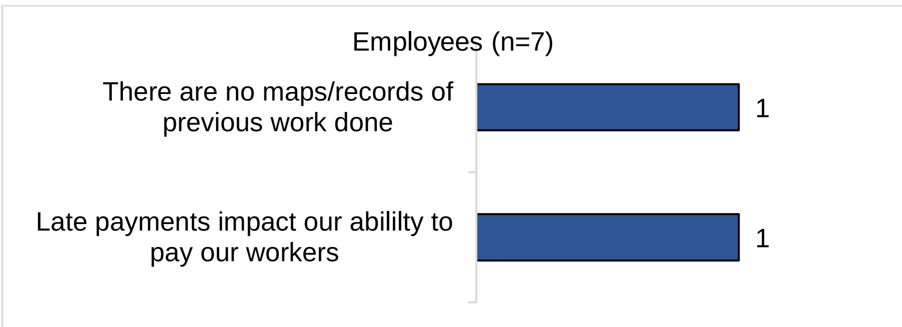

Figure 6.46: Contractor employees' views of interventions by the city

Figure 6.46 illustrates two of the challenges faced by the contractor employees, namely the absence of previous records and late payments that impact the workers. These challenges created disagreements between the contractors and the city. The employees also mentioned further challenges, this meant that the city did not intervene to challenges that were encountered.

6.5.7.2 Do you consider the CoT as number one city in managing WI

The purpose of this question was to assess the city in terms of the management of WI. According to the South African Citizen Satisfaction Index, the CoT obtained position four, from a total of eight metros in 2019 (Head 2019). This question was posed to the contractors' employees and not the management. The views of the respondents regarding the management of WI are presented in Figure 6.47.

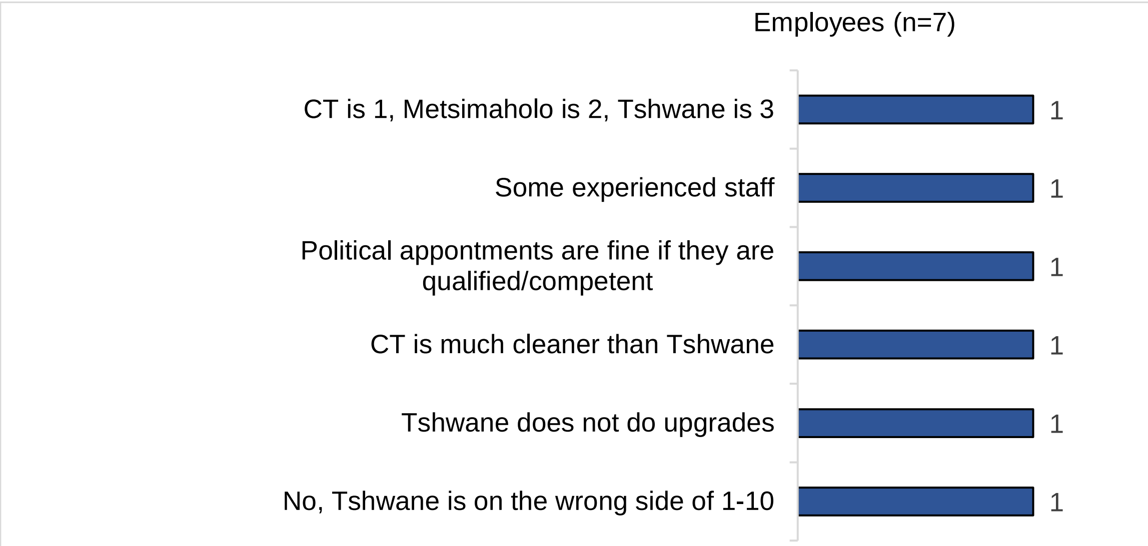

Figure 6.47: Perceptions of employees regarding management of WI

Figure 6.47 presents six different opinions of the contractors' employee respondents, each with the frequency of one. The responses of the contractors' employees were that the CoT occupied position three when compared to the cities of Cape Town and Metsimaholo. The employees further expressed that political appointments were fine if the candidates were qualified and competent.

6.5.7.3 Question 2.3: Are there any suggestions you can put forward to address the challenges mentioned

The purpose of this question was to provide support to the municipality in how to address the challenges. The findings are presented in Figures 6.48 and 6.49.

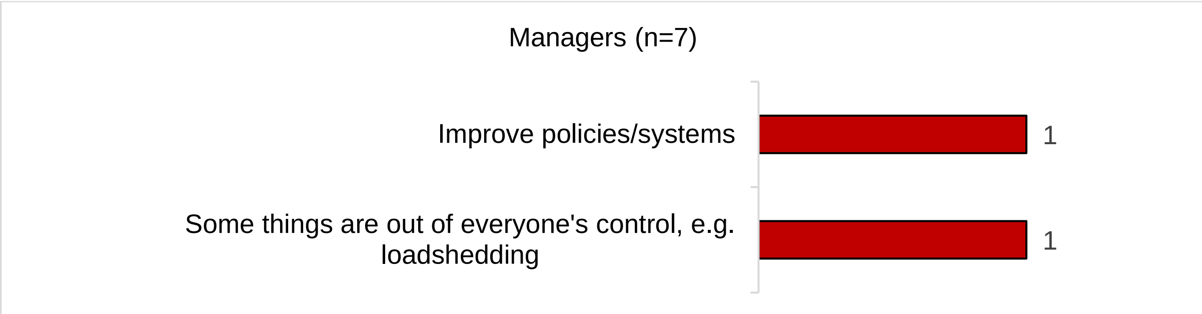

Figure 6.48: Contractor managers' suggestions to address challenges

Figure 6.48 illustrates two findings each mentioned once. One manager suggested improvement of the policies and systems, while another implied nothing could be done as load-shedding was out of the control of contractors. The findings from the employees are illustrated in Figure 6.49.

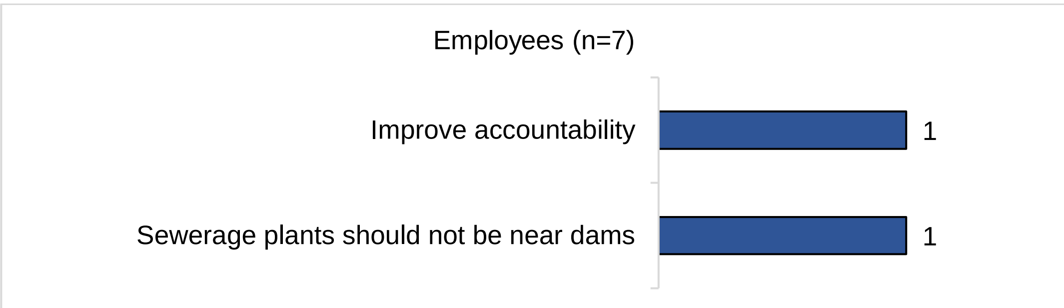

Figure 6.49: Contractor employees' suggestions to address challenges

Figure 6.49 indicates the two findings from the employee focus group which suggested that accountability should be improved, and sewerage plants should be far away from dams. These were both mentioned once.

6.5.8 Obligations of the contractors

Some contractors abided by the obligations specified in the SLAs. According to Olivier (2021: 288), corruption has manifested in the CoT, and Poplak (2017) added that it originated during the ANC's term of office with wasteful outsourcing of the organisation PEU without competitive tendering. The outsourced organisation received a payment of R1-billion a year, with an annual turnover for smart metering of R630-million.

6.5.8.1 Question 3.1: Do you adhere to the contractual obligations? If no state why

The purpose of this question was to check if the contractors honoured the agreements. The views of contractual obligations by the contractor managers are depicted in Figure 6.50.

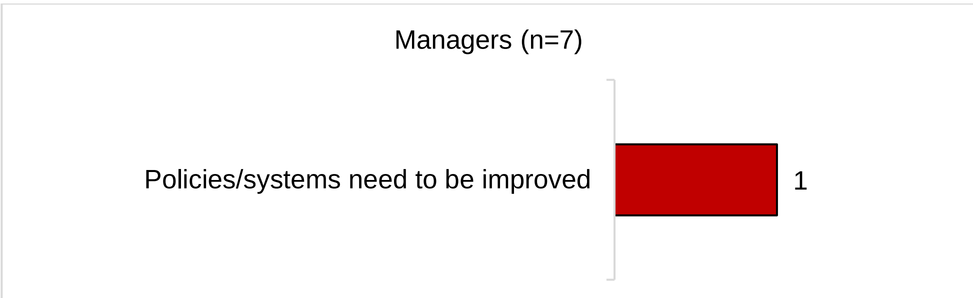

Figure 6.50: Contractor managers' views of contractual obligations

Figure 6.50 shows that only a single opinion was provided, namely that the policies and systems first must be approved by the officials of the city. The contractor employees' views are expressed in Figure 6.51.

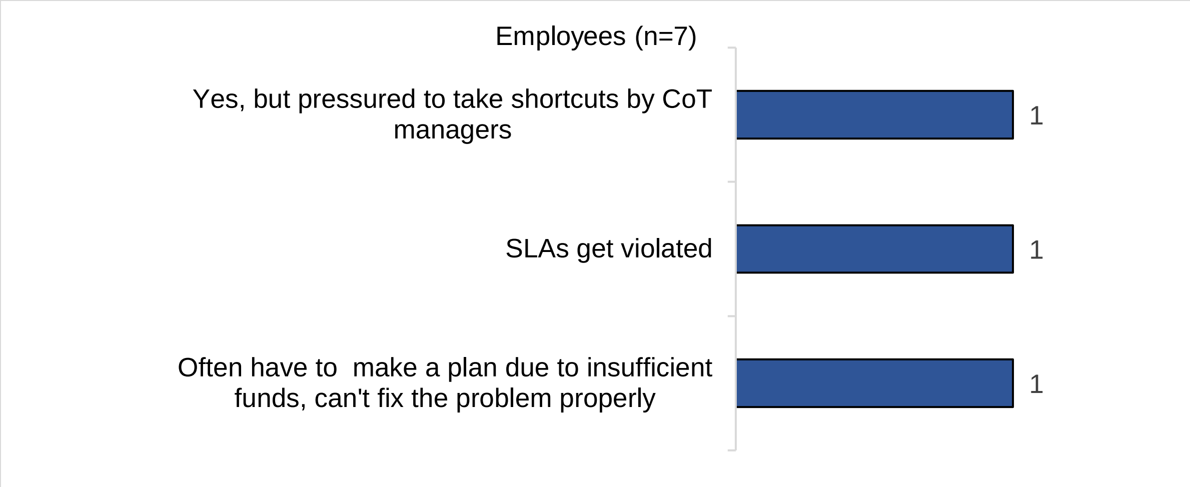

Figure 6.51: Contractor employees' views of contractual obligations

Figure 6.51 indicates three views from the contractor employees, namely coercion by the managers of the city to take shortcuts, violation of the SLAs, and quality is compromised to fit into the allocated budget.

6.5.8.2 Question 3.2: Are you able to complete the contracts within the contract period? If no state why

The question aimed to determine whether the contractors finish the work within the contract period. The results are shown in Figures 6.52 and 6.53.

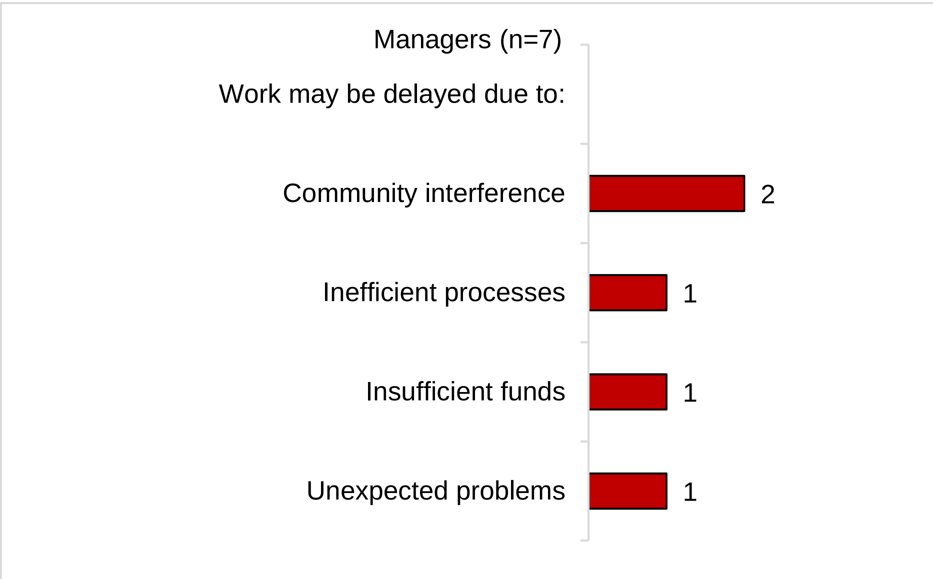

Figure 6.52: Contractor managers' perceptions of completion of contracts

Summarising the findings in Figure 6.52, the contractor managers agreed that delays are due to factors such as community interference, tedious processes, depleted funds, and other unforeseen circumstances. The findings of community interference were mentioned twice compared to once each for the other three problems. The results of contractor employees are in Figure 6.53.

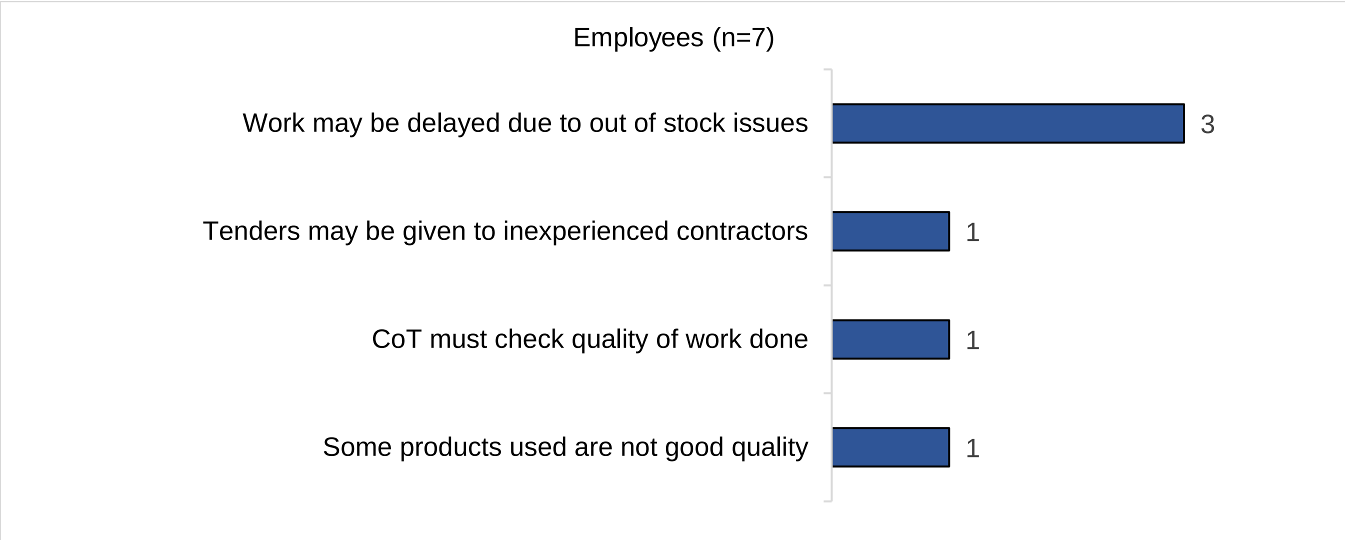

Figure 6.53: Contractor employees' perceptions of completion of contracts

The findings in Figure 6.53 highlighted that contractor employees view most delays as arising from out-of-stock issues. The aspect of delays due to out of stock issues had the highest frequency compared to fewer mentions about inexperienced contractors, quality inspections, and defective products.

6.5.8.3 Question 3.3: Are you able to manage the magnitude of installations and maintenance contracts awarded

The question aimed to check if the contractors are able to cope with the size of contracts awarded. The views are outlined in Figures 6.54 and 6.55.

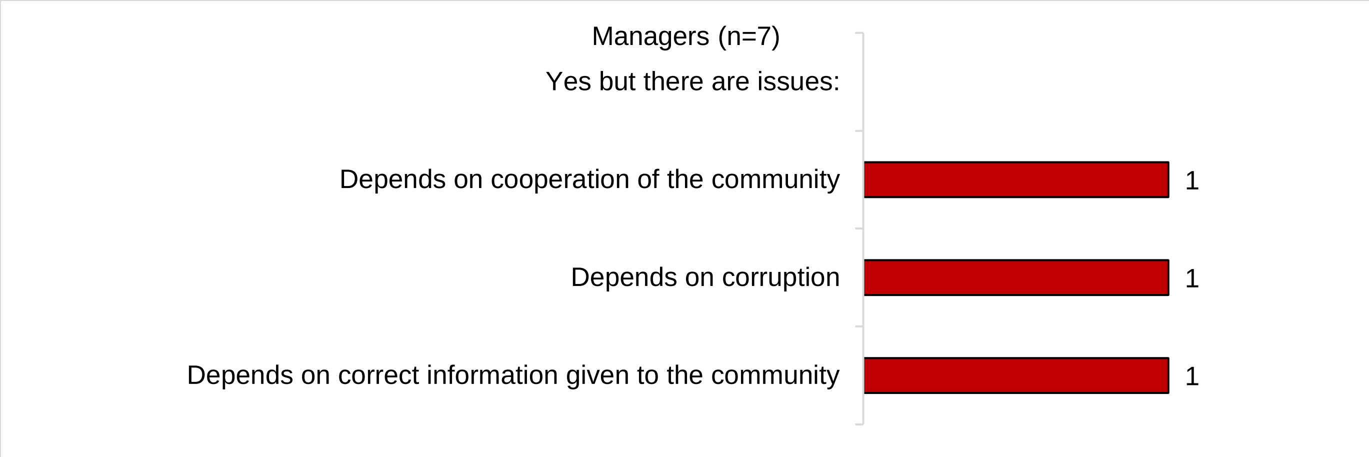

Figure 6.54: Contractor managers' views of ability to cope with workload

The findings in Figure 6.54 illustrate that the contractor managers acknowledge that projects were managed successfully, but that this depends on cooperation from the community, the level of corruption, and information fed to the community. The contractor employees' views are shown in Figure 6.55.

Figure 6.55: Contractor employees' views of ability to cope with workload

Figure 6.55 illustrates the opinions of contractor employees that the magnitude of work to be managed depends on the behaviour of the community, community interference, the residents' demand for employment, inability to hire the local residents (although community projects can hire local residents).

6.5.8.4 Conclusion

The CoT did not manage the challenges of contractors satisfactorily. The complaints raised by the contractors took a long time to solve. The city has been rated with poor performance by the respondents of this study. There was a suggestion that the city must reshape the policies and systems to improve the accountability of the managers. The contractors did adhere to their obligations, providing an effective service to the city, despite the interferences from city employees to bend the rules.

6.6 Qualitative research main themes, sub-themes, and suggested solutions

The discussions with the focus groups (contractor managers and contractor employees) and the CoT managers have generated some patterns that have been grouped into the main themes.

6.6.1 Main themes of the challenges

Figure 6.56 depicts a word cloud of the respondents' frequently said words about the challenges of managing water infrastructure. These words were identified from the discussions with two focus groups of the contractors (managers and employees). The bigger the word in the cloud, the more frequently it was used, thus indicating its greater perceived importance by the respondents.

Figure 6.56: Word cloud of main themes on challenges

A summary of the main themes for the challenges is depicted in Table 6.7.

Table 6.7: Main themes of challenges from qualitative data:

Main theme 1 Challenges	Main theme 2 Community challenges	Main theme 3 Budget/ Financial challenges	Main theme 4 Staff challenges	Main theme 5 Compliance challenges	Main theme 6 Infrastructure challenges
Community	Lack of com-munity support	Poor long-term planning	Staff shortage	CoT poor compliance enforcement	Infrastructure is old
Financial/ Budget	Illegal activities	Poor stock control	Not enough staff training	Contractor not always compliant with compliance enforcement	Poor maintenance
Staff	Inefficient communication	Inefficient tendering processes	Lack of security	Covid compliance increased costs and stress	Lack of security
Compliance	Water shutdowns	Inefficient contractor payments	Teams must cover a large area		Long tender process
Infrastructure	Informal settlements	Regional issues			
		Cost of new infrastructure			
		Water shutdowns			
		Covid compliance			

6.6.2 Main themes of the suggested solutions

Figure 6.57 indicates a word cloud generated for the suggested solutions to the challenges that were encountered. These solutions may be helpful overall for the CoT or other municipalities which may be experiencing similar challenges. The suggestions were generated from both the focus groups and interviewees' frequently mentioned words to help the CoT. The larger the words and phrases, the more frequently they were mentioned in the interviews and focus groups and are the main themes of the suggested solutions.

Figure 6.57: Word cloud of main themes regarding suggested solutions

The deliberations with the focus groups and the CoT employees generated some solutions to the challenges that were encountered. These solutions have been unpacked in terms of the main themes as shown in Figure 6.57. The suggested solutions of the main themes in Table 6.8 were obtained from the results as illustrated in Figures 6.26, 6.28, 6.44, 6.48, and 6.57. The main themes of the suggested solutions are illustrated in Table 6.8.

Table 6.8: Main themes of suggested solutions

Main theme 1 Solutions on staff	Main theme 2 Integrated approach	Main theme 3 Long term planning	Main theme 4 Financial/Budget
More staff training	Inclusion	Improved long-term planning and delivery	Increased budget
More staff	Implementation	Longer relationship with contractors	Better financial controls
Security		Improved policies/ systems	
Stock			
Incentives			

The CoT employees' most frequently said words during the discussions are shown in a word cloud. The bigger the appearance of the word the more frequently it was mentioned. The word cloud is illustrated in Figure 6.58.

Figure 6.58: World cloud of most frequently mentioned words

Table 6.9 illustrates the frequencies of the most frequently mentioned words by the contractors' focus groups. The words in the Table have been mentioned between 5 and 28 times by the managers, and between 5 and 32 times by the employees. The words which were mentioned only one to four times were omitted from the Table because the researcher felt that they were less significant. Sixteen similar words were mentioned by both focus groups, and the remaining 16 are unique words as illustrated in Table 6.9.

Table 6.9: Word count from focus groups

Focus groups frequent word use			
	By Managers	**By Employees**	**Total**
Work	28	28	56
Equipment/ Plant	8	32	40
Maintenance	21	13	34
Water	12	20	32
Community	7	25	32
Challenges/Problem	12	20	32
Infrastructure	18	10	28
Part	22	6	28
Contractors/Contractor	7	19	26
People	10	16	26
Time	9	16	25
Tender	24	-	24
Tshwane	6	16	22
Project	7	14	21
Municipality	5	15	20
Management/Manager	10	7	17
Budget	12	5	17
Employees/employee	-	17	17
Issues	16	-	16
Service	16	-	16
Site	-	15	15
Job	-	15	15
Old	5	9	14
Process	13	-	13
City	5	6	11
Communication	8	-	8
Poor	6	-	6

These word frequencies are further illustrated in the word clouds. Figure 6.59 demonstrates a word cloud created from the focus group of the contractors' management team. The larger the word the more frequently the word dominated the discussions.

Figure 6.59: Word cloud of contractor manager's

Figure 6.60 illustrates the most mentioned words from the focus group of the contractor's employees. The words with a larger appearance indicates they were most dominant in the discussions.

Figure 6.60: Word cloud of contractor employees

6.7 Chapter summary

This chapter focused on the presentation and analysis of the research results. The quantitative data presented the findings from the citizen community of the CoT, and the qualitative results section presented the results from the interviews with CoT managers and the two focus groups with the contractors (managers and employees). According to the survey, the overall measurement of satisfaction of CoT resident respondents regarding the WI was 55 percent and the dissatisfaction was 31 percent. The survey, however, also indicated that there were various challenges that the residents were facing with the CoT WI. Some residents (42 percent) agreed that there were challenges when the installation of WI was in progress compared to 34 percent who disagreed. More than half of the respondents agreed that when maintenance was in progress the community felt the impact. The highest percentage of respondents indicated other challenges from the contractors who conducted maintenance on the WI. A higher percentage of respondents (46 percent) indicated that the community had experienced some challenges with the installations of WI from the municipality. Most respondents (67 percent) believed that political interference influenced the awarding of jobs to contractors. The survey also noted that striking contractors affected the output of the CoT WI installations. The survey highlighted that the technical and management capacity of the CoT management was questionable, and the community was not satisfied with the project management strategies used by the CoT's management.

The CoT interviewees and focus groups noted with concern the challenges faced by the city in various aspects of management, financial management, communication, procurement, training of staff, tender processes, and maintenance of WI. The aspects of political interference, staff shortage, vandalism and theft, and lack of security featured multiple times in the interviews and focus groups discussions. The budget allocated for service delivery ended up in the hands of thieves or was not fully utilised.

6.8 Conclusion

This chapter has presented the findings from the information that was supplied by the respondents of this study. The results have pointed out that the CoT WI suffered from leadership challenges. The management of CoT was not in the driving seat regarding WI, due to political interference. Community interference also made it difficult for management to appoint suitably qualified contractors. The long processes of finalisation of tenders created challenges for providing effective community service. The WI department struggled to cope with vacancies that have not been occupied for some time. In addition, management lacked the required technical and leadership expertise to execute the work. The city's failure to pay the contractors according to the agreed SLA was viewed seriously, as was the non-conformance to the Public Finance Management Act.

Concerning the WI, there were various challenges that, if not addressed, may bring a complete halt to service delivery. The maintenance of WI was not treated as a priority by the senior management of the municipality. The budget was not always used for the intended purpose by those authorised to do so. There was no accountability or due diligence in the execution of functions. There was ignorance in, and unethical conduct by, some of the city's employees who were influential over the contractors, encouraging them to follow similar unethical behaviour. Training of the city's employees was viewed by the managers as a race against time and a waste of time. The city had no proper flow of communication. There were no inspections conducted on the completed work and no record-keeping of work that was done. The interests of the community were not prioritised in the CoT.

The next chapter presents the discussion and interpretation of the above results.

CHAPTER 7: DISCUSSION AND INTERPRETATION OF RESULTS

7.1 Introduction

This chapter presents the discussion of the research findings regarding the application of space technology and the challenges of managing water infrastructure in a selected South African municipality. The selected city of focus for this research is the CoT. The main purpose of this chapter is to discuss and interpret the views of the participants against the research questions and the objectives in relation to the literature reviewed for this study.

The main aim of this study was to investigate the challenges of managing water infrastructure in a selected South African municipality and to find ways to resolve such challenges with the help of space technology. This chapter prepares the base for the next chapter which provides the recommendations and avenues of further research for the CoT. In addition, it provides new insights into the application of space technology and the challenges of managing water infrastructure in the CoT.

To achieve the aim this study sought to achieve the following objectives:

Objective 1: To identify the challenges experienced by the municipality during and after installations of water infrastructure

Objective 2: To rank the importance of the identified challenges experienced by the municipality.

Objective 3: To explore the root causes of the challenges experienced during the installation of water infrastructure.

Objective 4: To identify how space technology can help with the management of water infrastructure.

Objective 5: To develop a framework of the challenges and their causes.

Objective 6: To explore water management strategies with the effort of finding possible ways to resolve the challenges.

7.2 Discussion of the research findings in relation to the research objectives

The findings of this study are grouped according to the respondents and are summarised in Table 7.1.

Table 7.1: Summary of combined research findings

CoT managers	Contractor's managers	Contractor's employees	Survey of residents
Community challenges leaks, no enforcement.	Poor maintenance	Unsafe sites	Installation challenges
Maintenance issues shutdowns, delays.	Long tender process	Community strikes	Maintenance challenges
An integrated approach, financial challenges.	Inefficient/poor communication	Vandalism/theft	Political interference
Multiple issues, lack of skills/experience.	Insufficient budget	Insufficient budget	Challenges from the municipality
Staff shortage.	Corruption	Corruption	Unsafe trenches
Challenges are related to communities, finance, and technology.	Inefficient decision making	Inexperienced municipal employees	Contractors' strikes
Lack of staff training.	Community interference	Community interference	Politicians own the companies
Insufficient budget.	Delays	Disregard for procedures	Lack of management skills from the CoT
Lack of enforcement.	Poor project management	No security	Lack of technical skills from the CoT
Old and dilapidated infrastructure.	Old infrastructure	No record-keeping	Neutral about health standards
Poor project management.	Community misinformation	Pressure to take shortcuts	Contractors delay the work
Poor communication.	Violation of SLAs	Violation of SLAs	No public vandalism
Inefficient tendering processes.	Lack of implementation	Defective materials	No proper project management
	Insufficient security	Tender nepotism	No political support for the projects
		Coerced to hire locals	

7.2.1 Challenges experienced during and after installations of WI

The results of this study support the observation that unattended and unbarricaded open trenches, obstructed streets, maintenance of water pipes, materials lying around haphazardly, and unnoticed water cut-offs, impact the community. The observations are in line with the literature of Bello *et al.* (2019: 2, 3) and Osman, Ammar and El-Said (2017: 29). Bello *et al.* (2019: 2, 3) suggested that the distribution networks demand a suitable person to improve the service delivery to the satisfaction of the clients. The findings pointed out that the CoT managers do not have a suitable strategy for managing projects from initiation until project closeout. Literature from Urich *et al.* (2013: 301) agreed with the findings, and further advised management to update their water management strategies to suit the future urban requirements of water systems.

The findings of the study agree that there are challenges that the community respondents experience during and after the WI is installed. Literature from Khale (2015: 674) is contrary to the observation from the community respondents. Khale's study conducted in 2015 revealed that 84.37 percent of the CoT residents approve of the services rendered by the city.

The findings of political interference agree with the literature from Soppe, Janson and Piantini (2018: xii-xiii), Chikowore and Willemse (2017: 87), Galaitsi *et al*. (2016: 18), and Sershen *et al*. (2016: 458). The results of this study indicate that striking contractors affect the smooth running of the installation and maintenance of WI. Literature from Pooe, Worku and Van Rooyen (2016: 24) make a different finding that the strikes in the SA municipalities emanate from the communities experiencing service delivery bottlenecks. Therefore, the observation from the literature is not supported by the findings of this study.

The results demonstrated that the CoT managers do not have enough technical and management capacity to oversee the installation and maintenance of the contractor's work. Literature is not specific about the CoT; however, the results of this study agree with the findings for the SA municipalities in general (Sershen *et al*. 2016: 458; Hay *et al*. 2012: 442).

The findings from the survey disagree that the public vandalises and disturbs the contractors' work, while the contractors' employees (from the focus group) agree that there is vandalism and theft. Literature confirmed that there is vandalism in the CoT, but there is no mention of who the perpetrators are (Portfolio Committee Human Settlement, Water and Sanitation: 2019).

The survey generated four research constructs, namely: community challenges, contractor's challenges, municipal and political challenges, and managerial and political support. The three research constructs scored above the allowable Cronbach's alpha value of 0.600 while the last construct scored marginally below at 0.596.

In addition, a Cronbach's alpha coefficient test that was applied to the individual survey questions of this study presented with results between 0.670 and 0.769. A detailed summary of Cronbach's alpha test for the individual survey constructs is illustrated in Table 6.3 earlier in this study. Finally, the means for the survey questions ranged between 2.46 and 4.00 which were inclined towards agree and strongly agree on the Likert scale. Therefore, the respondents of the survey generally agreed with the questions in the measurement scale. A summarised version of the survey results is illustrated in Figure 7.1.

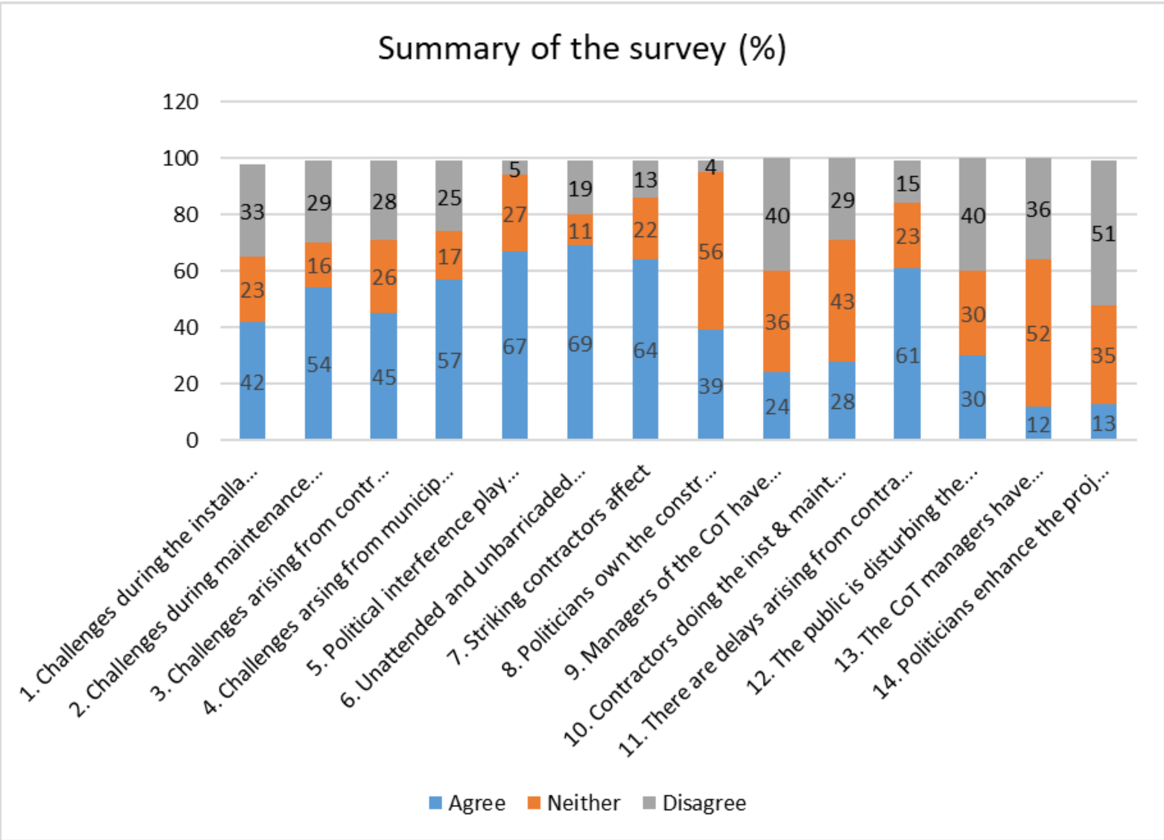

Figure 7.1: Summary of the survey

Figure 7.1 illustrates the visual presentation of the survey results. The picture being painted in questions 1, 2, 3, 4, 5, 6, 7, 8, and 11 are positive or agreed with. The common phenomena among the agreed with questions are that there are indeed mounting challenges of WI, political interference, and delays from the contractors in the city. The survey respondents disagreed with Questions 9, 10, 12, 13, and 14. The common phenomena observed in the disagreements are that the city's management, the contractors, and the politicians are perceived by the public to not be fully participating in their work. In addition, that there are no disturbances posed by the public to the workforce. The strongly agreed with points are that there is no attention paid to open trenches without the barricades (Q6), political interference (Q5), and the negative impact of striking contractors (Q7). The strong disagreement is regarding no political support for the projects. The citizens are negative about the politicians' role in the CoT. Figure 7.2 shows a graphical presentation of the means.

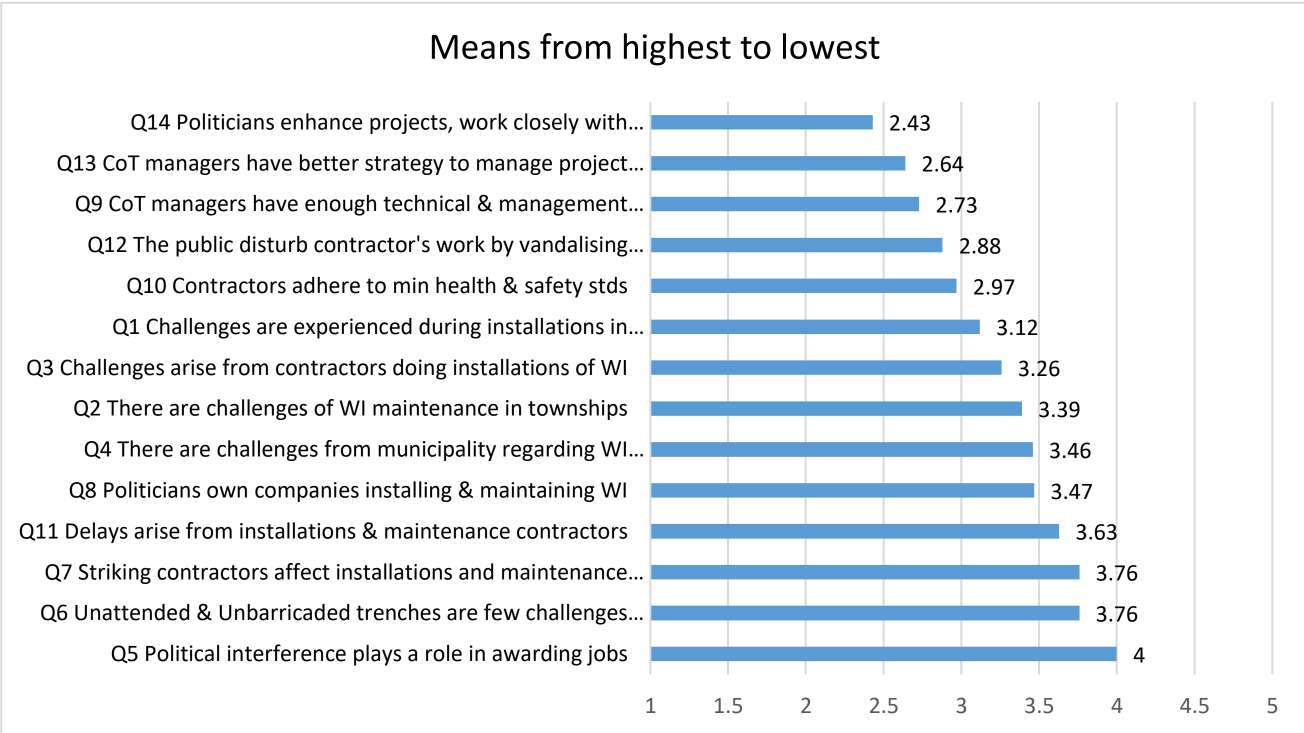

Figure 7.2: Means of survey responses illustrated from the highest to the lowest

Figure 7.2 illustrates the means from the highest to the lowest. The higher the mean (Q1, Q3, Q2, Q4, Q8, Q11, Q7, Q6, and Q5) the more significant was the question to the residents. The lower the mean the less significant was the question to the residents. The midpoint of the means is 3; five means (Q10, Q12, Q9, Q13, and Q14) are less than the midpoint and this implies that the questions were less significant to the survey. The positive and negative perceptions of the survey participants are listed in Figure 7.3.

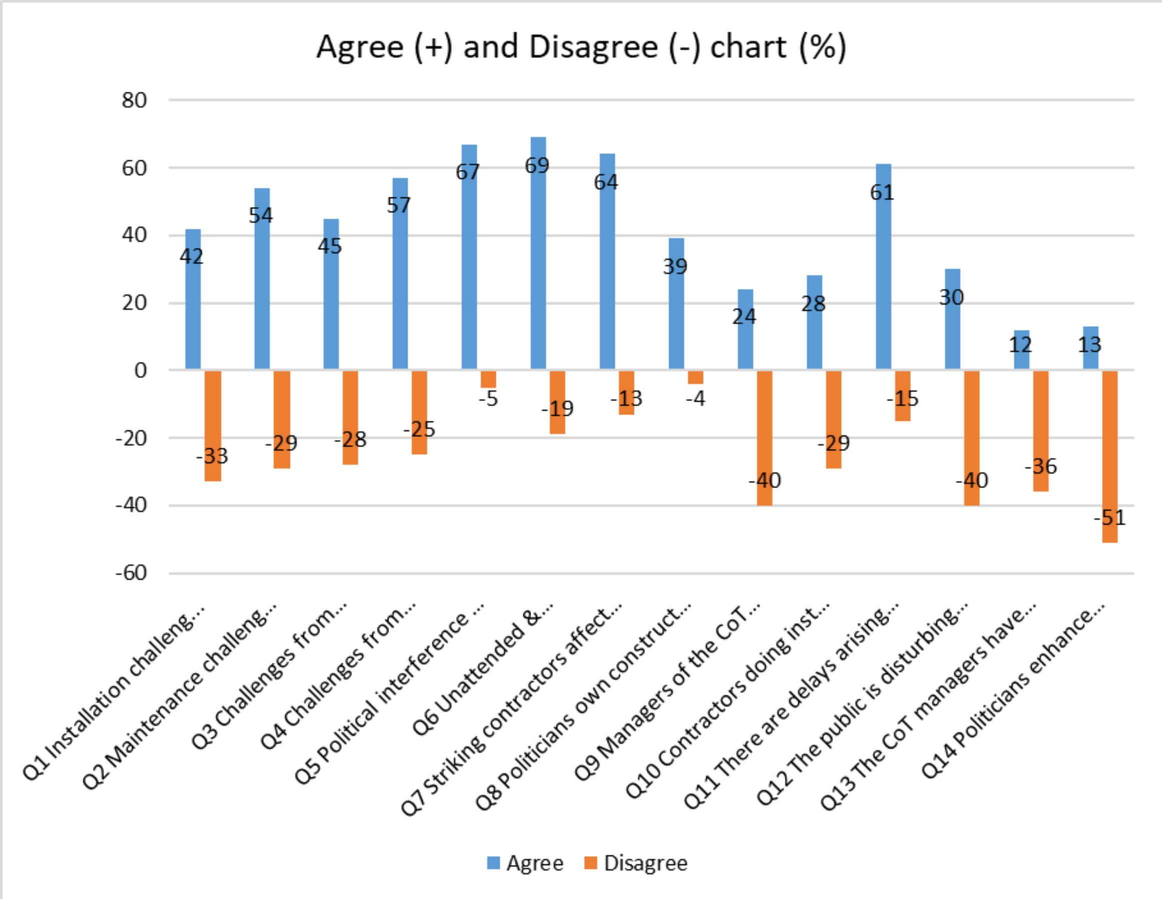

Figure 7.3: Agree and disagree chart from the survey

Figure 7.3 illustrates that nine agreed questions were important to the survey and have outperformed the negative answers. The common phenomena of the agreements are challenges with the WI, political interference with processes, and delays arising from the contractors. The columns above the midpoint (0) indicate the agree scores (positives) and the disagree scores (negatives) are below the midpoint. There were five negative answers for the overall survey that outperformed the positives. The common issues on the negative side are that the city's management, the contractors, and the politicians contribute less effort to their own work.

The survey noted that the CoT managers lack strategic management of projects, and shortage of technical and management skills. The contractors do not adhere to minimum safety standards. The politicians do not enhance the projects that are being executed in the CoT.

The CoT manager participants also agreed that there were challenges experienced during and after the installation of WI. These participants mentioned that the various issues that affected the community were: burst pipes, leakages, equipment issues, poor enforcement of the requirements, and poor planning. The challenges of burst pipes, leaks, lack of equipment, and poor planning were reflected in the survey results. The CoT manager participants also mentioned the aftermath of installations as water shutdowns, lack of finances, theft, vandalism, and communication breakdown. Lack of plans for the previously installed WI exacerbate the delays, and cause damages to the existing installations.

The contractors' focus groups mentioned the challenges to the installations as being: delays in the project delivery due to vandalism, difficulties of access to the sites, poor communication, red tape, lack of maintenance, lengthy process to finalise the tenders, dilapidated infrastructure, and payments 'taking forever.' Similarly, to this study, Kopung (2017: 195) concluded that a lengthy process to finalise the successful tender affects the project output and results in under expenditure. The results of this study do agree with the literature.

7.2.2 Ranking the importance of the challenges experienced by the CoT

The results of this study provided a ranking of the challenges that have been experienced by the CoT. The ranking of the challenges is in line with studies conducted by Miya and Grobbelaar (2015: 941) and Sershen *et al*. (2016: 450). The challenges experienced by the CoT are like those outlined in both studies. Similarities such as vandalism and theft were also identified in the studies conducted by Birkett (2017: 1), Chauke (2017: 79), and Mokgobu (2017: 88). The challenges of this study have been ranked according to the urgency of attention required. Therefore, the observation from the findings of this study agrees with the literature. The frequencies of the contractors' challenges are displayed in Figure 7.4.

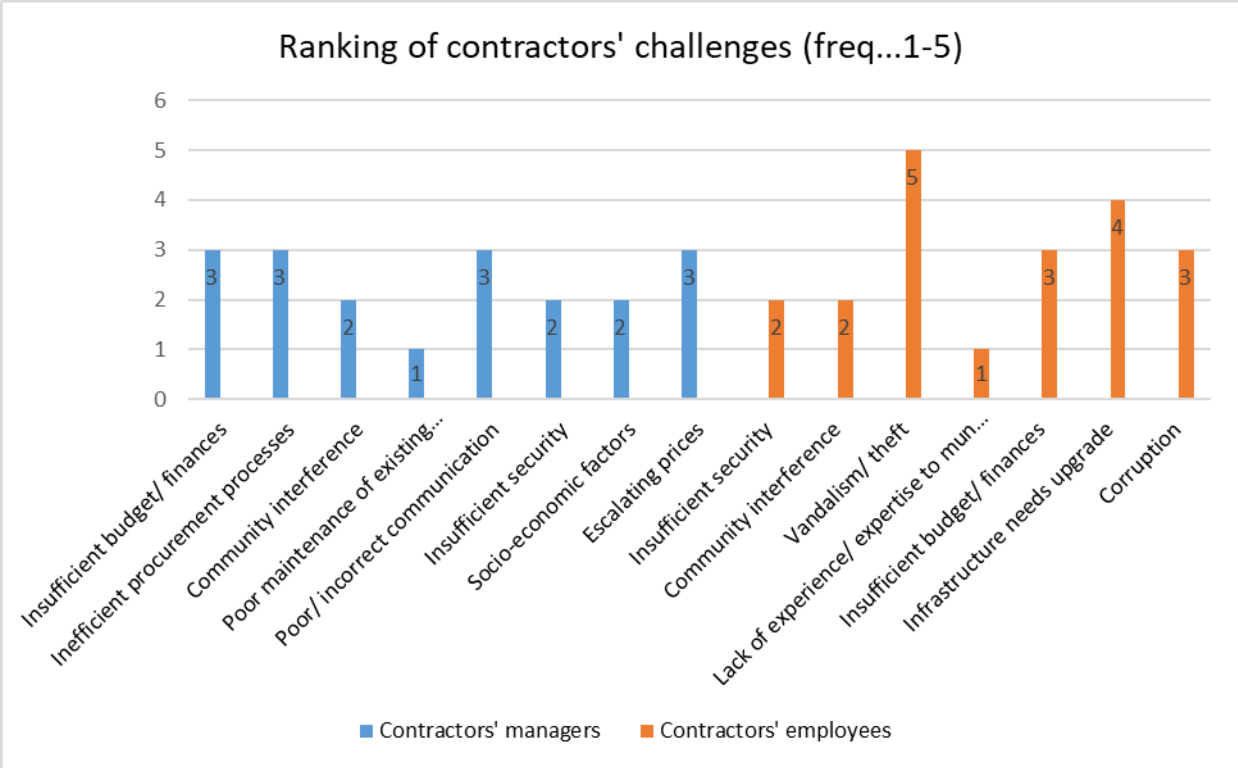

Figure 7.4: Combined ranking of the challenges

Figure 7.4 illustrates the combined perceived challenges of the contractors in terms of the rank or frequency level. The higher the rank the higher the level of response required to address the challenge. The highest level of attention required for the perceived challenges of the contractor managers is on rank level 3. There were four level 3 perceived challenges raised by the managers. The contractor's employees' biggest challenges were vandalism and theft, which were ranked at level 5. The employees ranked the infrastructure that needed to be maintained at level 4. The contractor managers were more concerned about insufficient budget, procurement, communication, and cost escalations. The previously mentioned activities were all ranked at level 4. They were more concerned about the financial side of ranking than any other activities, whereas the employees were more concerned with operational issues inhibiting the completion of the installation or maintenance work.

7.2.3 Exploring the root causes of the challenges during the installation of WI

The findings of this study were that the root causes are mainly the skills shortage, planning issues, financial problems, and political issues. Most studies have demonstrated how budget shortfalls impact the management of infrastructure operations, such as installations, and maintenance (Lawhon *et al*. 2018: 723; Miller *et al*. 2018: 1; Boulos 2017: 42; Schwartz *et al*. 2017: 3, 8; Ruiters and Matji 2016: 291; Ruiters and Matji 2015: 662, 663). Studies conducted by Dludla (2020); Portfolio Committee Human Settlement, Water and Sanitation (2019); Pooe, Worku and Van Rooyen (2016: 29) and Khale (2015: 675) attest to these aspects. Thus, there is an agreement between the findings of this study and the literature. A pie chart displaying the frequencies of mentions of the root causes is shown in Figure 7.5.

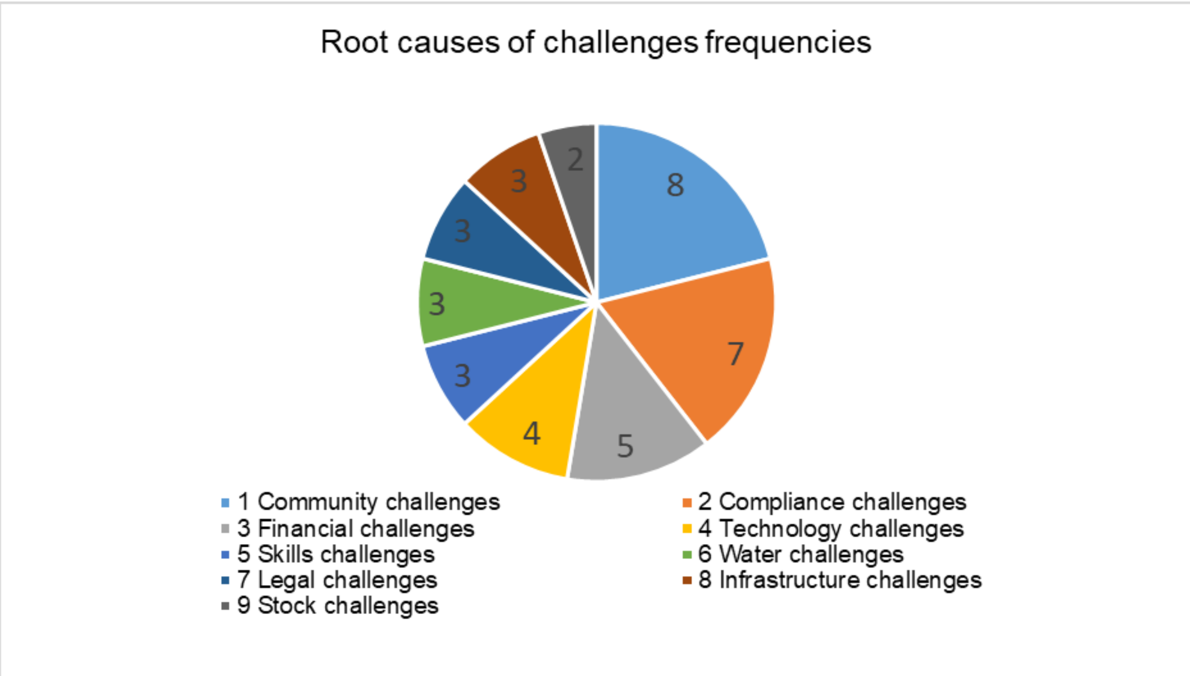

Figure 7.5: The frequencies of the root causes of the challenges

Figure 7.5 indicates the frequencies of mention of the root causes of the challenges. The highest frequency level of mention is the community challenges (8 times) and the compliance challenges (7 times). Therefore, these two categories of challenges were the most important points of interest of the root causes of the challenges. These challenges were frequently mentioned by the CoT managers, the contractor managers, and the contractor employees. The CoT management will have to focus on the community and address non-compliance from both the city and the contractors. Table 7.2 outlines the various categories mentioned by the respondents. The CoT managers had something to say about every challenge in Figure 7.5 and Table 7.2, whereas only five challenges were mentioned by the contractor employees and three by the contractor managers.

Table 7.2: Challenges categorised according to the respondents

Challenges	CoT managers	Contactor managers	Contractor employees
Community challenges	X	X	X
Compliance challenges	X		X
Financial challenges	X	X	X
Technology challenges	X		
Skills challenges	X		X
Water challenges	X		
Legal challenges	X		
Infrastructure challenges	X	X	X
Stock challenges	X		

7.2.4 To identify how space technology can help with the management of WI

Space in Africa (2020) states that there are gradual positive developments with investments in the space and satellite industry. In addition, Githathu (2020) notes a R4.5 billion space sector boost initiative that aims to encourage the public and private sectors to come together, to bring forth the development of infrastructure, and to support economic growth. Space technology requires an advanced level of knowledge for application. The skills shortages faced in this regard by the CoT will be overcome by the decision to build a University of Science and Innovation in Ekurhuleni and the construction of nine new Technical and Vocational Education and Training (TVET) Colleges (South Africa, The Presidency 2020: 11/23). The results of this study, highlighting the perceptions about space technology, are given in Figure 7.6.

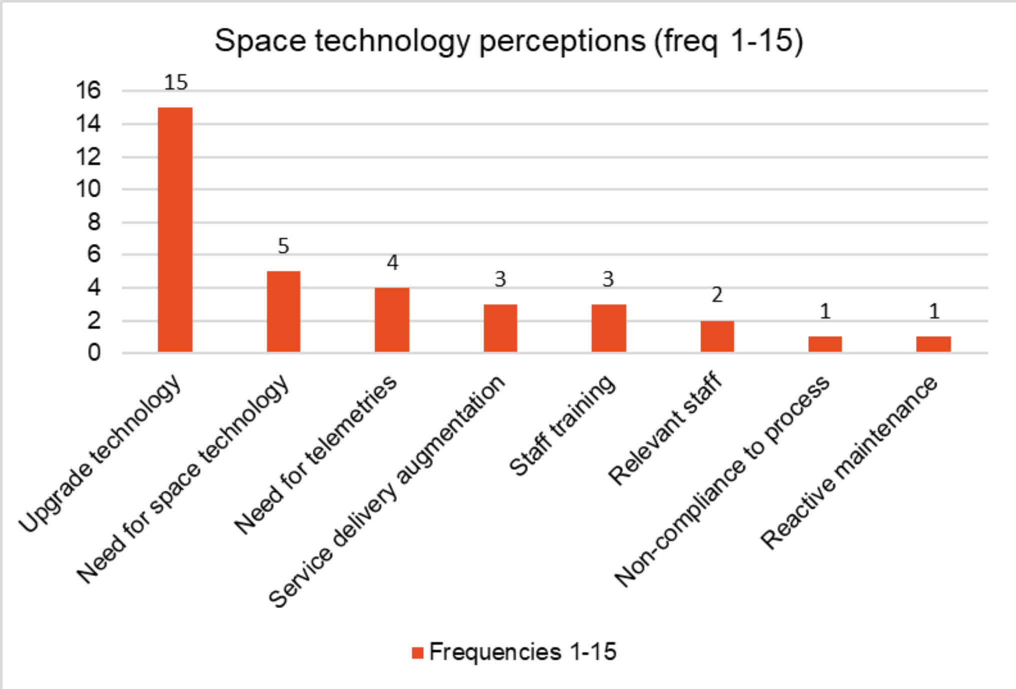

Figure 7.6: Perceptions about space technology

Figure 7.6 highlights the perceptions of the CoT manager respondents regarding space technology in the city. The respondents' perceptions were directed towards the upgrade of technology for the appropriate application of space technology. The upgrade of technology dominated the discussions. The respondents indicated their willingness to adopt a more sophisticated technology provided the existing technology is upgraded to adapt to the changes. Reactive maintenance and non-compliance to the process were the lowest mentioned in the discussions. The challenges of space technology and the solutions to these challenges as suggested by the literature are listed in Table 7.3.

Table 7.3: Challenges and solutions of space technology

Challenges of space technology	Solutions of space technologies
Financial constraints	R4.5 billion government boost for SA space sector (Githathu 2020).
No training on space technology	The decision to build a University of Science and innovation in Ekurhuleni and the TVET colleges (South Africa, The Presidency 2020: 11/23).
Resistance to adapt to technology	Public and private sectors to start education and training systems (Dadios *et al*. 2018: ii).
Lack of security	Satellites can be used for security purposes (Space in Africa 2018).
No records of the location of the infrastructure.	Location of infrastructure like pipelines (Chang 2015: 1-2).
Underground leaks	Leak detection through RS (Maccioni 2019).
Theft and vandalism of telemetry equipment	Earth surveillance, safety, and security (South Africa, Department of Science and Technology 2018: 4-5).
Contaminated water	Detection of impurities through RS (Evagorou *et al*. 2019: 397).

Literature from Sutherland (2019: 1) highlighted the challenges noticed for the 4IR which may impact the application of space technology in SA if a higher gear is not swiftly engaged. These challenges have been noted as: skills shortage, inadequate production of managers, researchers, and other skills, SA's ailing education system, quality of infrastructure, poor governance, state capture, poor records of creating and applying policy, and cyber security and information security. In addition, Hattingh (2017: 20; 22) mentioned the two core obstacles that impacted SA: inadequate understanding of disturbing changes, and misalignment of strategies between the working class and innovative technology. These obstacles have also been acknowledged by the World Economic Forum (Hattingh 2017: 22). These aspects of literature have been confirmed by the results of this study about the CoT.

Therefore, the results of this study can be seen as supporting the literature. The findings are that for the development of the city and its WI infrastructure, there is a need to upgrade technology in the city. For this reason, space technology will enhance the value of technology in the CoT. As a result, if attention is directed to these challenges, the aspects identified from the reviewed literature can be of particular benefit and of relevance to the CoT to solve many future challenges connected with WI.

7.2.5 To develop a framework of the challenges and the causes

Based on the literature and this study's findings, a framework of the challenges and their causes has been developed. The findings have suggested that the framework should be presented to the senior management of the city. Miya and Grobbelaar (2015: 941) prepared a framework reflecting similar challenges from other municipalities. The results of this study are in line with the literature review. The results of the challenges, the causes, and the effects are presented in Figure 7.7.

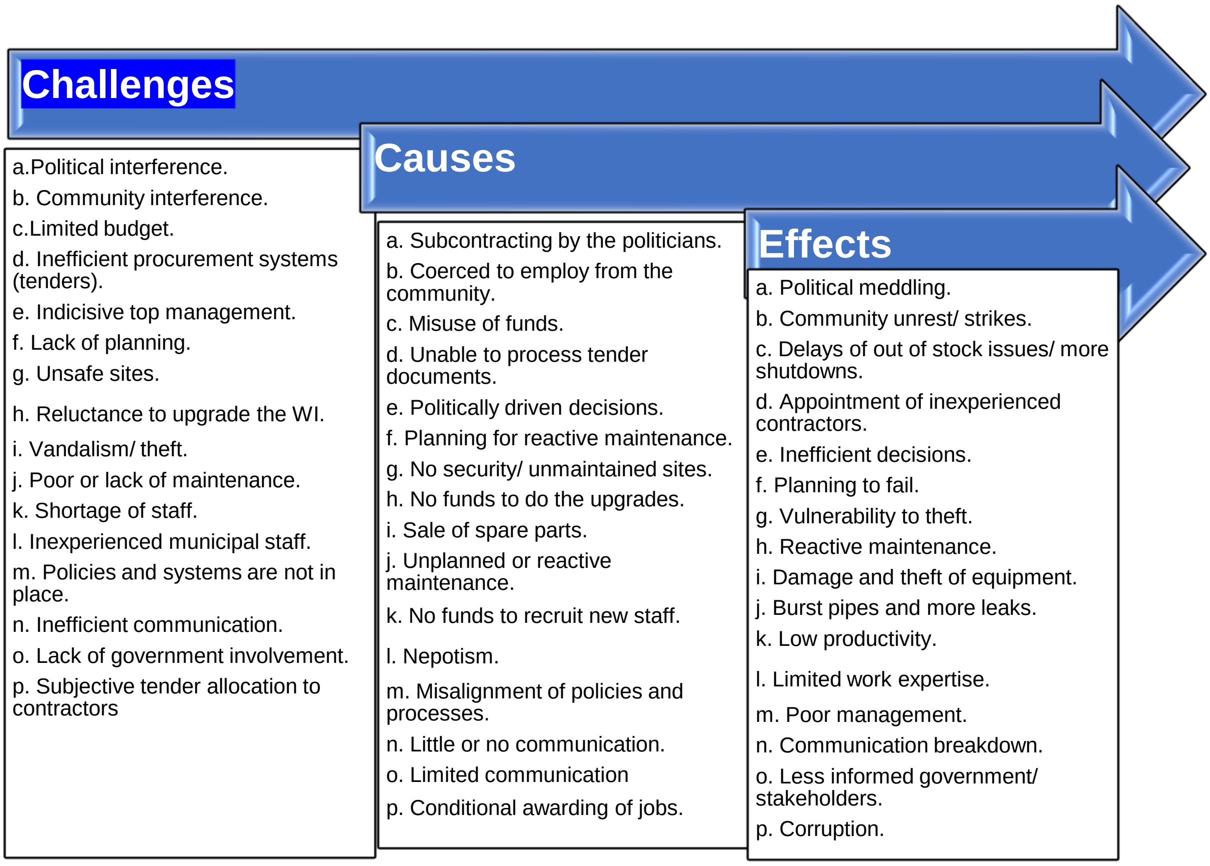

Figure 7.7: Relationship between perceived challenges, causes, and effects

Figure 7.7 shows the results of the challenges, the causes, and the effects experienced in the CoT. The framework was generated from the interviews and focus group discussions. The three aspects – the challenges, the causes, and the effects – have some dependencies on each other. For example, the community interferes by coercing the contractors or the municipality to award a job or a tender to a community member. Any resistance to this demand by the contractor or municipality would then lead to multiple protests, strikes or interference by the community.

7.2.6 Exploration of water management strategies

City of Tshwane (2019b: 7) reported that the CoT's vision 2030 would enable the city to realise its vision. This vision will be realised only if the city adheres to its strategic pillars of economic growth, development, and creation of jobs; formation of a caring atmosphere and encouraging togetherness; outstanding service delivery and environmental protection; protection of residents; and honesty, openness, and approachability. Bello *et al.* (2019: 5) added that another strategy for utility managers is to keep losses to a minimum by sustaining water assets, protecting the environment, growing revenue, and delivering outstanding client service levels. Urich *et al.* (2013: 301) point out that water utility managers are duty-bound to keep their water management strategies up to date to align with future urban requirements of water systems.

The results of this study indicate that service delivery must be increased through improved project management, proper demarcation of areas, conducting of inspections, proper record-keeping, more efficient communication, upgrading of infrastructure, training, and creation of relationships with contractors. The findings of the study are in support of the literature review. These strategies are illustrated in Figure 7.8.

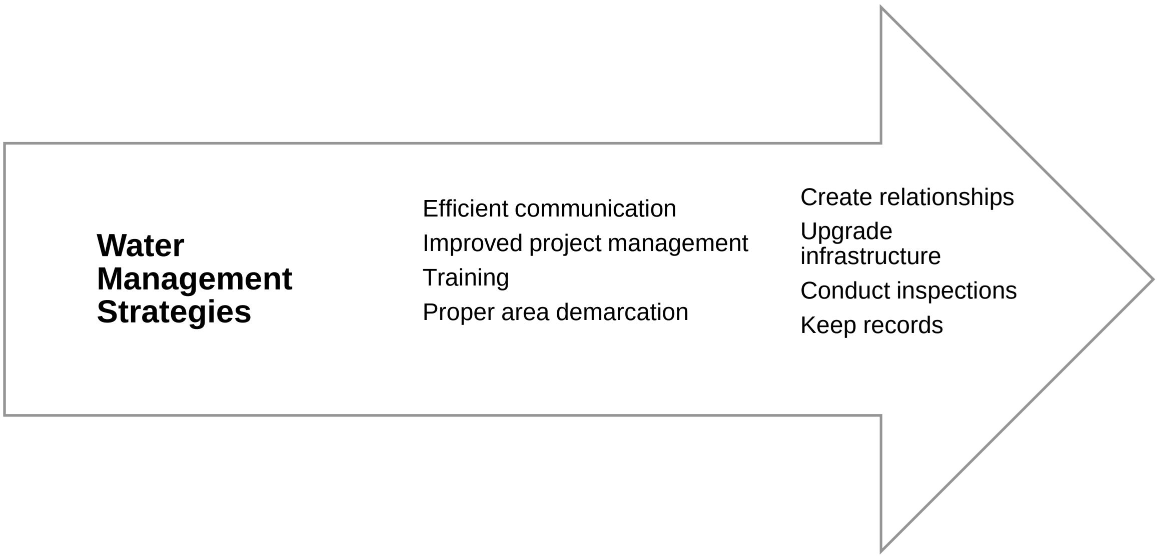

Figure 7.8: Explored water management strategies to improve performance

Figure 7.8 shows the issues to be focused on to improve the strategies of water management. These strategies were explored during the interviews and focus group discussions. The strategies explored regarding water management can help to bring the city to a better level of management of the infrastructure and improved performance.

7.3 Summary of the solutions to the findings linked to each objective

The key issues surrounding the challenges centred on the community, finance/ budget, staff, compliance, and the infrastructure. The CoT suffers from internal process challenges, internal staff challenges, internal financial challenges, external community challenges, and external socio-political challenges to mention a few. These challenges have escalated over the years due to the lack of leadership direction of the city.

These challenges have been caused by political interference, community interference, inadequate budget, unplanned use of budget, inexperienced staff, unsecured sites, and a lack of planning. The solutions to the challenges centred on staff, an integrated approach, long-term planning, and financial planning. A few suggested solutions were training of staff, inclusion in the decision-making process, improved long-term planning and delivery, increased budget, and better financial controls.

7.3.1 Objective 1: To identify the challenges experienced by the municipality during and after installation of WI

a) Findings related to Objective 1:

- Residents are satisfied with the CoT's service and acknowledged the challenges.
- Politics play a key role in the awarding of the contracts.
- The strikes by contractors affect the city's progress.
- Limited technical and management expertise to manage installation and maintenance.
- Contractors do not adhere to health and safety standards.

b) Solutions to the findings:

- Involve all stakeholders in long-term planning and implementation of strategies.
- Recruit qualified staff.
- More staff training.
- Improve project management.

7.3.2 Objective 2: To rank the importance of the identified challenges experienced by the municipality

a) Findings related to Objective 2:

- Vandalism and theft.
- Inadequate budget/ finance.
- Inefficient procurement processes.
- Poor communication of messages.
- Delays that result in escalating prices.
- Dilapidated infrastructure.

b) Solutions to the findings:

- Security on site.
- Increased budget with better financial controls.
- More efficient communication.

- Decision making responsibility at the correct level to make a positive impact on delays.
- Replace and overhaul old infrastructure.

7.3.3 Objective 3: To explore the root causes of the challenges experienced during the installation of water infrastructure

a) Findings related to Objective 3:

- Inefficient decision making.
- Interference by community members.
- Unsecured sites.
- Inexperienced staff.
- Disregard of the SOPs that lead to non-compliance.
- Corruption leads to financial losses.

b) Solutions to the findings:

- Policies and systems must be approved.
- Improve accountability.
- Superiors must exercise control.

7.3.4 Objective 4: To identify how space technology can help with the management of water infrastructure

a) Findings related to Objective 4:

- Upgrading of technology.
- Some employees are still behind with technology.
- Ignorance of processes.
- Space technology is a necessity.

b) Solutions to the findings:

- Recruitment of qualified staff.
- Training of staff.
- Compliance with the processes.

- Plan maintenance.

7.3.5 Objective 5: To develop a framework of the challenges and their causes

a) Findings related to Objective 5:

- The framework would result in improvement of work.
- Would result in an integrated approach.
- Would bring better inputs in the research reports.

b) Solutions to the findings:

- Improve project management.
- Improve financial controls.
- Hire more staff.
- Improve understanding of the challenges by the executives.

7.3.6 Objective 6: To explore water management strategies to find possible ways to resolve the challenges

a) Findings related to Objective 6:

- Efficient communication.
- Trust.
- Improve project management.
- Upgrade the infrastructure.

b) Solutions to the findings:

- Clear communication.
- Create a relationship between contractors and employees.
- Better stock control/ adequate supply of stock.

7.4 Summary of the research findings concerning the research questions

This research has provided the answers to the research questions by providing the various findings and solutions. The research objectives have been carefully aligned to the findings and the solutions outlined in sections 7.2.1 to 7.2.6. The discussions around the research questions are presented:

7.4.1 Causes of challenges experienced by CoT during and after installation of WI

The causes of the challenges have briefly been found to be politics, strikes, limited technical capacity, and ignorance of the standards. A detailed explanation of the challenges has been outlined in section 7.2.1.

7.4.2 Ranking the importance of challenges experienced by the CoT

Each of the challenges experienced has been ranked in detail in section 7.2.2. A few of them are ineffective procurement systems, management indecisiveness, inefficient policies, and dilapidated WI.

7.4.3 Root causes of challenges experienced during installation of WI

A few root causes have been discussed, namely vandalism and theft, non-adherence to deadlines, and the areas with underlying dolomite. The full details of the root causes are discussed in section 7.2.3. Dolomite is prevalent in the Centurion area in the CoT (Montjane *et al*. 2020: 1).

7.4.4 Space technology can help to manage WI

This question has revealed that the use of technology in the CoT is still at its formative stage. This research has identified avenues for the exploration of space technology for the WI in the CoT. The study has revealed that space technology has been applied to WI in other cities of the world. The CoT is currently using the infrastructure management query station to locate the WI and other applications. The details are discussed in item 7.2.4.

7.4.5 A framework of the challenges and their causes

A detailed framework of the challenges and their potential causes is presented in Figure 7.7, with the findings and the solutions discussed in Table 7.1 and Table 7.4, respectively.

7.4.6 Exploration of WI strategies for finding ways to resolve the challenges

The strategies to plan and make the city better are outlined in section 7.2.6. The findings related to communication breakdown and unobserved performance tally with those of Northwest Province municipalities in a study conducted by Kopung (2017: 195-196). These types of failures result in endless community meetings and eventually protests. A summary of the solutions to the challenges is discussed in Table 7.4.

Table 7.4: Possible solutions to the challenges

Challenges	Causes	Solutions
Political interference.	Subcontracting by the politicians.	Inform stakeholders in all issues
Community interference.	Coerced to employ from the community.	Include relevant stakeholders in decision-making processes
Limited budget.	Misuse of funds	Better financial controls/ increased budget
Inefficient procurement systems (tenders).	Unable to process tender documents.	Ensure adequate supply of stock
Indecisive top management.	Politically driven decisions	Decision making at the correct level.
Lack of planning.	Planning for reactive maintenance.	Improved planning and delivery
Unsafe sites.	No security/ unmaintained sites.	Earth surveillance/ Hire security on site
Reluctance to upgrade the WI.	No funds to do the upgrades	Replace and overhaul old infrastructure
Vandalism/ theft.	Sale of spare parts	Space technology/ On site security
Poor or lack of maintenance.	Unplanned or reactive maintenance	Better maintenance of WI
Shortage of staff.	No funds to recruit inexperienced staff	Hire qualified staff
Inexperienced municipal staff.	Nepotism.	More staff training
Policies and systems are not in place.	Misalignment of policies and processes	Improved policies and systems
Inefficient communication.	Little or no communication	Communicate clear messages
Lack of government involvement.	Limited communication	Different departments must work together
Subjective tender allocation to contractors.	Conditional awarding of jobs	Relevant stakeholders to form part of long-term planning and implementation of strategies
No space tech training	Financial constraints	R4.5 billion SA space sector boost
Resistance to technology	Old age	Recruit technology literate youth
Underground leaks	No space tech systems	Leak detection through RS
Contaminated water	Less maintenance to WI	Detection of impurities through RS
Unlocatable WI	Lost/ misfiled WI plans	Detection sensors/ Proper filing of WI plans

Table 7.4 highlights the solutions to the challenges that were pointed out during the fieldwork. Each of the challenges and the causes has been provided with a solution. However, the challenges and causes have already been presented in Figure 7.7.

7.5 Chapter summary

This chapter has demonstrated the research findings from the quantitative (survey) and qualitative (interviews and focus groups) respondents' points of view. Firstly, these findings were grouped according to the relevant objectives. Secondly, the findings in each objective have been provided with workable solutions. The findings from the survey were articulated in Objective 1 where the identified challenges experienced by the municipality were outlined. Most of the findings from the interviews and focus groups were relevant to Objectives 2 to 6. Objective 2 discussed the ranking of challenges, and the CoT managers recommended the challenges to be presented to the senior officials of the municipality.

Objective 3 exposed the origin of the challenges from the CoT managers' and the contractors' points of view. Objective 4 discussed the management of WI with the application of space technology. A framework of the challenges and causes thereof was developed as required in objective five. Objective 6 discussed the water management strategies to resolve the challenges. A summary of the research findings has been linked to the research questions to see if the answers have been provided.

7.6 Conclusion

This study has achieved its aim and research objectives and answered all the research questions. Areas without answers that may need further investigations will be recommended for further research in the next chapter. The responses from the citizens' survey, the CoT managers' interviews, and the contractors' focus groups demonstrated that the CoT faced multiple challenges. Management shortfalls have also exacerbated the challenges to a certain extent. Most of the challenges require immediate intervention while some need senior officials to answer the relevant questions to be asked.

The contractors are operating on their own without being monitored. There was no response from the CoT management when the contractors needed the city's intervention. Indecisive management of the CoT WI revealed to the contractors that the city's employees lacked the required skills to manage the maintenance and management functions. If the managers do not know the rules of the game, they should not form part of the decision-making process. In other words, a mismatch of skills may bring service delivery to a halt, which would be problematic considering that the role of the municipality is service delivery.

The next chapter presents the conclusions and recommendations of the study and suggestions for further research.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter discusses the following: summary of the findings, conclusions regarding the research objectives, conclusions about the research questions, implications for the study, lessons learned from the study, recommendations, limitations, and recommendations for further research. The relevance and applicability of the findings also form part of the discussions. The results obtained in this study will contribute to the body of knowledge of the research community, academics, and other various fields. The study aimed to investigate the challenges of managing water infrastructure in a selected South African municipality and to find ways to resolve such challenges with the help of space technology. The aim brought forth the objectives that had been discussed in detail in the previous chapter of this study and are to be summarised in this introductory part of this chapter.

The first objective sought to identify the challenges that the municipality experienced during and after the installation of WI. The responses identified the various stages at which the municipality experienced the impact of the challenges. The second objective aimed at ranking the challenges according to their importance. The ranking would then identify the major challenges of the municipality and exclude those that were perceived to be minor. The third objective sought to identify the foundation causes of challenges in the process of WI installation. The objective drilled deeper to find if there were hidden issues to unveil. The fourth objective focused on identifying if there could be assistance from space technology to manage WI. This objective required the study to demonstrate the help obtainable from space technology to manage the WI.

The fifth objective sought to develop a framework of the identified challenges and matched each with the cause. After the challenges experienced were identified, a framework of the challenges and an outline of the causes were organised. The framework informs the strategies formulated in the next (sixth) objective. The sixth and last objective explored the water management strategies to find ways to resolve the challenges. This objective focused on developing the various management strategies with the idea to resolve the challenges. All the six objectives of this study have been achieved and the research questions have been successfully answered, as demonstrated in Chapter 7.

After all the various challenges, the causes and solutions that are directly affecting the CoT were discussed in Tables 7.3 and 7.4 (all incorporated in Table 7.4) as part of the findings from the interviews and focus groups, it is important to restate that these challenges are directly linked to those listed in Tables 3.6 and 3.7 as obtained from the literature about the SA cities. It is worthwhile to restate the challenges with higher frequency levels from Table 3.6, 3.7 and 7.4 to this conclusions and recommendations chapter.

These challenges are: inadequate maintenance, vandalism and theft, skills shortages, long procurement process, ageing infrastructure, low staff morale and shortage of historical data, incapable decision makers, unreliable political undertakings, dispersed roles of the local authority, illegal connections, financial constraints, no training in space technology, resistance to technology, lack of planning, inefficient communication, community interference, political interference, unsafe sites and subjective tender allocation. Detailed information about the challenges, the causes and solutions are in the relevant Tables mentioned earlier.

Space technology can help to solve some the challenges as revealed by the findings and for the CoT to discharge an improved level of service. Space technology has assisted various governments, aviation industries, universities and schools in applications such as EO, RS, weather forecasting, research and development. This space technology would therefore assist if implemented in the CoT, as the findings have demonstrated that there is a need for an upgrade of water infrastructure in the city.

8.2 Summary of the findings

The study aimed to investigate the challenges of managing water infrastructure in a selected South African municipality and to find ways to resolve such challenges with the help of space technology. The results of this study have prompted the researcher to draw the following conclusions:

- **Human resource issues**
  - There is a staff shortage with a lack of training.
  - The staff lacks technical skills, management skills, and experience to do the work.

- **Management issues**
  - There are long processes to finalise the procurement of tenders, resulting in nepotism.
  - The municipality does not keep records.
  - The communication between sections is poor and inefficient.
  - There is little information being provided to the community.
  - Poor management of the projects.
  - Managers take inefficient decisions.
  - There is a lack of implementation from the city.
  - The contractors execute the work in unsafe sites/ environments.
  - The delays arise from the contractors due to strikes.

- **Maintenance issues**
  - There are challenges of poor maintenance of infrastructure that led to shutdowns and eventually result in delays of successful maintenance.
  - Leaks are the major challenges that the community face.
  - The WI is old and dilapidated.
  - There are challenges with the installation of WI that result in inaccessible roads, and dangerous open trenches without safeguards.

- **Financial issues**
  - There is an insufficient budget that leads to financial challenges, the purchase of defective materials, and leading contractors to take shortcuts.

- **Socio-political issues**
    - There is no support for the projects by politicians.
    - Politicians interfere with the processes of the municipality.
    - The community interferes with the smooth running of the municipal operations by striking.
    - Contractors are coerced to hire from the local communities without the required skills.

- **Legal issues**
    - There is a lack of enforcement from the municipality.
    - Disregarding the procedures and SLAs.

- **Criminal Issues**
    - There is vandalism and theft because of a lack of security.
    - There are manifest corrupt practices in the CoT.

8.3 Conclusions regarding the objectives

This section presents the conclusions reached about the objectives as presented in section 7.2.

Objective 1

Concerning the challenges experienced during and after the installation of WI, it is concluded that there are challenges that the community experience during and after the installation of WI. These challenges are unbarricaded trenches, materials lying around, inaccessible streets, and water cut-offs, to mention a few.

Objective 2

The challenges have been ranked according to the importance or the urgency that they deserve, it is concluded that the challenges ranked in Figure 7.4 require urgent attention for the smooth running of the city's operations. The challenges that require attention first are those ranked three, four, and five as shown in Figure 7.4. However, those ranked between one and two would still need to be addressed.

Objective 3

In terms of the root causes of the challenges experienced during the installation of water infrastructure, it is concluded that the root causes emanated from the nine important challenges as outlined in Figure 7.5. The challenges have been rated according to the frequencies, where challenges seven and eight are the most important.

Objective 4

Regarding the identification of how space technology can help with the management of water infrastructure, it is concluded that space technology can enhance the management of WI. The CoT firstly must sort out the skills shortage, recruit the relevant staff, provide the training of staff, and upgrade the available technology to connect to the future innovations.

Objective 5

In terms of the required development of a framework of the challenges and their causes, such a framework of the challenges, the effects, and the causes have been developed in Figure 7.7. It is recommended that the framework should be presented to the senior management.

Objective 6

Relating to the exploration of water management strategies to find ways to resolve the challenges, it is concluded that efficient communication, improved project management, training, proper area demarcation, creation of relationships, upgrading of infrastructure, inspections, and record-keeping are good water management strategies to create a successful city.

8.4 Conclusions regarding the research questions

Based on the findings of this study the following conclusions about the research questions can be drawn.

The causes of challenges during the installations of WI are community challenges, leaks and pipe bursts, lack of proper equipment, poor enforcement of compliance, poor planning, informal settlements, and damages during installations. The challenges during maintenance are water shutdowns, escalating delays, poor enforcement of compliance, lack of finance, staff shortage, poor long-term planning, vandalism and theft of equipment and infrastructure components, communication breakdown, security issues, and informal settlements.

When ranking the importance of the challenges experienced by the municipality, the highest-ranking was five (highest priority) and lowest-ranking was one (lowest priority). According to the rankings, vandalism and theft were at 'five' (highest priority), poor maintenance of the infrastructure, and lack of experienced municipal employees were 'one' (lowest priority). The root causes of the challenges during the installations of WI are community issues (strikes), non-compliance with the minimum requirements (quality standards), lack of financial management expertise, limited technical capability (technology), lack of skills, inefficient decisions, vandalism and theft, dilapidated infrastructure, corruption, and ignorance of legal requirements.

Concerning the use of space technology to manage water infrastructure, the CoT is still at the initial stage of applying space technology to manage the WI. The current application of space technology in the CoT involves the infrastructure management query station to locate WI and other applications. There is no mention of a remote sensing application to locate leaks or to monitor the water levels in reservoirs in the CoT. The CoT currently uses telemetry systems that use radio frequencies to view the water levels in the reservoirs.

The framework of the challenges and the potential causes has been developed in Figure 7.7. It is concluded that the city faces multiple challenges that need attention. These challenges manifest because of the failure of managers to execute the managerial functions to plan, lead, control, coordinate and organise. Some of these challenges are, however, out of managerial control and need political solutions.

In terms of the water management strategies to find ways to resolve the challenges, the conclusions reached were that management must improve communication, create an environment of trust, upgrade the infrastructure, order sufficient stock, improve project management, and improve training. These aspects of management can be improved through an integrated approach.

8.5 Implications for the study

The implications of this study include the following: implications for project management theory, maintenance theory, and system theory. This study has shown that space technology can make the implementation of these theories more effective in WI and project management, maintenance, and systems.

The CoT managers would benefit from this study especially in influencing policy decisions regarding how to overcome the challenges in managing WI. Another positive development from this study demonstrated that planning for a project or service leads the organisation to a better level of service, organises the resources on time, coordinates the various divisions and controls the activities for successful project or service delivery.

The study opened new opportunities for the managers to look back and rethink new strategies for improved service delivery. The study conscientises the managers about the challenges before they happen. The application of space technology to this study is a 'wakeup call' for the managers to be well equipped for the Fourth Industrial Revolution. If the recommendations are implemented, the CoT may reap more benefits from this study, especially from the introspection by the city's management and politicians and by setting the bar higher in terms of the recruitment of managers.

The community would welcome more engagement, as this study has reiterated that involvement of the community is key in matters that involve them. This study has stressed that the community should have a stake in the projects in and around their locality. The study added a benefit that service delivery or the life cycle of a project realises success when there is a buy in from the community. The study made a valuable input by confirming that successful service delivery and project life cycle depends on political buy in. In addition, the study has contributed to the theories of project management. A brief explanation of how this study has contributed to these theories is outlined below.

8.5.1 Implications for project management theory

In terms of project management in the study area, the finding revealed a lack of project management, lack of monitoring, and lack of enforcement in the study area. Zwikael and Smyrk (2019: 45) confirmed that water infrastructure underpins itself with the four phases of project management namely: initiation, planning, execution, and outcomes realisation. Project management phases play a pivotal role in the installation and maintenance of water mains, boreholes, water pumps, and construction of towers and reservoirs, which have a defined period to start and end. Project management theory would help to eliminate haphazard work done by the city employees and the contractors, by making them stick to project management tools and techniques. Koskela and Howell (2002a: no page) says that theory should be specific and should demonstrate how an application gets converted into an objective.

Koskela and Howell (2002b: 3) maintained that project management theory has two theories namely, project theory and management theory. Project theory divides tasks into smaller cost-effective manageable independent tasks. The theory of management has three sub-theories namely, theory of planning, theory of execution, and theory of control. The theory of management sets performance standards, measures performance output, and takes corrective action after recognising the difference between the measured and the standard performances.

Project management theory has contributed knowledge to this study about the aspects of project management, monitoring, and enforcement in the study area. This theory sets a tone for the study area to execute the knowledge areas of project management for the successful completion of projects. The solutions to the findings of this study support the theory through improved project management, efficient communication, and more staff training.

8.5.2 Implications for maintenance theory

This study has unveiled that there was a lack of planning for maintenance, lack of implementation and the resources have not been sufficient in the study area. Maintenance theory will contribute knowledge of maintenance planning to the study area. According to Phogat and Gupta (2017: 213), maintenance theory encompasses strategies that cover activities, processes, assets, and time. These strategies enable an organisation to perform its set targets successfully through maintenance planning. Consequently, maintenance planning will then be followed by the necessary strategic allocation of resources. The planning of maintenance will be followed by actions such as the implementation of maintenance, control, and observation of the production systems.

This study has contributed new knowledge about how space technology can be used to detect buried water pipes that need to be maintained or replaced, especially in a South African context. This should save time as it will avoid employees having to haphazardly dig and search for the pipes for several days, often without success. Further, the technology can be used to secure municipal assets from vandalism and theft, and enable reservoirs to be remotely observed, again saving time and costs. The findings of this study support this theory by including planned maintenance, compliance to the processes, and recruitment of qualified staff as part of the solutions to the findings.

8.5.3 Implications for system theory

Firstly, this study has unveiled that there were no policies and systems in place in the study area. Secondly, the information did not flow uniformly to the recipients and resulted in a distorted flow of messages. Kerzner (2009: 38) defines systems theory as a management style trying to incorporate and bring uniformity of scientific facts to be known. The initial stage of getting things done is to first get the systems right. The systems theory approaches and solves problems collectively. This theory recognises policies and systems, the installation and maintenance of WI, and communication as a system rather than a single component. This theory contributes better to the body of knowledge of this study about the aspects of policies, systems, installation and maintenance of WI, and communication in the study area. The solutions to the findings support the theory by suggesting the approval of policies and systems, improved accountability and superiors must exercise control.

8.6 Lessons that contributed additional knowledge to the study

Some additional lessons have been learned during the study from the discussions with the CoT managers' interviews and contractors' focus groups discussions. These are the researcher's views and are not strictly empirical findings, but are interesting perceptions that working under the Covid-19 pandemic has contributed to, such as:

- Organisations should always plan for any eventualities such as the Covid-19 pandemic.
- Technology has made the life of organisations easier by organising meetings through applications such as Zoom and Microsoft teams.
- Physical contact is not the only way to conduct business.
- There have been significant savings from fewer travel and accommodation bookings.
- The interviews and focus group meetings were organised in well-ventilated spaces due to the Covid-19 restrictions on the numbers and the distances between the occupants.
- Organisations have taught employees new ways to do business and not to resist technology.
- There are enough technology gadgets in the CoT, but limited skills to use the gadgets.
- Investing in the older generation in the work environment is detrimental to the organisations.
- Space technology may contribute as a modern technology in the CoT for the WI.

8.7 Recommendations from the study for the CoT

The following recommendations are proposed for adoption by the CoT to improve and become a productive city with a sound WI:

- **Human resources**
  - The CoT should recruit more staff to do the work.
  - The CoT must introduce a better communication channel among the employees.
  - Employees to be recruited must undergo a rigorous scrutiny process.
  - Under-qualified officials must be given a reasonable timeframe to complete the required studies for the occupied positions.
  - Senior officials and executives must possess at least a relevant postgraduate degree qualification.
  - The tender procurement process takes too long and needs to be revisited.

- **Training**
  - The CoT should introduce a fully-fledged training department/section for technology for the employees to find relevance in the 4IR era.
  - Senior officials and executives must attend intensive training for skills development.

- **Culture**
  - Employees must drive a culture of service delivery to the communities.

- **Finance**
  - The budget must be used for the relevant work budgeted for.
  - Budget diversion or roll-over for unintended purposes must come to a halt.

- **Operations**
  - Service delivery issues reported by the community should receive first priority.
  - The challenges revealed in this study should be addressed with an integrated approach with other departments of the CoT.
  - Thorough inspections must be conducted of the work done by contractors at every stage and records must be kept.
  - The CoT should investigate investing in space technology in the areas of RS and security for the WI.
  - Senior officials and executives must demonstrate the skills needed for the recruited positions.
  - Senior officials must weigh better options of whether to replace or fix the old WI.

- **Control**
  - Managers for the CoT regions should meet weekly to discuss and address the WI challenges.

8.8 Limitations of the research

This study was conducted when SA and the rest of the world experienced the Covid-19 pandemic. The movement restrictions from provinces had a major negative impact on this study. Some respondents did not make it for the interviews and focus group discussions despite their agreement to appointments. Some offices were closed due to suspected cases of Covid-19 infection. Most of the employees were working on a rotational basis. The pandemic caused devastating losses in multiple organisations. The cancellation of appointments during the interviews and focus group sessions and closure of offices caused the study to take longer than planned.

Some of the respondents had to postpone appointments because of having been in contact with someone infected with the Covid-19 virus. These respondents had to isolate, and the isolation periods had not lapsed to allow them free contact with others. This study experienced various postponements of appointments because of the adjustments of the Covid-19 regulations (prohibited gatherings and restricted interprovincial travels). Some of the respondents had to be interviewed from home due to other commitments. Nevertheless, most respondents were interviewed in their workplaces.

One respondent refused to be interviewed and cited reasons of unwillingness to be interviewed, and that there is no benefit from the study. The travelling from one unknown place to another created a state of nervousness for the researcher. The fear of getting stuck in the traffic-congested area also created anxiety for the researcher regarding arriving on time for the appointments. The responses to the questions were often indistinct with connotations that needed further probing. These types of interactions exposed the respondents to a state of discomfort. Due to the study being conducted with city employees some of the information was limited similarly to a study conducted by Hernández-Bedolla *et al*. (2017: 16). Nonetheless, the researcher managed to make use of the available data to produce the results.

A weakness of the qualitative research method of this study was that the researcher relied on the opinions of small samples. Nevertheless, the researcher overcame this weakness via data source triangulation (Patton 1999: 1193), by selecting a range of different respondents (managers, contractors, and employees), and did not only rely on a homogeneous group for data collection. The view of the researcher was that small samples have a tendency for producing results with less degree of variety. The study of a single municipality is a limitation; as a result, any attempt to extrapolate these results to other municipalities should be done extremely carefully.

8.9 Recommendations for further research

This research has unveiled certain aspects that may have been unanswered as they were not the focus of this study. Nonetheless, these aspects have emerged from the literature review, the interviews, and focus group interactions. It is justifiable that further research should be conducted on the aspects that became apparent when this study was undertaken. Misuse of funds, defective maintenance of WI, the qualifications of the managers and executives, and community strikes need in-depth qualitative research. The research may be conducted with high-level management team members (heads of departments and executives) to ascertain in more detail the causes of underperformance of the WI division and remedies. It is therefore the researcher's view that areas of future research should be focus on the following aspects:

- Examining the proper usage of funds for the CoT WI.
- The cause of community violence against the contractors doing maintenance of WI.
- Investigating the causes of delays in the procurement of WI service providers in the CoT.
- Examining the turnaround time for the various WI activities in the CoT.
- Exploring the WI assets that have reached the useful life for replacement in the CoT.
- Relationship management between the CoT municipal employees and the contractors.
- Defining clearer roles between the municipal employees and politicians.
- The impact of lack of reporting in the CoT WI.
- Further academic research into WI, based on the use of and relationship between WI and space technology.

8.10 Chapter summary

This chapter has presented a summary of the research findings, showing that the recommendations were derived from the findings. These findings covered the issues relating to human resources, management, finance, socio-political, legal, maintenance of WI, and criminal issues.

The implications of this study in terms of the project management theory, maintenance theory, and system theory were covered in the discussions. There have been various lessons that were learned during the execution of this research which have contributed new knowledge to the field of WI management. The findings gave rise to recommendations based on the aspects of human resources, training, culture, finance, operations, and control to be drawn. Some limitations applying to this study have been mentioned, together with the means used to minimise the effect of, or overcome, the limitations. The findings of this study have culminated in recommendations for further research, relating to the use of funds, violence, procurement, turnaround time, replacement of WI, and lack of reporting being made.

8.11 Conclusion

This chapter has achieved its aim in terms of the presentation of findings, conclusions about the objectives, conclusions about the research questions, recommendations from the results, and recommendations for further research. The findings of this study have identified the shortfalls of the city in terms of management of the WI. The researcher hopes that the recommendations of this study will be applied by the managers in charge of the WI division of the CoT and any other water utilities experiencing the same challenges. It is imperative to note that the results pointed out the challenges of staff shortage, employees' technical and management skills deficit, and inexperienced staff to mention a few and that these aspects need attention.

The various theories presented in this study should be adhered to in order to make the CoT a better city. These theories are the basis from which the managers operate to build a successful city. The municipalities are regarded as central to the delivery of services to the communities in SA. This chapter and the rest of the study provide answers to effective and efficient management of the WI for sustainable service delivery for the CoT and SA.

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APPENDICES

APPENDIX A: QUESTIONNAIRE/SURVEY - CITIZENS OF TSHWANE

My name is Lesley Mokgobu, I am a student at the Durban University of Technology. I am currently studying a Doctor of Philosophy of Management Sciences specialising in Business Administration.

This questionnaire has been prepared for the fulfilment of the title "The application of space technology and the challenges of managing water infrastructure in a selected South African municipality".

The aim of the study is to investigate the challenges of managing water infrastructure in a selected South African municipality, and to find possible ways to resolve such challenges with the help of space technology.

Water infrastructure is defined as an arrangement of water supply, treatment, storage, water asset management, prevention of flood and hydropower with systems connected thereto to form a network. In the context of water sector these are tangible equipment such as pipes, pumps, meters, generators, storage tanks, valves etc.

Participation is voluntary and you will not receive any monetary or other form of remuneration, nor will you incur any costs. There are no foreseeable risks or discomforts and the research does not expose participants to any hazards. You may withdraw from participation in this survey at any time with no adverse consequences for withdrawal.

The information supplied by you will be treated as confidential and your identity, where known, will be kept anonymous. The study will hopefully help the City of Tshwane to reduce costs and provide better service to citizens by improving installation and maintenance of water infrastructure.

Regarding Any Problems or Queries:
Please contact the researcher Matlou Lesley Mokgobu on 0824030689, my supervisor Prof RB Mason on **0317670863** or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof S Moyo on 031 373 2382 or dvctip@dut.ac.za.

Statement of Agreement to Participate in the Research Study:

By completing the questionnaire, I confirm that:

- I have been informed by the researcher, Matlou Lesley Mokgobu, about the nature, conduct, benefits and risks of this study – DUT Research Ethics Clearance dated 8 May 2020,
- I have also read and understood the above written information regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.

I agree to participate in this survey ☐

SECTION A

Indicate the extent to which you agree with the following statements, by marking a cross (x) next to the appropriate number using the rating scale below:

a) **1-Stronly disagree; 2-Disagree; 3- Neither agree nor disagree; 4- Agree; 5-Strongly agree**

1. There are challenges experienced during the installation of water infrastructure in your township or suburb.

1		2		3		4		5	

2. There are challenges experiencied during the maintenance of water infrastructure in your township or suburb.

1		2		3		4		5	

3. There are challenges arising from the contractors doing the installations of water infrastructure.

1		2		3		4		5	

4. There are challenges arising from the municipality regarding water infrastructure installations.

1		2		3		4		5	

5. Political interferences play a major role in the awarding of jobs to contractors by the municipality.

1		2		3		4		5	

6. Unattended and unbarricaded open trenches, inaccessible streets due to installation and maintenance of water pipes, materials lying around for long time, unnoticed water cut-offs etc. are a few challenges experienced by the citizens.

1		2		3		4		5	

7. Striking contractors affect the smooth running of installation and maintenance of water pipes.

1		2		3		4		5	

8. Politicians own the construction companies doing the installation and maintenance of water infrastructure.

1		2		3		4		5	

9. Managers of the City of Tshwane have enough technical and management capacity to oversee the installation and maintenance of contractor's work.

1		2		3			4		5	

10. Contractors doing the installation and maintenance adhere to the minimum health and safety standards.

1		2		3		4		5	

11. There are delays arising from the contractors doing installations and maintenance of water infrastructure.

1		2		3		4		5	

12. The public is disturbing the smooth running of contractor's work by vandalising the projects.

1		2		3		4		5	

13. The City of Tshwane managers have a better strategy of managing project initiation until project close out by contractors.

1		2		3		4		5	

14. Politicians enhance the projects and work closely with the municipality, the citizens and contractors for project success.

1		2		3		4		5	

Thank you for participating in this study.

APPENDIX B: **SEMI-STRUCTURED INTERVIEW SCHEDULE (CoT Managers)**

My name is Lesley Mokgobu, I am a student at the Durban University of Technology.
I am currently studying a Doctor of Philosophy of Management Sciences specialising in Business Administration.
The questions to be discussed have been prepared for the fulfilment of the study titled *"The application of space technology and the challenges of managing water infrastructure in a selected South African municipality"*.

The aim of the study is to investigate the challenges of managing water infrastructure in a selected South African municipality, and to find possible ways to resolve such challenges with the help of space technology.

In order to achieve this aim, this study has the following objectives;

- To identify the challenges experienced by the municipality during and after installations of water infrastructure.
- To rank the importance of these challenges experienced by the municipality.
- To explore the root causes of the challenges experienced during the installation of water infrastructure.
- To identify how space technology can help with management of water infrastructure.
- To develop a framework of the challenges and their causes.
- To explore water management strategies with the effort of finding possible ways to resolve the challenges.

Semi-structured interview schedule (Discussion topics)

1. The purpose of this section is to probe into the challenges that the municipality experience during and after the installations of water infrastructure:
    - What would you say are the challenges experienced by the municipality that affect the community during installations of water infrastructure?
    - Are there any challenges the municipality experiences which affect the community during the maintenance of water infrastructure?
    - What are the root causes of the challenges during installations of water infrastructure?
    - How serious are the challenges experienced in the division?
    - Can the framework of the challenges and the causes be recommended to the city?
2. This section seeks to establish if there is any assistance given to the contractors by the municipality:
    - Are there challenges experienced by the contractors in the execution of projects?
    - Are the contractors abiding by their contractual obligations in this municipality?
3. The purpose of this section is to probe the management capacity in executing the work:
    - Is the division having enough staff component to do the work?
    - What would you say about the staff competence in the division?
    - What is the turnaround time in response to the installation and maintenance complaints?
4. This section probes for strategies and innovation:
    - Are there any gaps that open for failures in the division?
    - Are there any new management strategies that you can suggest for the development of the division?
    - What is the state of readiness of the City of Tshwane to space science technology?

Thank you for participating in the study.

<u>APPENDIX C</u>: <u>FOCUS GROUP 1- DISCUSSION TOPICS-(CONTRACTORS' MANAGEMENT)</u>

My name is Lesley Mokgobu, I am a student at the Durban University of Technology.
I am currently studying a Doctor of Philosophy of Management Sciences specialising in Business Administration.
These questions to be discussed have been prepared for the fulfilment of the study titled *"The application of space technology and the challenges of managing water infrastructure in a selected South African municipality".*

The aim of the study is to investigate the challenges of managing water infrastructure in a selected South African municipality, and to find possible ways to resolve such challenges with the help of space technology.

In order to achieve this aim, this study has the following objectives;

- To identify the challenges experienced by the municipality during and after installations of water infrastructure.
- To rank the importance of these challenges experienced by the municipality.
- To explore the root causes of the challenges experienced during the installation of water infrastructure.
- To identify how space technology can help with management of water infrastructure.
- To develop a framework of the challenges and their causes.
- To explore water management strategies with the effort of finding possible ways to resolve the challenges.

Discussion questions or topics:

1 The purpose of this section is to probe into the challenges that the municipality experience during and after the installations of water infrastructure:
  - What has been your general experience working as a contractor in this municipality?
  - What is your experience regarding the installation of water infrastructure in this municipality?
  - What are the things you like (and or dislike) about the installation of water infrastructure in this municipality? (Please state why).
  - What would you say are the biggest challenges that the municipality is experiencing regarding installation of water infrastructure?
  - Are these challenges experienced during or after installations?
  - Thinking deeply what could be the root causes of the challenges?
  - Rank the challenges from most severe to least severe?

2. The purpose of this section is to check if there are any interventions from the city's management:
   - Was there any intervention by management to the challenges which were encountered?
   - What would you advise management to do to improve their strategies?
   - Are there any suggestions you can put forward to address the challenges mentioned?
3. The purpose of this section is to establish if contractors are able to adhere to their obligations:
   - Do you adhere to the contractual obligations? If no state why?
   - Are you able to complete the contracts within the contract period? If no state why?
   - Are you able to manage the magnitude of installations and maintenance contracts awarded?

Thank you for your participation in the study.

APPENDIX D: FOCUS GROUP 2 DISCUSSION TOPICS (CONTRACTORS' EMPLOYEES)

My name is Lesley Mokgobu, I am a student at the Durban University of Technology.
I am currently studying a Doctor of Philosophy of Management Sciences specialising in Business Administration.
These questions to be discussed have been prepared for the fulfilment of the study titled *"The application of space technology and the challenges of managing water infrastructure in a selected South African municipality"*.

The aim of the study is to investigate the challenges of managing water infrastructure in a selected South African municipality, and to find possible ways to resolve such challenges with the help of space technology.

In order to achieve this aim, this study has the following objectives;

- To identify the challenges experienced by the municipality during and after installations of water infrastructure.
- To rank the importance of these challenges experienced by the municipality.
- To explore the root causes of the challenges experienced during the installation of water infrastructure.
- To identify how space technology can help with management of water infrastructure.
- To develop a framework of the challenges and their causes.
- To explore water management strategies with the effort of finding possible ways to resolve the challenges.

Discussion questions or topics:

1. The purpose of this section is to probe into the challenges that the municipality experience during and after the installations of water infrastructure:
    - What has been your general experience working as a contractor in this municipality?
    - What is your experience regarding the installation of water infrastructure in this municipality?
    - What are the things you like (and or dislike) about the installation of water infrastructure in this municipality? (Please state why).
    - What would you say are the biggest challenges that the municipality is experiencing regarding installation of water infrastructure?
    - Are these challenges experienced during or after installations?
    - Thinking deeply what could be the root causes of the challenges?
    - Rank the challenges from most severe to least severe?
2. The purpose of this section is to check if there are any interventions from the city's management:
    - How has the city dealt with the disagreements between the contractors and the city?
    - What would you advise management to do to improve their strategies?
    - Do you consider the City of Tshwane as number one city in managing water infrastructure?
    - Are there any suggestions you can put forward to address the challenges mentioned?
3. The purpose of this section is to establish if contractors are able to adhere to their obligations:
    - Do you adhere to the contractual obligations? If no state why?
    - Do you complete the contracts within the contract period? If no state why?
    - Are you able to manage the magnitude of installations and maintenance contracts awarded?
    - How is the cooperation between contractors, municipality and residents during the execution of the projects?

Thank you for your participation in the study.

APPENDIX E: GATEKEEPER LETTER CITY OF TSHWANE

Matlou Lesley Mokgobu
P.O Box 119
JUNO
0748
07 June 2020

The Municipal Manager
City of Tshwane
P.O Box 440
Pretoria
0001

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN CITY OF TSHWANE

I wish to apply for permission to conduct research in your municipality through in-depth interviews with government officials working for the City of Tshwane.

I am currently a postgraduate student at Durban University of Technology studying for a Doctoral degree in Management Sciences (Business Administration). I would like to explore "*The application of space technology and the challenges of managing water infrastructure in a selected South African municipality*".

This research is important to the municipality and the community at large because it will contribute to our understanding of service delivery from different perspectives in this particular municipality.

I furthermore request permission to conduct interviews with twenty of your staff members (Managers, Superintendents, Artisans, Artisan assistants etc.) in the water division and to distribute questionnaires.

Please note that I will provide you with a copy of my proposal which will include copies of the data collection tools and consent forms to be used in the research process, as well as a copy of the approval letter when I receive it from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me at the contact details below. Thank you for your time and consideration in this matter.

Yours sincerely

Matlou Lesley Mokgobu.

Cell: 0824030689/ 0824173612
Email: mokgobul72@gmail.com

APPENDIX F: CITY OF TSHWANE PERMISSION TO CONDUCT RESEARCH

CITY OF TSHWANE
IGNITING EXCELLENCE

City Strategy and Organizational Performance

Room CSP22 | Ground Floor, West Wing, Block D | Tshwane House | 320 Madiba Street | Pretoria | 0002

My ref:	**Research Permission/ L.Mokgobu**	Tel:	012 358 4559
Contact person:	**Pearl Maponya**	Email:	PearlMap3@tshwane.gov.za
Section/Unit:	**Knowledge Management**	Date	15 July 2020

Mr Lesley Mokgobu
P.O box 119
Juno
0748

Dear Mr Mokgobu,

RE: THE APPLICATION OF SPACE TECHNOLOGY AND THE CHALLENGES OF MANAGING WATER INFRASTRUCTURE IN A SELECTED SOUTH AFRICAN MUNICIPALITY.

Permission is hereby granted to Mr Lesley Mokgobu, Doctoral Degree Candidate in Management Sciences at Durban University of Technology (DUT), to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that the research aims to investigate the challenges of managing water infrastructure in a selected South African municipality, and to find possible ways to resolve such challenges with the help of space technology. The City of Tshwane further notes that all ethical aspects of the research will be covered within the provisions of DUT Research Ethics Policy. You will be required to sign a confidentiality agreement with the City of Tshwane prior to conducting research.

Relevant information required for the purpose of the research project will be made available as per applicable laws and regulations. The City of Tshwane is not liable to cover the costs of the research. Upon completion of the research study, it would be appreciated that the findings in the form of a report and or presentation be shared with the City of Tshwane.

Yours faithfully,

PEARL MAPONYA (Ms.)
DIRECTOR: KNOWLEDGE MANAGEMENT

City Strategy and Organisational Performance • Stadstrategie en Organisatoriese Prestasie • Lefapha la Thulaganyo ya Tiro le Togamaano ya Toropokgolo • UmNyango wezokuSebenza namaQhinga aHleliweko kaMasipala • Kgoro ya Leanopeakanyo la Toropokgolo le Bodiragatsi bja Mmasepala • Muhasho wa Vhupulani ha Dorobo khulwane na Mashumele • Ndzawulo ya Maqhinga ya

APPENDIX G: CONFIDENTIALITY AGREEMENT BETWEEN THE RESEARCHER AND THE CITY OF TSHWANE MUNICIPALITY

CITY OF TSHWANE
IGNITING EXCELLENCE

City Strategy and Organisational Performance

Room CSP23 | Ground Floor, West Wing, Block D | Tshwane House | 320 Madiba Street | Pretoria | 0002
PO Box 440 | Pretoria | 0001
Tel: 012 358 7542

My ref:	Confidentiality Agreement	Tel:	012 358 4559
Contact perso	Pearl Maponya	Email:	PearlMap3@tshwane.gov.za
Section/Unit:	Knowledge Management		

CONFIDENTIALITY AGREEMENT BETWEEN THE RESEARCHER AND THE CITY OF TSHWANE MUNICIPALITY

(To be completed by researchers who require access to conduct research within the City of Tshwane Municipality)

Name of Researcher	Matlou Lesley Mokgobu
ID Number	7208245438082
Research Topic	The application of space technology and the challenges of managing water infrastructure in a selected South African municipality.

I, the undersigned, acknowledge, understand and agree to adhere to the following conditions of access to source information related to the management of water infrastructure e.g challenges, successes, complaints from community, complaints from contractors, etc., information relevant to space technology in water infrastructure, and a database of any 20 contractors doing installation/ repairs of water infrastructure for the City of Tshwane:

- I will maintain the privacy and confidentiality of all accessible research data and understand that unauthorized disclosure of personal/confidential data is an invasion of privacy and may result in disciplinary, civil, and/or criminal actions against me.

- I will not disclose data or information to anyone other than those to whom I am authorized to do so.

- I will access data only for the purposes for which I am authorized explicitly. On no occasion will I use research data, including personal or confidential information, for my personal interest or advantage, or for any other business purposes.

- I will comply at all times with the City of Tshwane's data/information security policies and confidentiality code of conduct.

- I am informed that the references to personal, confidential and sensitive information in these documents are for my information and research purposes, and are not intended to replace my obligations under the Data Protection and Privacy policies and regulations of South Africa.

- I understand that where I have been given access to confidential information I am under a duty of confidence and would be liable under common law for any inappropriate breach of confidence in terms of disclosure to third parties and also for invasion of privacy if I were to access more information than that for which I have been given approval or for which consent is in place.

- Should my work in relation to the research discontinue for any reason, I understand that I will continue to be bound by this signed Confidentiality Agreement.

________ 15/07/2020

Signature **Date**

APPENDIX H: ETHICS APPROVAL

MANAGEMENT SCIENCES: FACULTY RESEARCH ETHICS COMMITTEE (FREC)

8 May 2020

Student Name: **Mr L Mokgobu**
Student No: 21143673

Dear Mr L Mokgobu

DOCTOR OF PHILOSOPHY IN MANAGEMENT SCIENCES: BUSINESS ADMINISTRATION

TITLE: The application of space technology and the challenges of managing water infrastructure in a selected South African municipality.

Please be advised that the FREC Committee has reviewed your proposal and the following decision was made: **Approved – Ethics Level 2**

Date of FRC Approval: 8th May 2020

Approval has been granted for a period of two years from the above FRC date, after which you are required to apply for safety monitoring and annual recertification. Please use the form located at the Faculty. This form must be submitted to the FREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the FREC according to the FREC SOP's. Please note that ANY amendments in the approved proposal require the approval of the FREC as outlined in the FREC SOP's.

Yours sincerely

____

Prof JP Govender
Chairperson: Faculty Research Ethics Committee

APPENDIX I: JOURNAL ARTICLE MOKGOBU AND MASON 2022

INTERNATIONAL JOURNAL OF RESEARCH IN BUSINESS AND SOCIAL SCIENCE 11(2)(2022) 306-317
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Business & Social Science IJRBS

Research in Business & Social Science

IJRBS VOL 11 NO 2 (2022) ISSN: 2147-4478

Matlou Lesley Mokgobu[(a)]* *Roger B Mason*[(b)]

Journalhomepage: https://www.ssbfnet.com/ojs/index.php/ijrbs

Potential of space science technology for water infrastructure management: A literature review

Crossref

[(a)] *PhD candidate. Department of Entrepreneurial Studies and Management, Durban University of Technology, Durban, South Africa* [(b)] *Professor, Retired Research Professor, Department of Marketing and Retail, Durban University of Technology, Durban, South Africa. P.O. Box 1973, Hillcrest, 3650, South Africa.*

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ABSTRACT

This article examines the potential of space science technology for water infrastructure (WI) management. It defines space technology in detail, and when South Africa (SA) started using it as a tool. To explain the context, the different types of orbits, altitudes, andfunctions of satellites are given, as well as the challenges that satellites encounter in orbit, including the quantity and sizes of orbital debris also known as space junk. The article articulates the international and local challenges to WI and further introduces space technology as a tool that can assist to overcome the challenges. Legislation governing the application of space technology in SA is discussed and the different satellites ownedby the various space agencies ofAfrica are outlined. A discussion on how space technology has boosted the economies and employment in Africa and South Africa is provided. How the various applications of the technology, such as remote sensing (RS), Earth observation (EO), Geo-Information sciences, navigation, communication, safety, and security can assist WI management are discussed. Details about the involvement of various African and SA universities and colleges in space science programmes that benefit the communities are explained. Also outlined are some experiments performed on the International Space Station (ISS) that benefit the Earth and that could be useful to WI management.

Introduction

The issues surrounding water infrastructure are always challenging to local authorities and water boards. These issues are, amongst others, burst pipes, leaks, vandalism and theft, reluctance to pay bills, ageing water infrastructure, lack of maintenance and poor planning (Venter, 2016). As a result, the communities suffer limited or no access to their homes due to road closures that result in trafficjams (Celik and Budayan, 2016; Brady, Burtwell and Thomson, 2001), unbarricaded trenches (Brady, Burtwell and Thomson, 2001), leaking water pipes (Alvisi et al., 2019), water cut-offs (Hamer et al.,

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2018), electricity supply interruptions (Muller, 2019; Folkman, 2018), and vandalism and theft (Mokgobu, 2017). Brady, Burtwell and Thomson (2001) noted an engineer who complained, "*Excavations are left open for an unreasonable time due to the diversification with the utilities and lack of coordination between departments* ". Kganyago and Mhangara (2019) noted efforts to address data gaps and sustainable development programmes by most African countries progressively embracing Earth Observation (EO) and Geospatial technologies. The following African countries have established their space agencies with increasing investment: Nigeria, Egypt, Algeria, Kenya, South Africa, and Gabon. They are the 21st-century players in the space industry with their EO satellites. Woldai (2020) outlined notable progress made by Algeria, Egypt, Kenya, and SA with two receiving and tracking satellite stations per country, and one receiving station each in Nigeria and Gabon.

The introduction of space technology may provide solutions to some of the challenges being faced by South African (SA) local authorities. South Africa today is leading African space research and is benefitting tremendously from the investments. Africa's

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expansion into space activities has been realised by collaborating with organisations like the National Aeronautics and Space Administration (NASA) in conferences and at workshops in Africa to share knowledge (Ligate, 2015).

Space technology refers to spacecraft, satellites, space stations, backup infrastructure, tools, and processes established and utilised by the aerospace environment in spaceflight, satellites, or space exploration (Ojoyi, 2016).

According to the Parliamentary Monitoring Group (2014), in the meeting held on the 14th of September 2014, the South African Council for Space Affairs (SACSA) outlined the importance of space technology to South Africa (SA). The meeting adopted satellite communication, satellite aided position, timing and navigation, and earth observation as the three pillars of space technology. The benefits of space technology to society and the importance of policy formulation to regulate the industry were discussed. Parliamentary Monitoring Group (2014) further details the services offered by the three pillars of space technology, namely, food security, water security, urban management, disaster management, nature preservation, land use, drought, climate change, desertification, treaty conformance, human rights exposure, and environmental destructions.

The South African National Space Agency (SANSA) is an entity of the Department of Science and Technology (DST) and derives its mandate from the South African National Space Agency Act, 2008 [Act No. 36 of 2008] and National Space Strategy (Kganyago and Mhangara, 2019). The Act promotes the use and cooperation of space-associated activities, space science research, and improvement in scientific engineering and maintains a favourable atmosphere of technological development in the space industry within the national government policy framework. The Act specifies the reasons SANSA was established and provided the objects and functions and specified the way the entity should be managed (South Africa, Department of Science and Technology, 2008). South African National Space Agency was launched on the 9th of December 2010, and this saw the transformation of South Africa's space landscape (South African National Space Agency, 2011).

Since it is a worldwide occurrence that the space sector is undergoing swift change, global players must adapt to the changes, especially new entrants into the sector. South African National Space Agency (2020a) envisions four vital fundamentals that motivate space industry innovation, namely, national security and scientific goals, downstream space applications growth, human space exploration, and the fourth industrial revolution (4IR).

Considering the problems SA municipalities are having with water infrastructure and water service provisions and maintenance, every effort needs to be made to help to address these problems. Although space technology, especially earth observation and remote sensing, may assist with these problems, it does not appear that they are being effectively used yet. With the speed at which the space industry is developing in Africa, and especially in South Africa, an attempt needs to be made to provide a better understanding of the potential role of space technology in assisting with the management of water infrastructure management.

Therefore, this study aimed to examine the potential of space technology to manage water infrastructure in Africa and South Africa, as discussed in the extant literature, with sub-objectives being to:

a) Identify how space technology can help with the management of water infrastructure.

b) Determine how best space technology can be applied to overcome the various challenges in managing the WI in Africa and SA. To achieve these objectives and to improve the understanding of space technology in water infrastructure management, a detailed literature search was conducted to explore the application of space technology in Africa, South Africa, and globally. Based on the identified literature a picture of the current and potential application of space science in the management of water infrastructure was developed.

Various searches were conducted for relevant literature on space technology in e-textbooks, e-journals, and e-newspapers, using several search themes that were established in advance. These themes helped guide the search. The themes used in the literature search were space technology; managing earth from space; managing water infrastructure from space. These themes produced several words guiding the search process. The words were space, space technology, managing earth, earth observation (EO), water infrastructure, managing water infrastructure from space, SANSA, ISS, remote sensing, and fourth industrial revolution (4IR).

Relevant data was extracted from Google.Com and Google Scholar (https://scholar.google.com), Scopus database and Sabinet search engines. However, other search engines such as Emerald and ProQuest were also visited but did not produce the required results. The reference lists of identified papers were also helpful in the search for the latest literature. Thus, it can be said that a form of snowball sampling was also used.

Once collected, the data was analysed, using NVivo qualitative analysis software, by categorising information from the literature into the relevant themes developed from the literature, as mentioned in Section 3.2. Thus, the information gathered from the literature was decomposed and then recomposed into the themes, as specified by Lee (1999).

The analysis found that much of the literature only covered the technical aspects of the topic. Literature related to the management aspects of water infrastructure was very limited and so it was necessary to be very selective and to extract the limited management successes and shortfalls included in the technical literature and apply it to this study. Furthermore, management principles were applied to the extant literature to find a way to develop a meaningful review and to draw significant conclusions from the literature.

Hereafter, the paper is presented in four main sections. First, the theoretical background is presented in three sections covering water infrastructure, how satellites operate as space technology and the current status of space technology in Africa and South Africa. Then, second, the practical, or empirical, application of space technology is presented via three sections covering the practical role of space technology, the relationship between water infrastructure and space technology and how space technology can help resolve the water infrastructure problems. The final sections cover conclusions and recommendations for further research.

Theoretical background

Managing Water Infrastructure

Management of water infrastructure requires a combination of organised managerial expertise and technical expertise. Management of infrastructure in South African (SA) cities has become problematic due to utilities' lack of skills (Zeraebruk et al., 2014; Venter, 2016), budget reductions (Meijer et al., 2020), and a lack of employee retention strategies (Phaladi, 2011). According to Venter (2016) SA experiences escalating water challenges because of a limited supply of technical skills, vandalism, and theft. Innovation is one of the gaps identified by various municipalities regarding water infrastructure. Some SA cities have been identified as examples of cities with innovative water infrastructure management (Mnguni, 2019). According to Githathu (2020) and South African National Space Agency (2020b) plans are underway to expand the data section, data visualisation centre, activation of satellite-based augmentation system over Southern Africa, new products and services, and human capital development and training. According to Mokgobu and Mason (2021), earth observation can enable satellites to locate, view and monitor the WI assets from space at any given distance and time for theft and vandalism prevention. This may see the SA space sector experience a paradigm shift with a recent boost of R4.5 billion from the government (Githathu, 2020). This technology can be an asset considering theft and vandalism experienced by many water infrastructures.

Ojogba et al. (2019) noted that as soon as satellites are launched, they become growth enablers that encourage economic development. Space technology could help to resolve the problems, experienced over many years, of challenges with water infrastructure. Observing the activities of the infrastructure requires advanced monitoring which is possible with the help of space technology. The following are phases of remote sensing and geospatial technologies, as outlined by Kurnaz and Rustamov (2008) that could benefit WI: Detection; Preparedness; Prevention; Protection and Response. Alsdorf, Rodríguez and Lettenmaier (2007) explain that many satellites are used for global observation of earth from space.

Dindar, Kaewunruen and Osman (2017) highlight the remote sensing (RS) for monitoring a railway system from space using satellites. This space technology records, observes, and identifies objects from extremely far away without having direct contact. The sun strikes the object on earth and the satellite's optical sensors detect and receive solar reflections and information gets transmitted to the receiver. Photographs are then taken by camera from space and sent to the earth using satellite dishes. Many remote sensing images (RSI) can be generated from this system. This technology is a perfect fit for monitoring the installed water infrastructure location against damaging activities such as vandalism and theft. Makapela et al. (2015) noted the two tools, RS and EO, as widely renowned tools for the provision of valuable data for the management of water resources. These tools are necessary for a water-stressed country like South Africa. Magidi and Ahmed (2019) suggest the use of high-resolution satellite, remotely sensed data for better identification of land patterns and features. According to Thakur et al. (2018) as the needs for remotely sensed data for water resources rise, they are projected to fit into the specialised RS missions of the forthcoming decades.

There are various fields of research as far as space technology is concerned (National Aeronautics and Space Administration, 2015). The use of mechanical means such as back-actors, excavators, etc. are costly and often result in broken pipes and electrical cables. A good example of the benefit of satellites is observing the plan view of a building remotely to locate a suitable position for the infrastructure (Shah, 2021). Chang (2015) proposes that space technology is, therefore, necessary to save time and locate the civil infrastructures such as buildings, railways, roads, bridges, dikes, dams, quays, and pipelines. Synthetic Aperture Radar Interferometry (InSAR) is a "precise and efficient technique to monitor deformation on Earth with millimetre precision". This technology therefore could help a municipality with monitoring aging pipe deformations, reservoir locations, etc. The use of this technology however requires an advanced degree of knowledge for its application. The next section presents the types of orbits, altitudes, functions, and the challenges of satellites.

Types of orbits, altitudes, functions, and challenges of satellites

Gleason (2021) and Reesman et al. (2021) agree that, since the space era inception over the past six decades, approximately 9800 satellites have been orbited. There are currently an estimated 3100 satellites in operation as recorded from March 2021, and approximately 6700 non-operational satellites still orbiting the Earth. Aglietti (2020) and European Space Agency (2020) estimated that by early February 2020 over 34 000 pieces of debris greater than 10 cm will exist in orbit, and a total of 900 000 particles ranging from 1 to 10 cm in diameter will also be orbiting the Earth. Further, a total population exceeding 128 million particles between 1 mm and 1 cm currently orbit the Earth. Aglietti (2020) raised a concern that the enormous speed at which the orbital debris travels may cause a detrimental effect on space assets such as satellites.

The National Aeronautics and Space Administration (n.d.) recorded the weight of the debris in the Earth's orbit at over 8000 tons on the 1st January 2020, while the European Space Agency (2020) recorded the latest weight at 9100 tons. These objects, also known as "space junk" (Gorman, 2020), of sizes greater than 10 cm, are monitored on a routine basis by the U.S Space Surveillance Network using ground-based radars. Most debris orbits within 2000 kilometres (km) of the Earth's surface and the largest amount of debris is in the 750 km -1000 km range (National Aeronautical and Space Administration n.d.). While satellites play a crucial role in providing information to the Earth, they also face various challenges. These challenges are the result of the 60 years of accumulation of space debris caused by various factors including collision, malfunctioning and explosion (Gorman, 2020). The predicaments associated with spacecraft colliding with each other, or with orbital debris, are most likely to happen (Drobyazko and Hilorme, 2021). This debris results from, among others, dormant satellites, rocket remains and collided or exploded particles of debris (Crisp et al., 2020; Vereen et al., 2018).

Satellites orbit the Earth at a variety of altitudes to collect information about the various phenomena on Earth. According to Space Operations (2018), the four main types of orbits that satellites are currently placed in are Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Highly Elliptical Orbit (HEO), and Geosynchronous Earth Orbit (GEO). Table 1 depicts the types of orbits, the altitudes, and the functions of each orbit.

Table 1: The different types of orbits, the altitudes, and the functions.

Orbit	Altitude	Use
Low Earth Orbit (LEO)	Up to 1609 km above the Earth's surface	Communications. Intelligence, surveillance, and reconnaissance Human spaceflight. Weather collection.
Medium Earth Orbit (MEO)	Approximately 1609 to 35398 km above the Earth's surface	Communications. Position, navigation and timing.
Highly Elliptical Orbit (HEO)	Long Ellipse altitudes 965.4 km at perigee (nearest to Earth), approx. 40225 km at apogee (farthest from Earth)	Communications. Intelligence, surveillance, and reconnaissance. Missile warning. Scientific.
Geosynchronous Earth Orbit (GEO)	Approximately 37007 km above the Earth's surface	Communications. Intelligence, surveillance, and reconnaissance. Missile warning. Weather collection.

Source: Space Operations (2018)

Having obtained some understanding of the basics of WI management and space technology, the next section presents literature covering the use of space technology in Africa and South Africa.

Space technology in Africa and South Africa

South Africa was the only country to be denied satellite launch by the West German corporation – Orbital Transport und Raketen Actiengesellschaft (OTRAG) in 1981-1983 (Cohn, 1979). The African continent still lacks the resources to carry out its launches. As a result, Africa sources launch services from China, French Guiana, Khazakhstan, India, Russia, and the United States (Oyewole, 2017). The high growth of investments realised gives Africa a good playing field for expansion of space technology use. Africa's expansion will further be realised if all states collaborate in the fields of agriculture, security, telecommunications, teaching and learning, earth observation and remote sensing. The information drawn from the satellites' data helps authorities to draw up management plans and to influence policies. African countries have made good progress with their space programmes. There have been 41 African satellites launched, three of which have multilateral ownership (Space in Africa, 2019a). The African space industry 2019 report outlined the exponential growth of African countries from 1998 to May 2019. The African space industry collected more than US$7 billion annual income, with a growth projection of 7.3%, expected to exceed US$10 billion in 2024 (Space in Africa, 2019a). These positive moves outweigh the critics about Africa's pursuit of space programmes when the basic issues of water and electricity supplies hang in the balance. Notwithstanding the continent's struggle with limited skills and the institutions that offer space research (Okon, 2018), the major milestones are still being achieved. Oyewole (2017) has attested to the continent's progressive involvement as an active role player in space research and development. Munsami and Offiong (2020) condemned the criticisms of the bystanders for raising questions about Africa's affordability of the high costs involved in the space sector.

According to Munsami and Offiong (2020), the socio-economic challenges that the African continent face is a phenomenon widely spread across developing countries. This impasse could be alleviated through propagation and knowledge exchange on related technology programmes. Woldai (2020) reflected on the slow pace of African countries' students who advance to the master's and Doctoral programmes in space technology abroad to become professionals. The programmes will equip them with the knowledge to interpret information derived from the EO and RS datasets. Other universities have started to offer RS and GIS studies to fight the skills deficit and enhance Africa's development. As a result, Africa will realise greater opportunities for growth in EO, RS and Geo-information sciences (Woldai, 2020). The African continent is gradually curtailing technology services consumed from other continents by committing to investment within its borders.

Egypt hosts the African Space Agency with approval granted by African heads of states during the African Union's last summit in January 2019 (Mnguni, 2019). The nineteen African countries form the African space programme with an escalating number of space technology businesses interested in offering services to the continent. Africa can solve serious problems in agriculture, security, telecommunications, and other fields with the assistance of current space technology. For example, satellites have assisted Mali herdsmen to locate water for cattle. Further, satellite assistance in Africa's TV programmes and a satellite internet connection to rural classrooms was realised in Angola and Rwanda (Space in Africa, 2019b). Regarding the African space programmes, Table 2 outlines the country of ownership, names of satellites and the year each satellite was launched.

Table 2: African countries' satellites constructed, purchased, or rented

Satellite	Country or organisation	Year launched
ALSAT1	Algeria	2002
ALSAT2A	Algeria	2010
ALSAT1B	Algeria	2016
ALSAT2B	Algeria	2016
ALSAT1	Algeria	2016
ALCOMSAT-1	Algeria	2017
AngoSat-1	Angola	2017
GhanaSat-1	Ghana	2017
NILESAT 101	Egypt	1998
NILESAT 102	Egypt	2000
EGYPTSAT1	Egypt	2007
NILESAT201	Egypt	2010
EGYPTSAT2	Egypt	2014
EGYPTSAT-A	Egypt	2019
NARSSCube-2	Egypt	2019
NARSSCube-1	Egypt	2019
TIBA-1	Egypt	2019
ETRSS-1	Ethiopia	2019
1KUNS-PF	Kenya	2018
Maroc-TUBSAT	Morocco	2001
MOHAMMED V1-A	Morocco	2017
MOHAMMED V1-B	Morocco	2018
RascomStar-QAF-1	Multilateral	
RascomStar-QAF-1R	Multilateral	
NewDawn	Multilateral	
Nigeriasat-1	Nigeria	2003
NIGCOMSAT1	Nigeria	2007
NigeriaSat-2	Nigeria	2011
NigeriaSat-X	Nigeria	2011
NIGCOMSAT1R	Nigeria	2011
NigeriaEduSAT-1	Nigeria	2017
RwaSat-1	Rwanda	2019
SUNSAT	South Africa	1999
ZACUBE	South Africa	2003
SUMBADILA	South Africa	2009
KONDORE	South Africa	2014
nSight1	South Africa	2017
ZA-AEROSAT	South Africa	2017
ZaCube-2	South Africa	2018
XinaBox ThinSAT	South Africa	2019
SRSS-1	Sudan	2019

Source: Space in Africa (2019a)

Having looked at the background to both WI management and space technology and how they are used, the next section discusses the practical roles and applications of space technology with special reference to water infrastructure management.

Empirical review of practical applications

Practical Role of Space Technology

Space technology is currently used for various applications in SA such as earth observation, remote sensing, aviation industry, research and development, weather forecasting and many more. Various SA universities are part of the space science programme which is forming part of their curricula. South African National Space Agency (SANSA) has started recruiting students in maths and science to join their initiatives in space science.

The following practical roles could be performed by space technology in SA to manage water infrastructure: communication, health, safety, security, advanced water filtration and purification systems, detection of water levels in reservoirs, monitoring earth's natural resources such as groundwater, water leak detection, underground water pipes detection and monitoring water quality.

However, there are potential problems associated with the application of space activities. One of the major drawbacks of space technology is that the costs of operation are very high (Adebola and Adebola, 2021; South Africa, Department of Science and Technology, 2018; Oyewole, 2017). Another challenge posed by some satellites is their discontinuity in mapping some data (Malahlela et al., 2018). The advantage of space technology is that observations of larger areas can be made in a short space of time compared to humans doing it at the same time/ space. Sekhula (2013) added that another advantage of satellites is borderless devices without political limitations. Giardino et al. (2010) confirm the agility of remote sensing capability to reproduce spatial and temporal observations, whereas similar *in situ* observations of surface water quality is impossible at the same space and time dimensions.

Other challenges in the use of space technology are the teaching of outdated curricula by higher learning institutions, poor funding and insufficient resources for Earth observations, satellite communication, satellite systems, navigation and positioning, and space agencies. Furthermore, there is no sharing of datasets by space agencies due to the restrictive bureaucracy of obtaining EO data in other African states, except for SA (Woldai, 2020). Space science and technology can assist in research and development for services, as a monitoring tool, as an evaluation of serious land resources and for better decision making (South Africa, Department of Science and Technology, 2018). South Africa had been purchasing and importing space technology but has now started developing its own systems to support local industry requirements. There are three key priorities in space technology development that have been identified by the government, namely, environmental and resource management; health, safety, and security; and innovative and economic development.

A good example showing that SA has started to develop the local space industry is the Cape Peninsula University of Technology (CPUT) Satellite Programme. The programme is aligned to the National Space Strategy and receives funds from the Department of Science and Technology and the National Research Foundation (NRF) Centre (French South African Institute of Technology, 2019). According to Timeslive (2022b), a mission to launch the three nanosatellites onboard Elon Musk's Falcon 9 spaceflight on the 13th of January 2022 has been concluded. The SA higher education, science, and innovation minister Blade Nzimande announced that the three would be the beginning of the Maritime Domain Awareness Satellite (MDASat) constellation. The minister concluded that the launch site would be at Cape Canaveral in the United States and is driven by CPUT and that in future a complete constellation would be comprised of nine cube satellites. The CPUT satellite programme has been successful in graduating 60 students in the master's programme and developing, building, and launching three CubeSats (South African Institute of Technology, 2019). Timeslive (2022a) noted that the Acting Chief Engineer of the French South African Institute of Technology (FSAIT), Nyameko Royi, announced that the satellites would be monitoring any intruders on the South African Economic Zone's entire coastline. In a nutshell, the purposes of these satellites would be to "detect"," identify" and 'monitor' the live movements of vessels (Timeslive, 2022b). The programme is jointly hosted by the FSAIT and the African Space Innovation Centre (French South African Institute of Technology, 2019).

Campbell (2019) advises of the launch of a non-profit making company, ZASpace Inc., in Pretoria. Its purpose is to encourage local space industry growth, particularly in geospatial technology for South Africa and Africa for skills development and innovative funding for beginners, and for small, medium, and micro-enterprises. During the launch, ZASpace Chief Executive Officer (CEO) Kamal Ramsingh announced that the world's geospatial market was valued at US$193 billion in 2013 and had risen to US$299 billion in 2017 and was anticipated to hit US$500 billion by the year 2020. Campbell (2019) further supported Kamal Ramsingh's statement that the drivers for the geospatial sector worldwide are travel and hospitality, disaster management, mapping agencies, banking and financial services and insurance, defence and security, mining and energy, retail and logistics, e-government, utilities, infrastructure, and smart cities. All these drivers are listed according to size from the smallest to the largest. The sector also consists of global satellite navigation systems, geographic information systems and spatial analysis, Earth observation, and three-dimensional scanning.

Campbell (2019) further noted the US, UK, and the whole of Europe as the leading geospatial markets. However, Africa has the fastest growth, with an annual compound growth rate of 16.8% with the spatial analysis market accounting for 30% of the African market. The continental growth comparison between the years 2018 and 2020 for Africa's geospatial market is 21%, with 11% for Europe and 10% for the US. The ZASpace CEO further noted the shortage of skills in South Africa with an even greater shortage of skills in other African countries. Regarding global geospatial preparedness, South Africa is ranked in position thirty-one. Campbell (2019) highlighted the CEO of SANSA Dr Val Munsami's emphasis on the importance of the local space agency, considering the growth of the African space industry. He further stressed that one of the objectives of the National Space Policy was to improve the national space industry. The creation of SANSA from organisations that existed before was difficult because of the shortage of a business model, unpredictable business models, and fragmented business models split amongst the divisions, each with dissimilar operational needs.

To further support the strategic space priorities, three programmes have been developed to make space initiatives a success (South Africa, Department of Science and Technology, 2018). These three programmes are thematic, functional and support. Thematic programmes are earth surveillance, navigation, communication, space science and discoveries. Functional programmes entail aiding technologies, mission improvement, space mission manoeuvre and space mission application. Support programmes include human capital advancement, infrastructure and partnering international communities.

Space technology has been used to solve social challenges in the areas of management, the environment, usage of natural assets, growing movement of individuals and products, increase in security threats and the move towards the knowledge economy. Space exploration has produced many benefits and continues to bear fruit internationally. Space exploration can solve many present and future challenges faced by South Africa. The costs associated with space activities are extremely high, but the returns associated therewith are worthwhile. Job creation, technological advancement, scientific familiarity, and space derivatives are some of the advantages associated with space technology (South Africa, Department of Science and Technology, 2018). For example, Atkinson et al. (2017) mentioned the Square Kilometre Array (SKA) project's 618 work opportunities that boosted the Northern Cape economy by R9 million rand between 2008 and 2010. Ojoyi (2016) maintains that many African countries are limited as far as space initiatives are concerned due to inadequate funding. They depend on external donations and for that reason adequate knowledge, infrastructure, tools, and education is unachievable. This technology is necessary for location, imagery, and security for infrastructure under threat of vandalism and other threats in the African continent. It is for these reasons that space technology is needed as a tool to help manage water infrastructure (South Africa, Department of Science and Technology, 2018).

The practical roles of space technology having been discussed, the next section discusses the link between WI and space technology.

Linking Water Infrastructure to Space Technology

Space technology can be applied to water infrastructure through the following activities: water quality detection in lakes (Malahlela et al., 2018); in lakes (Giardino et al, 2010); dams and pipelines location (Chang, 2015); imagery, location, and security (Ojoyi, 2016); security and management (South Africa, Department of Science and Technology, 2018). Another good example is the remote sensing of water quality assessment and chlorophyll-a (chl-a) with the application of Landsat 8 Operational Land Imager (OLI) data. The technology tested the red to near-infrared (NIR-red) bands in the Vaal Dam of SA for the categorisation of chl-a concentrations (Malahlela et al. 2018). Regarding water infrastructure specifically, there is little literature. However, detection of underground water sources is one of the advantages offered by space technology. Israeli scientists launched a freshwater leak detection and prevention technology from space. They have adopted a technology previously used on Mars and Venus for the detection of water. The technology was invented after an estimated annual worldwide freshwater loss of 32 billion cubic metres was reported by the World Bank in developing countries. Synthetic-Aperture Radar (SAR) has been adopted by universities and research institutions for the detection of water underground, as well as on other planets. The CEO of Utilis confirmed the technology's usefulness for underground treated water detection in urban settlements (Maccioni, 2019). This technology is necessary for the detection of water infrastructure, especially of pipes buried below the surface of the earth. According to Evagorou et al. (2019), space technology can achieve optical satellite images for bathymetric data to a depth of 30 metres below sea level. Azambuja (2017) notes that space technology saved community lives with the innovative filtration and purification systems developed aboard the space station. The partnership of aid organisations and NASA technology demonstrated the effectiveness of space research in response to global difficulties. This resulted in global collaborative efforts between Water Security Corporation and other organisations by organising systems with NASA water-processing technology. Froehlich, Siebrits and Lindgren (2019) noted health and water as part of the key needs of the African space sector and the special role they play in the Sustainable Development Goals 3 and 6 (SDG's). The technology could help fight waterborne diseases in most African states, which according to Akinyende and Adepoju (2010), still suffer the challenge of providing potable water supply. To turn things around the continent must intensify the required level of skills in space science and technology to manage the water resources. According to Adebola and Adebola (2021), water is one of few key commodities that has been earmarked for improvement in the policies of African space programs.

Another space technology benefit is remote image sensing of water quality from space using Hyperspectral Imager for the Coastal Ocean (HICO). HICO was invented by the U.S. Naval Research Laboratory for use in coastal ocean water quality assessment. The quality parameters for detection are water clarity, phytoplankton concentrations, light absorption, and distribution of cyanobacteria. HICO's obtained data is used by U.S. Environmental Protection Agency (EPA) researchers to develop a smartphone application for the detection of harmful concentrations of pollutants (Azambuja, 2017). The smartphone technology has provided positive results in California by detecting mercury contamination in water samples obtained from a tap, river, lake, and sea. The multi-functional use of the smartphone enables it to sense, track, and detect water contamination and provide real-time global data (Wei et al., 2014). Greenblat and Anzaldua (2019) outline earth observation functions as a support of agricultural production, fisheries management, freshwater management, managing forests and monitoring detrimental activities.

The next section outlines how space technology can benefit communities and help resolve the challenges being faced by WI.

How Space Science Technology Can Assist in Resolving the Challenges

The use of space technology can aid managers in issues such as positioning of the infrastructure, remote sensing of underground water availability, and leak detection. This will be a valuable time-saving method for local authorities and other organisations. It has benefits for managers and policymakers in decision-making. To this end, the technology has proven itself to be a good management tool in groundwater exploration, climate change and flood hazard monitoring (Woldai, 2020).

Space technology has previously been used locally and internationally to address the challenges of water infrastructure and management. According to the National Aeronautics and Space Administration (2019), the countries and communities that have enjoyed the benefits of space activities include sub-Saharan Africa and the Kurdish village of Kendala in Iraq. Iceland, Luo and Donchyts (2018) noted Morocco, India, Spain, and many other countries as also having benefitted from the use of space technology. In addition, National Aeronautics and Space Administration (2019) notes that an advanced water filtration and purification system developed for the International Space Station (ISS) is being used in sub-Saharan Africa for managing water resources. Also, a non-profit organization, Concern for Kids (CFK), sourced funds from NASA to help Iraq, Malaysia and Indonesia with aid and disaster relief programmes. The community of the Kurdish village of Kendala in Iraq drank dirty, fabric-sifted water together with their livestock. They were aided by NASA-developed technology that provides clean water, so that now they enjoy clean drinking water.

Iceland, Luo and Donchyts (2018) show a satellite image that, using space technology, detected a 60% drop in water level in 2016 of Al Massira dam, the second-largest in Morocco. Various drops in dam levels in many parts of the world, such as Indira Sagar Dam in India, Mosul Dam in Iraq, and Buendia Dam in Spain, have been identified with the help of space technology (Iceland, Luo and Donchyts, 2018). This technology can be applied in SA cities for monitoring water levels in reservoirs without having to physically travel to the reservoirs for inspections. Similarly, the assistance offered by NASA engineers to the Kurdish village of Kendala (National Aeronautics and Space Administration, 2019), could be sourced for SA cities, organisations, and communities. This is an opportunity for the SA cities that experience the challenges of overworked water purification plants, and wastewater treatment plants due to high sewage volumes. The technology could help overcome the health risks faced by communities due to malfunctioning water purification systems.

Having discussed how the literature suggests space technology can contribute to WI management, and how this is being applied practically in other countries, the next section concludes the literature review by relating the findings to the study's aim and sub-objectives and making some recommendations for the use of space technology by the water infrastructure industry in South Africa, and, if fact, across Africa.

Conclusion

Concerning space technology, South Africa must dedicate this era of the 4IR to embrace this technology. Any barriers to the execution of this global transformation require a concerted effort to overcome the resistance. New African space initiatives must be undertaken in collaboration with the international community. African states must avail themselves of space technology to become future space champions. African countries must cooperate to make sure that resources to educate people in space sciences are directed to the youth and other relevant sectors of their populations. This would involve the introduction of space technology curricula in high schools and all institutions of higher learning, and the encouraging of researchers to follow a career in space technology with funding for inspiration.

Space technology must be used to benefit South Africa and their local authorities for the management of water infrastructure and water resources. South Africa should collaborate with other countries which are already ahead with space affairs to help train learners in various space technologies and activities, including, for example, to further the application of techniques used in the ISS for terrestrial water filtration and purification. The South African government must try to contain cost escalations for space technology to accommodate new entrants and people must be up skilled to operate this highly advanced technology.

This paper's objectives have been met by exposing some issues which are hindering the African continent from optimal participation in space affairs. The paper has identified African countries which are making slow progress in participation in space affairs. The exploitation of space technology in the management of water infrastructure also suggests other avenues for further research. This paper has provided a review of the literature on space activities which other researchers and authors can apply for their studies. Managers and water specialists may also apply this literature for better application of managerial functions and to influence policy decisions. Learners in schools and institutions of higher learning can also use this to increase their knowledge about space technology and its applications, especially in the field of water infrastructure management. The next section presents the recommendations for future research.

Empirical exploratory research and empirical explanatory research, both qualitative and quantitative, needs to be undertaken to:

i. *Identify how big the potential industry of space-based water monitoring might be in Africa and South Africa,*
ii. *Break the barriers preventing cooperation and business between African countries in space technology,*
iii. *Explore in greater depth, the benefits of space science technology to water infrastructure,*
iv. *Identify the possibilities of Africa's collaboration with developed countries in the space industry,*
v. *Identify Africa's challenges for increased participation in space science technology.*

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Chapter 38
Space Technology and the Management of Water Infrastructure in South Africa

Matlou Lesley Mokgobu and Roger B. Mason

38.1 Introduction

The issues surrounding water infrastructure are always challenging to local authorities and water boards. These issues are, among others, burst pipes, unlocated leaks, vandalism, blocked pipes, and ageing water infrastructure. As a result, the challenges experienced are street inaccessibility, limited or no access to homes, traffic jams, unbarricaded deep trenches, leaking water pipes, water and electricity supply interruptions, vandalism, and theft. To this end, some of these challenges may be addressed via the space technologies of monitoring and remote sensing.

The problem of lack of knowledge about the management of water infrastructure may be prevalent. The introduction of space technology may provide success to some of the challenges being faced by South African (SA) local authorities. The involvement of South Africa in space research started as far back as 1820, with the establishment of the South African Astronomical Observatory in Cape Town [1]. The country today is leading African space research and is benefitting tremendously from the investments. Africa's expansion into space activities has been realised by collaborating with organisations like National Aeronautics and Space Administration (NASA) in conferences and at workshops in Africa to share knowledge [2].

Space technology refers to spacecraft, satellites, space stations, backup infraS structure, tools, and processes established and utilised by the aerospace environment in spaceflight, satellites, or space exploration [3]. This literature review will focus on the application of space technology and the challenges of managing water infrastructure in South Africa. The literature will explore not only the internal issues of organisations managing water infrastructure but also local, national, and international

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applications of space technology regarding water infrastructure. For example, space technology could help in the detection of the location of buried infrastructure. Kganyago and Mhangara [4] noted efforts to address data gaps and sustainable development programmes by most African countries progressively embracing Earth observation (EO) and geospatial technologies. The following African countries have established their own space agencies with increasing investment: Nigeria, Egypt, Algeria, Kenya, South Africa, and Gabon. They are the twenty-first-century players in the space industry with their own EO satellites. Parliamentary Monitoring Group [5] recalls the meeting held on 14 September 2014, where the South African Council for Space Affairs (SACSA) outlined the importance of space technology to South Africa (SA). Satellite communication; satellite-aided position, timing, and navigation; and Earth observation were mentioned as the three pillars of space technology. The benefits of space technology to society and the importance of policy formulation to regulate the industry were discussed. Parliamentary Monitoring Group [5] further details the services offered by the three pillars of space technology, namely, food security, water security, urban management, disaster management, nature preservation, land use, drought, climate change, desertification, treaty conformance, human rights exposure, and environmental destructions.

The South African National Space Agency (SANSA) is an entity of the Department of Science and Technology (DST) and derives its mandate from South African National Space Agency Act, 2008 [Act No. 36 of 2008], and National Space Strategy [4]. Since it is a worldwide occurrence that the space sector is undergoing swift change, global players have to adapt to the changes, especially new entrants into the sector. The South African National Space Agency [6] envisions four vital fundamentals that motivate space industry innovation, namely, the national security and scientific goals, downstream space application growth, human space exploration, and Fourth Industrial Revolution (4IR).

38.2 Aims and Objectives

Aim of the Study

The aim of this paper is to provide a background to possible ways space science can assist with the management of water infrastructures in a developing country and thus form the basis for more detailed empirical research into such applications.

Objectives of the Study

- Identify the application of space technology to the management of water infrastructure.

- Determine barriers to African countries becoming business players in the space industry.

38.3 Methodology

Research Design

This study applied secondary research to explore the application of space technology in South Africa and in Africa and globally. Secondary research was further used to establish barriers to the African continent's full participation in the space industry.

Research Approach

Various searches were conducted for relevant literature on space technology in e-text books, e-journals, and e-newspapers, using a number of search themes that were established in advance. These themes were helpful in guiding the search. The themes used in the search for literature were space technology, managing Earth from space, and managing water infrastructure from space. These themes produced a number of words in guiding the search process. The words were space, space technology, managing Earth, Earth observation (EO), water infrastructure, managing water infrastructure from space, SANSA, ISS, remote sensing, and Fourth Industrial Revolution (4IR).

Data Extraction

Data was extracted from Google.Com and Google Scholar (https://scholar.google.com) search engines. However, other search engines such as Emerald and ProQuest were also visited but did not produce the required results. The reference lists of other authors were also helpful in forming part of the search for the latest literature.

Analysis

A review process aimed at generating an assessment of the research topic in comparison with the existing literature was followed. The review was created with the assistance of the themes and keywords as the guiding principles of the review process.

Interpretation

Much of the literature that the researcher found covered the technical aspects of the topic. Literature related to the management aspects of water infrastructure were very limited, and so it was necessary to be very selective and to extract the limited management successes and shortfalls included in the technical literature and apply it to this study. Furthermore, management principles were applied to the extant literature to find a way to develop a meaningful literature review.

38.4 Managing Water Infrastructure

Management of water infrastructure requires a combination of organised managerial expertise and technical expertise. Management of infrastructure in South African (SA) cities has become problematic due to utilities' lack of skills, budget reductions, and poor employee retention strategies. Innovation is one of the gaps identified by various municipalities regarding water infrastructure. Some SA cities have been identified as examples of cities with innovative water infrastructure management [7].

Space technology is one of the innovations in water infrastructure management that could help African cities. This technology can be a valuable asset considering theft and vandalism experienced by many water infrastructures. Earth observation can enable satellites to locate, view, and monitor these assets from space at any given distance and time for theft and vandalism prevention. Ojogba et al. [8] noted that satellites are infrastructures experiencing swift growth and that can support economic improvement.

Space technology could close this gap, experienced over many years, of challenges with water infrastructure. Observing the activities of the infrastructure requires advanced monitoring which is possible with the help of space technology. The following are phases of remote-sensing and geospatial technologies as outlined by Kurnaz and Rustamov [9]: detection, preparedness, prevention, protection, and response. Alsdorf, Rodríguez, and Lettenmaier [10] explain that many satellites are used for global observation of Earth from space.

Dindar, Kaewunruen, and Osman [11] highlight the remote sensing (RS) for monitoring a railway system from space using satellites. This technology from space records observes and identifies objects from extremely far away without having direct contact. The sun strikes the object on Earth, and the satellite's optical sensors detect and receive solar reflections, and information gets transmitted to the receiver. Photographs are then taken by camera from space and sent to the Earth by means of satellite dishes. Many remote-sensing images (RSI) can be generated from this system. This technology is a perfect fit for monitoring the installed water infrastructure location against vandalism, theft, etc. Magidi and Ahmed [12] suggested the use of high-resolution satellite and remotely sensed data for better identification of land patterns and features. There are various fields of research in as far as space technology is concerned [13].

The use of mechanical means such as back-actors, excavators, etc. is costly and often results in broken pipes and electrical cables. Chang [14] proposes that space technology is therefore necessary to save time and locate the civil infra-structures such as buildings, railways, roads, bridges, dikes, dams, quays, and pipelines. Synthetic aperture radar interferometry (InSAR) is a "precise and efficient technique to monitor deformation on Earth with millimetre precision". This technology therefore could help a municipality with monitoring aging pipe deformations, reservoir locations, etc. The use of this technology, however, re-quires an advanced degree of knowledge for its application.

Water supply infrastructure is perceived to be the most steady, "well-developed, and long-lasting infrastructures" – it is robust. Geography of technology and science and technology studies (STS) can be introduced to create a bond between communities and infrastructure, and possible inspiration of minor technology is largely ignored [15].

38.5 Space Technology in Africa and South Africa

The high growth of investments realised gives Africa a good playing field for expansion of space technology use. Africa's expansion will further be realised if all states collaborate in the fields of agriculture, security, telecommunications, teaching and learning, Earth observation, remote sensing, and so on. The in-formation drawn from the satellites' data helps authorities to draw up management plans and to influence policies.

African countries have made outstanding progress in the space programme. There have been 41 African satellites launched, 3 of which have multilateral ownership [16]. The African Space Industry 2019 report outlined the exponential growth of African countries from 1998 to May 2019. The African space industry collected more than 7 billion USD annual income, with a growth projection of 7.3%, expected to exceed 10 billion USD in 2024 [17]. Egypt hosts the African Space Agency with approval granted by African heads of states during the African Union's last summit in January 2019 [6].

Table 38.1 African countries' satellites constructed, purchased, or rented

Satellite	Country or organisation	Year launched
ALSAT1	Algeria	2002
ALSAT2A	Algeria	2010
ALSAT1B	Algeria	2016
ALSAT2B	Algeria	2016
ALSAT1	Algeria	2016
ALCOMSAT-1	Algeria	2017
AngoSat-1	Angola	2017
GhanaSat-1	Ghana	2017
NILESAT 101	Egypt	1998
NILESAT 102	Egypt	2000
EGYPTSAT1	Egypt	2007
NILESAT201	Egypt	2010
EGYPTSAT2	Egypt	2014
EGYPTSAT-A	Egypt	2019
NARSSCube-2	Egypt	2019
NARSSCube-1	Egypt	2019
TIBA-1	Egypt	2019
ETRSS-1	Ethiopia	2019
1KUNS-PF	Kenya	2018
Maroc-TUBSAT	Morocco	2001
MOHAMMED V1-A	Morocco	2017
MOHAMMED V1-B	Morocco	2018
RascomStar-QAF-1	Multilateral	
RascomStar-QAF-1R	Multilateral	
NewDawn	Multilateral	
Nigeriasat-1	Nigeria	2003
NIGCOMSAT1	Nigeria	2007
NigeriaSat-2	Nigeria	2011
NigeriaSat-X	Nigeria	2011
NIGCOMSAT1R	Nigeria	2011
NigeriaEduSAT-1	Nigeria	2017
RwaSat-1	Rwanda	2019
SUNSAT	South Africa	1999
ZACUBE	South Africa	2003
SUMBADILA	South Africa	2009
KONDORE	South Africa	2014
nSight1	South Africa	2017
ZA-AEROSAT	South Africa	2017
ZaCube-2	South Africa	2018
XinaBox ThinSAT	South Africa	2019
SRSS-1	Sudan	2019

Source: [16]

There are 19 African countries forming the African space programme with an escalating number of space technology businesses interested in offering services to the continent. Africa is capable of solving serious problems in agriculture, security, telecommunications, and other fields with assistance of the current space technology. For example, satellites have assisted Mali herdsmen to locate water for cattle. Further, satellite assistance in Africa's TV programmes and satellite internet connection to rural classrooms were realised in Angola and Rwanda [17].

Table 38.1 outlines the country of ownership, names of satellites, and the year each satellite was launched.

38.6 Practical Role of Space Technology

The following practical roles could be performed by space technology in SA to manage water infrastructure, communication, health, safety, security, advanced water filtration and purification system, detection of water levels in reservoirs, monitoring Earth's natural resources such as ground water, water leak detection, underground water pipe detection, and monitoring water quality. Space technology is currently used for various applications in SA such as Earth observation, remote sensing, aviation industry, research and development, weather forecasting, and many more. Various SA universities are part of the space science programme which is forming part of their curricula. South African National Space Agency (SANSA) has started recruiting students in maths and science to join their initiatives in space science.

However, there are potential problems associated with the application of space activities. One of the major drawbacks of space technology is that it is expensive. Another challenge posed by some satellites is their discontinuity in mapping some data [18]– satellites do not have any concern for politics and know no demarcations [19]. The advantage of space technology is that observations can be made of larger areas in a short space of time compared to humans doing it in the same time/space. Giardino et al. [20] confirmed the agility of remote-sensing capability to reproduce spatial and temporal observations, whereas similar *in situ* observations of surface water quality are impossible at the same space and time dimensions.

Other challenges in the use of space technology are the teaching of outdated curricula by higher learning institutions, poor funding, and insufficient resources for Earth observations, satellite communication, satellite systems, navigation and positioning, and space agencies. Furthermore, there is no sharing of datasets by space agencies due to the restrictive bureaucracy of obtaining EO data in other African states, except for SA [21].

The South African Department of Science and Technology [22] pointed out that space science and technology can assist in research and development for services, as a monitoring tool and as an evaluation of serious land resources, and for better decision-making. South Africa has been purchasing and importing space technology and has started developing its own systems to support local industry requirements. There are three key priorities identified by the government in space exploration, namely, environmental and resource management; health, safety, and security; and innovative and economic development.

A good example of SA having started to develop the local space industry is the Cape Peninsula University of Technology (CPUT) Satellite Programme. The programme is aligned to the National Space Strategy and receives funds from Department of Science and Technology and the National Research Foundation (NRF). The satellite programme has been successful in graduating 60 students in the master's programme and developing, building, and launching a CubeSat. The programme is jointly hosted by the French South African Institute of Technology and the African Space Innovation Centre [23].

Campbell [24] advises of the launch of a non-profit-making company, ZASpace Inc., in Pretoria. Its purpose is to encourage local space industry growth particularly in the area of geospatial technology for South Africa and Africa and for skills development and innovative funding for beginners, small and medium enterprises and microenterprises. During the launch, ZASpace Chief Executive Officer (CEO) Kamal Ramsingh announced that the world's geospatial market was valued at $193 billion in 2013 and had risen to $299 billion in 2017 and was anticipated to hit $500 billion by the year 2020.

Campbell [24] supported Kamal Ramsingh's statement that the drivers for the geospatial sector worldwide are travel and hospitality, disaster management, mapping agencies, banking and financial services and insurance, defence and security, mining and energy, retail and logistics, e-government, utilities, infra-structure, and smart cities. All these drivers are listed according to size from the smallest to the largest. The sector also consists of global satellite navigation systems, geographic information systems and spatial analysis, Earth observation, and three-dimensional scanning.

Campbell [24] further noted the USA, the UK, and the whole Europe as the leading geospatial markets. However, Africa has the fastest growth, with annual compound growth rate of 16.8%, whereas the spatial analysis accounts for 30% of the African market. The continental growth comparison between the years 2018 and 2020 for Africa's geospatial market is 21%, with 11% for Europe and 10% for the USA. ZASpace CEO further noted the shortage of skills in South Africa with an even greater shortage of skills in other African countries. Regarding global geospatial preparedness, South Africa is ranked in position 31.

Campbell [24] highlighted the CEO of SANSA Dr. Val Munsami's announcement that for the local space agency, Africa is the way to go considering its growth. He further reminded that one of the objectives of the National Space Policy was to improve the national space industry. The creation of SANSA from organisations that existed before was difficult because of the shortage of a business model, unpredictable business models, and fragmented business models split among the divisions, each with dissimilar operational needs. Finally, the CEO pointed out that ZASpace was viewed by SANSA as a key role player in the local space industry.

The South African Department of Science and Technology [22] noted that to further support the priorities, there are three programmes that have been developed to make space initiatives a success. These programmes are thematic, functional, and supportive. Thematic programmes are Earth surveillance, navigation, communication, space science, and discoveries. Functional programmes entail aiding technologies, mission improvement, space mission manoeuvre, and space mission application. Support programmes include human capital advancement, infrastructure, and partnering international communities.

Space technology has been used to solve social challenges in the areas of management, environment, usage of natural assets, growing movement of individuals and products, increase in security threats, and the move towards the knowledge economy. Space exploration is going to solve many present and future challenges faced by South Africa. Space exploration has produced many benefits and continues to bear fruit internationally. The costs associated with space activities are extremely high, but the returns associated therewith are worthwhile. Job creation, technological advancement, scientific familiarity, and space derivatives are some of the advantages associated with space technology. It is for that reason that this study investigates space technology as a tool to help manage water infrastructure [22].

Ojoyi [3] maintains that many African countries are limited as far as space initiatives are concerned due to inadequate funding. They depend on external donations, and for that reason, adequate knowledge, infrastructure, tools, and education are unachievable. This technology is necessary for location, imagery, and security for infrastructure under threat of vandalism and other threats in the African continent.

38.7 Linking Water Infrastructure to Space Technology

Space technology can be applied to water infrastructure through the following activities: water quality detection in lakes [18] and in a dam [20]; dam and pipeline location [14]; imagery, location, and security [3]; and security and management [22]. Another good example is the remote sensing of water quality assessment and chlorophyll a (chl-a) with the application of Landsat 8 Operation-al Land Imager (OLI) data. The technology tested the red to near-infrared (NIR-red) bands in the Vaal Dam of SA for the categorisation of chl-a concentrations [18]

Regarding water infrastructure specifically, there is little literature. However, detection of underground water sources is one of the advantages offered by space technology. The Israelis launched a freshwater leak detection and prevention technology from outer space. They have adopted a technology previously used on Mars and Venus for detection of water. The technology was invented after an estimated annual worldwide freshwater loss of 32 billion cubic metres was reported by the World Bank in developing countries. Synthetic-aperture radar (SAR) has been adopted by universities and research institutions for detection of water underground and on other planets. The CEO of Utilis, in a telephone interview, confirmed the technology's usefulness for underground treated water detection in urban settlements [25].

This technology is necessary in the detection of water infrastructure, especially buried pipes below the surface of the Earth. According to Evagorou et al. [26], space technology can achieve optical satellite images for bathymetric data to a depth of 30 metres below sea level. Azambuja [27] notes that space technology saved community lives with the innovative filtration and purification systems developed aboard the space station. The joint partnership of aid organisations and NASA technology demonstrated the effectiveness of space research in response to global difficulties. This resulted in global collaborative efforts between Water Security Corporation and other organisations by organising systems with NASA water processing technology.

Another space technology benefit is remote image sensing of water quality from space by means of Hyperspectral Imager for the Coastal Ocean (HICO). The HICO was invented by the US Naval Research Laboratory for use in coastal ocean water quality assessment. The quality parameters for detection are water clarity, phytoplankton concentrations, light absorption, and distribution of cyanobacteria. HICO's obtained data is used by US Environmental Protection Agency (EPA) researchers to develop a smartphone application for detection of harmful concentrations of pollutants [27]. Greenblat and Anzaldua [28] outline Earth observation functions as support of agricultural production, fisheries management, freshwater management, managing forests, and monitoring detrimental activities.

38.8 How Space Science Technology Can Assist in Resolving the Challenges

The use of space technology can aid managers in issues such as positioning of the infrastructure, remote sensing of underground water availability, and leak detection. This will be a valuable time-saving for local authorities and other organisations. It has benefits for managers and policy-makers in decision-making. To this end, the technology has proven itself to be a good management tool in groundwater exploration, climate change, and flood hazard monitoring [21]. This section of the paper summarises the countries and communities of sub-Saharan Africa, the Kurdish village of Kendala in Iraq, and Morocco, India, Spain, and many other countries that have enjoyed the benefits of space activities.

Space technology has previously been used locally and internationally to address the challenges of water infrastructure and management. The National Aeronautics and Space Administration (NASA) [29] notes that an advanced water filtration and purification system developed for the International Space Station (ISS) is being used in sub-Saharan Africa for managing water resources. A representative (Todd Harrison) from a non-profit organisation, Concern for Kids (CFK), sourced funds from NASA to help Iraq, Malaysia, and Indonesia with aid and disaster relief programmes.

The community of the Kurdish village of Kendala in Iraq drank dirty, fabricT sifted water together with their livestock. They were aided by NASA-developed technology for the provision of clean water so that now they enjoy clean drinking water. Iceland, Luo and Donchyts [30] show a satellite image that, through the use of space technology, detected a 60% drop in water level of the second-largest Al Massira Dam in Morocco in 2016. Various drops in dam levels in many parts of the world, such as Indira Sagar Dam in India, Mosul Dam in Iraq, and Buendia Dam in Spain, have been identified with the help of space technology. This technology can be applied in SA cities for monitoring water levels in reservoirs without having to physically travel to the reservoirs for inspections.

Similarly, the assistance offered by NASA engineers to the Kurdish village of Kendala could be sourced for SA cities, organisations, and communities. This is an opportunity for SA cities experiencing the challenge of overworked water purification plants due to high sewage volumes. The technology could help overcome the health risks faced by communities due to malfunctioning water purification systems.

38.9 Conclusion

With regard to space technology, South Africa must dedicate this era of the 4IR to embrace this technology which can bring investment into the country. The country needs to be equal to the task.

Any barriers to execution of this global transformation require a concerted effort to overcome the resistance. New African space initiatives must be undertaken in collaboration with the international community. African states must avail themselves of space technology to become future space champions. African countries must join hands to make sure that resources to educate people in space sciences are directed to the youth. This would involve the introduction of space technology curricula in high schools and all institutions of higher learning in South Africa and the encouraging of researchers to follow a career in space technology with funding for inspiration.

Space technology must be used to benefit South Africa and the local authorities for the management of water infrastructure. South Africa should collaborate with global countries which are already ahead with space affairs to help train learners and to further the application of technology used in the ISS for terrestrial water filtration and purification and other space activities. The South African government must try to contain cost escalations for space technology to accommodate new entrants, and people must be upskilled to operate this highly advanced technology.

The study objectives have been met by exposing some issues which may be hindering the African continent from optimal participation in space affairs. The study identified African countries which are making slow progress in participation in space affairs. Exploitation of space technology in the management of water infrastructure also exposed other avenues for further research. This study has provided a helpful literature of space activities which other researchers and authors can apply for their studies. Managers and water specialists may also apply this literature for better application of managerial functions and to influence policy decisions. Learners in schools and institutions of higher learning can also use this to increase their knowledge about space technology and its applications.

38.10 Recommendations for Future Research

Further empirical exploratory research and empirical quantitative research need to be undertaken to identify how big the potential industry of space-based water monitoring might be. Further research is recommended on:

- Breaking the barriers preventing cooperation and business between African countries in space technology
- Exploring in greater depth the benefits of space science technology to water infrastructure
- Possibilities of Africa's collaboration with developed countries in the space industry
- Africa's challenges for increased participation in space science technology

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APPENDIX K: CONSENT TO PARTICIPATE IN A RESEARCH STUDY

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Matlou Lesley Mokgobu, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ___________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____________________ ___________ ______ _______________

Full Name of Participant Date Time Signature / Right Thumbprint

I, Matlou Lesley Mokgobu herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

\- ___________________ ___________

____

Full Name of Researcher Date Signature

__________________ ___________

____

Full Name of Witness (If applicable) Date Signature

Full Name of Legal Guardian (If applicable) Date Signature

Please note the following:

Research details must be provided in a clear, simple and culturally appropriate manner and prospective participants should be helped to arrive at an informed decision by use of appropriate language (grade 10 level - use Flesch Reading Ease Scores on Microsoft Word), selecting of a non-threatening environment for interaction and the availability of peer counseling (Department of Health, 2004)
If the potential participant is unable to read/illiterate, then a right thumb print is required and an impartial witness, who is literate and knows the participant e.g. parent, sibling, friend, pastor, etc. should verify in writing, duly signed that informed verbal consent was obtained (Department of Health, 2004).
If anyone makes a mistake completing this document e.g. wrong date or spelling mistake a new document has to be completed. The incomplete original document has to be kept in the participant file and not thrown away and copies thereof must be issued to the participant.

References:

Department of Health: 2004. *Ethics in Health Research: Principles, Structures and Processes* http://www.doh.gov.za/docs/factsheets/guidelines/ethnics/

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APPENDIX L: WORD CLOUD, TREE MAP, FLOW CHART CLUSTER ANALYSIS, CIRCULAR CLUSTER ANALYSIS

NVivo WORD CLOUD

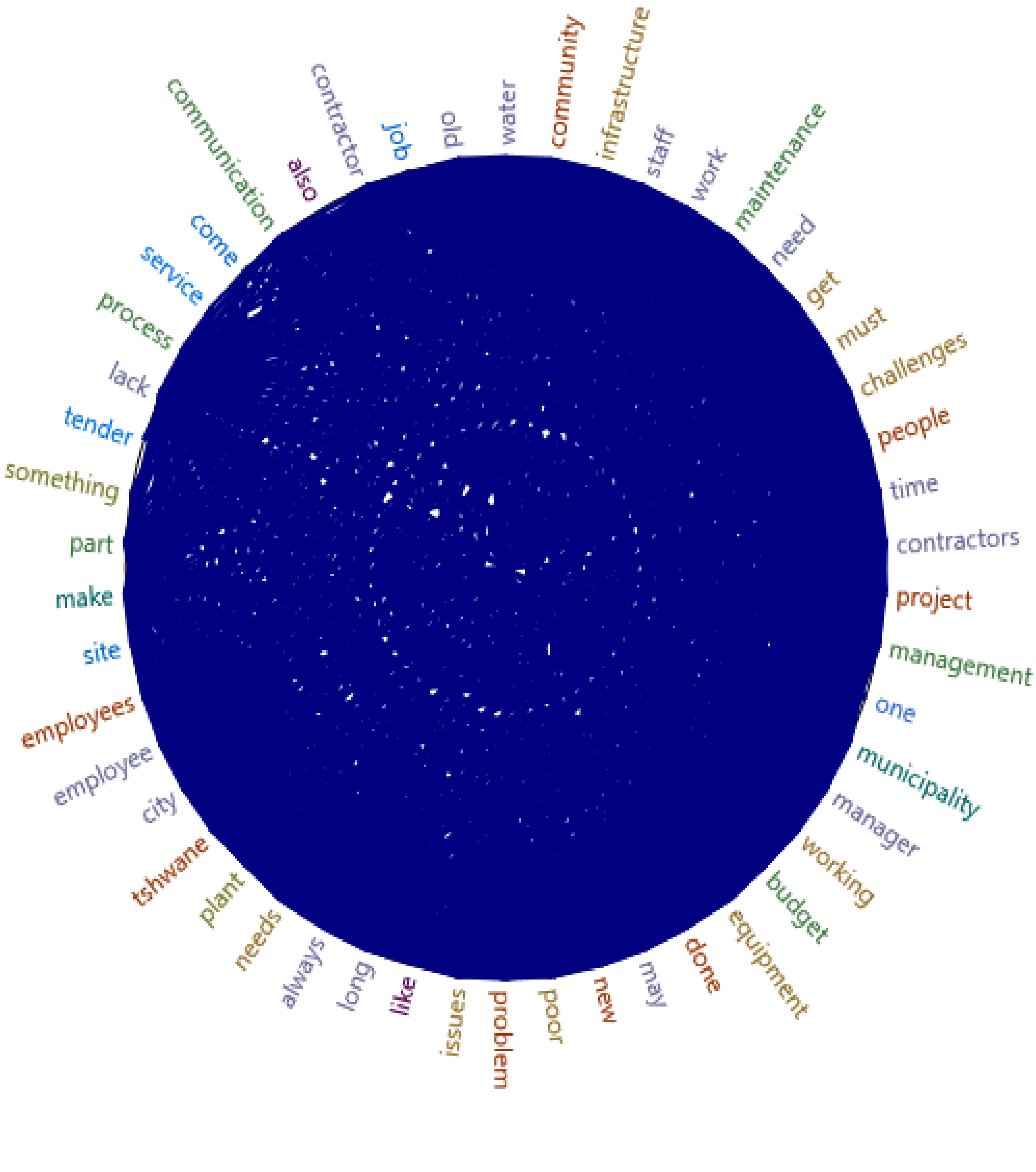
50 WORDS: EXACT MATCH

WORD CLOUD MANAGERS

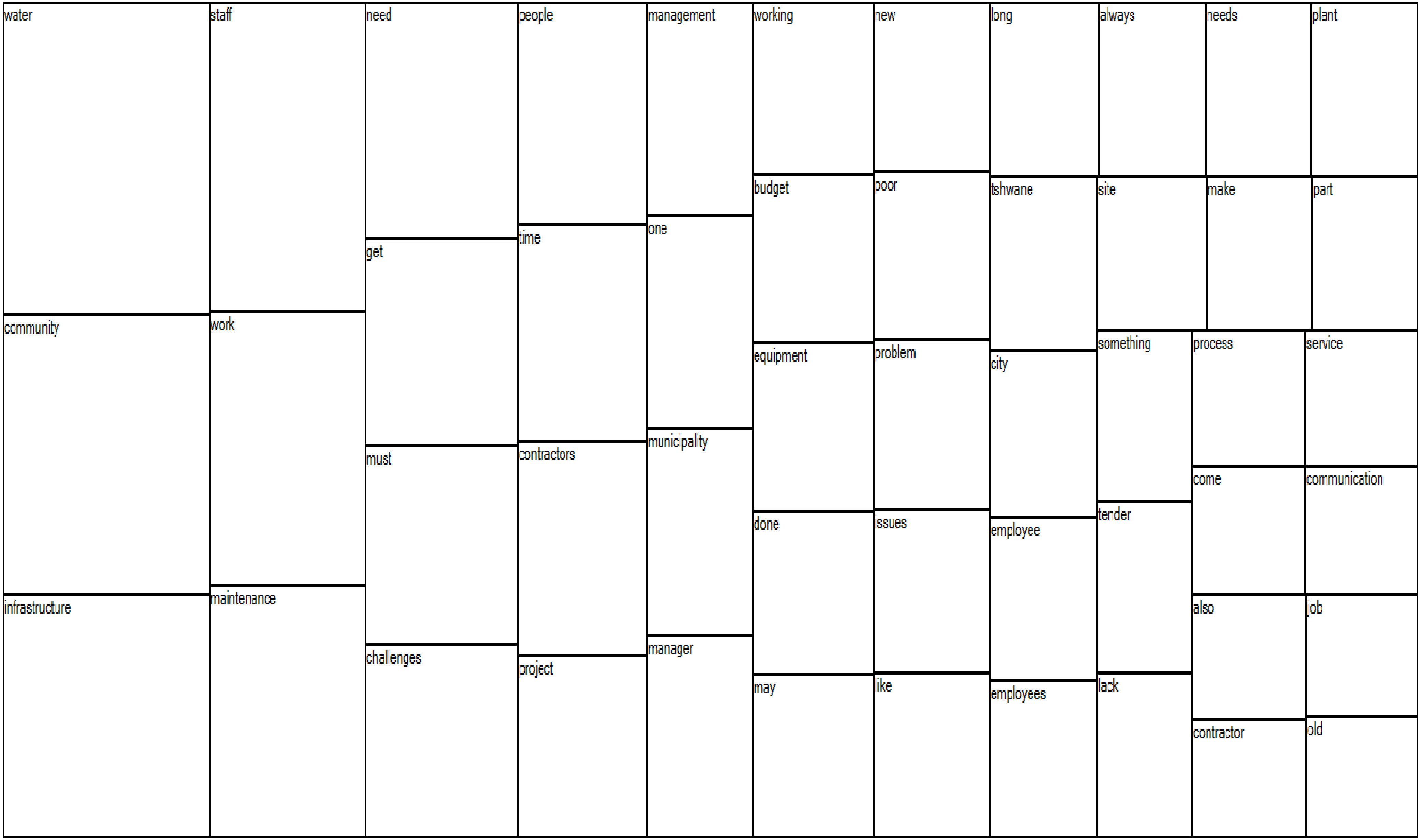
WORD CLOUD EMPLOYEES

NVivo CLUSTER ANALYSIS

50 WORDS: EXACT MATCH

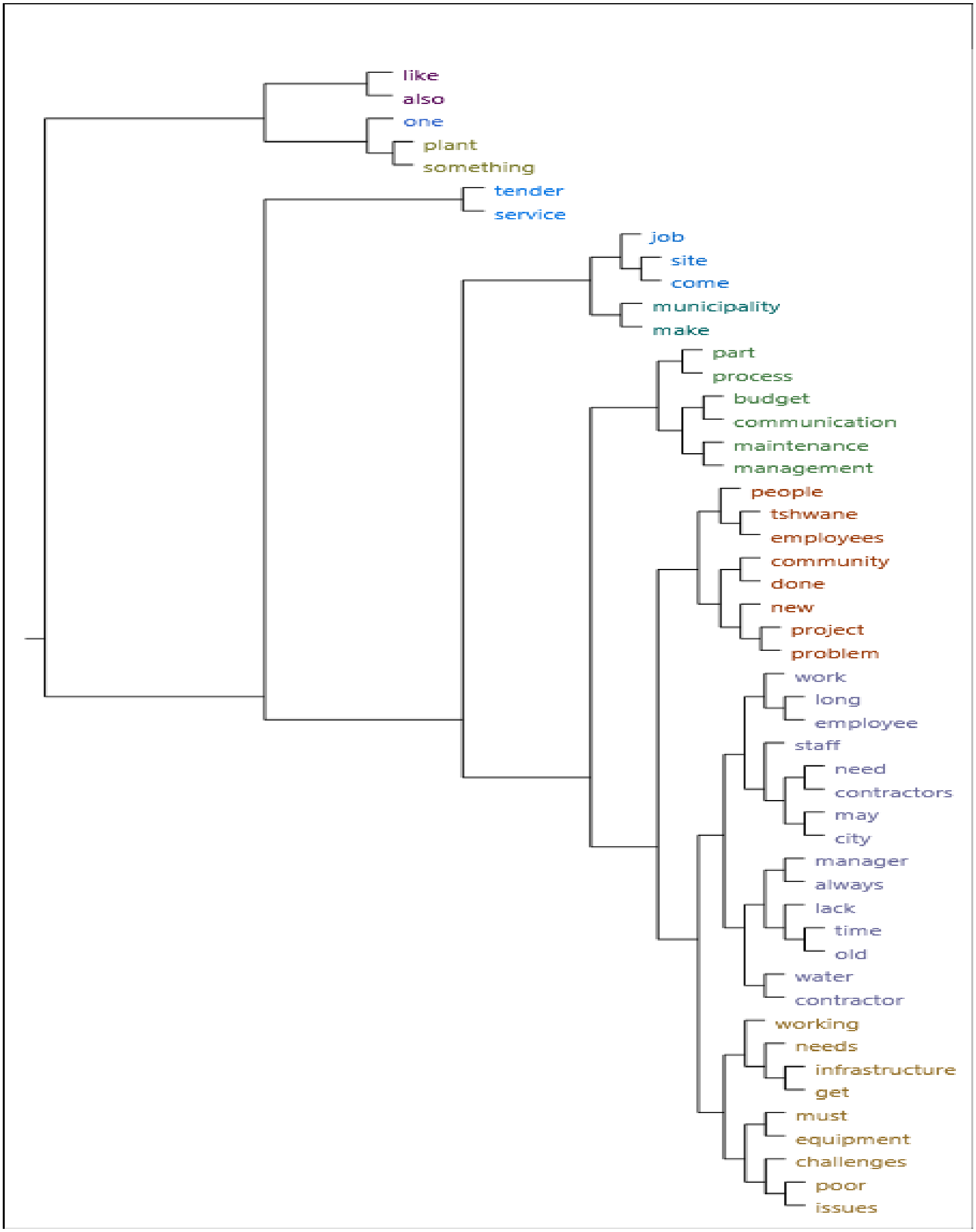


NVivo Tree Map- 50 words: Exact match



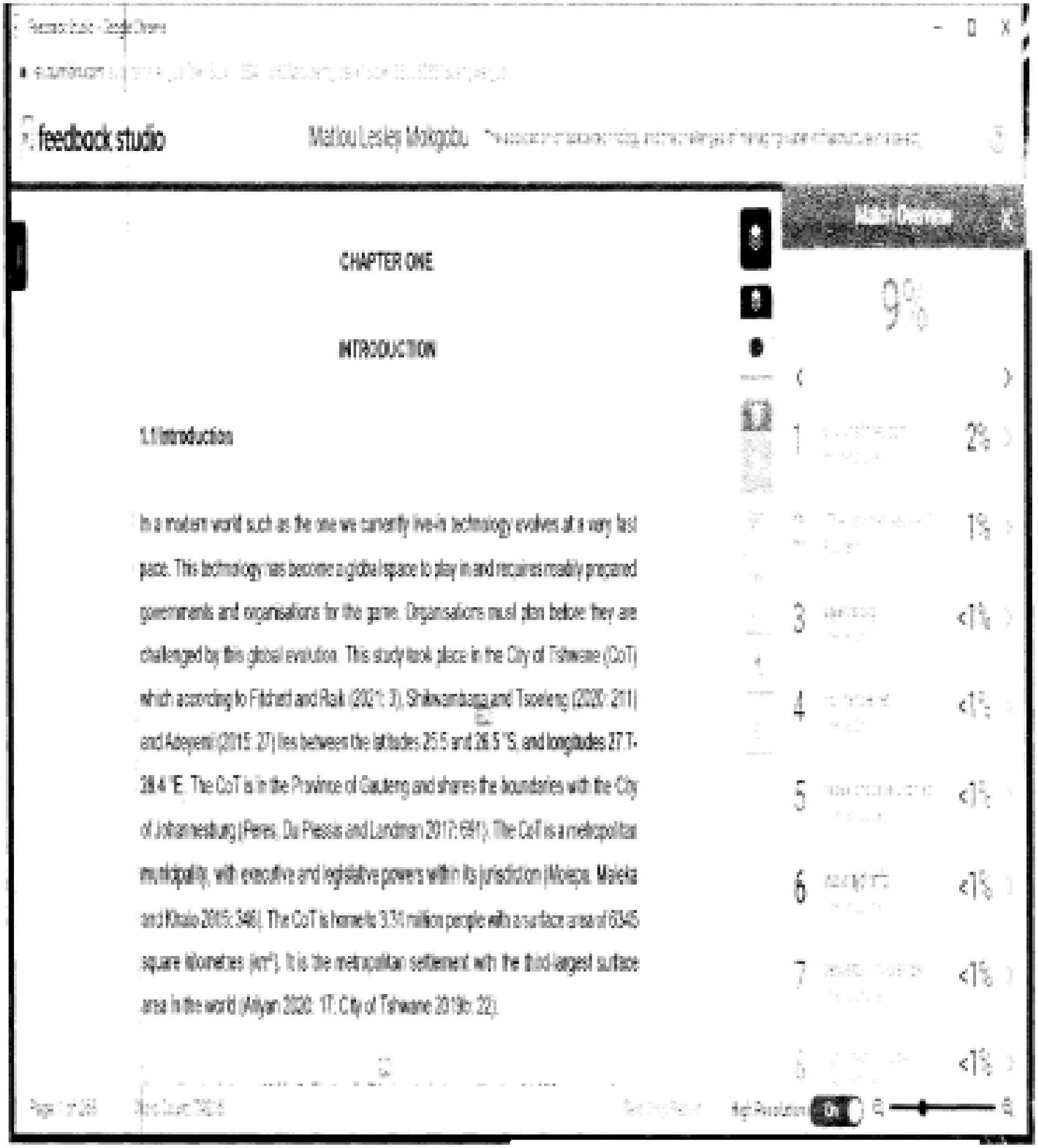
NVivo CLUSTER ANALYSIS

50 WORDS: EXACT MATCH



APPENDIX M: TURNITIN REPORT

Matlou Lesley Mokgobu Turnitin report 08-08-2022



Name of student: Matlou Lesley Mokgobu

Name of supervisor...Roger Bruce Mason

APPENDIX N: EDITING CERTIFICATE

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EDITING CERTIFICATE

Re: **Matlou Lesley Mokgobu**
PhD thesis: **The application of space technology and the challenges of managing water infrastructure in a selected South African municipality**

I confirm that I have edited this thesis and the references for clarity, language and layout. I returned the document to the author with track changes so correct implementation of the changes and clarifications requested in the text and references is the responsibility of the author. I am a freelance editor specialising in proofreading and editing academic documents. My original tertiary degree which I obtained at the University of Cape Town was a B.A. with English as a major and I went on to complete an H.D.E. (P.G.) Sec. with English as my teaching subject. I obtained a distinction for my M.Tech. dissertation in the Department of Homoeopathy at Technikon Natal in 1999 (now the Durban University of Technology). I was a part-time lecturer in the Department of Homoeopathy at the Durban University of Technology for 13 years and supervised many master's degree dissertations during that period.

Dr Richard Steele
29 August 2022
per email