A SUSTAINABLE INFORMATION SYSTEM FRAMEWORK FOR THE ADOPTION OF A SMART WATER METER SYSTEM

by

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DECLARATION

I, Nwakego Joy Okoli, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

_______________________ **__16 October 2024_______**

Signed **Date**

ABSTRACT

Water utility providers continue to follow ‘traditional, manual or analogue’ water management solutions despite having witnessed several challenges. This research explored the reasons why water institutions in Nigeria fail to adopt an IoT-based Smart Water Meter System (SWMS) to improve the efficiency of water management for a sustainable future. The study sought to identify factors influencing the adoption of a SWMS, people’s perceptions about adopting a SWMS, how institutions can adopt a SWMS as part of their water management method, the role of government in facilitating and engaging water institutions to use a SWMS, existing practical evidence on the adoption of a SWMS by water utilities, smart water application technologies for water management, and what framework can be developed to adopt a SWMS.

The interpretivist philosophy was selected as the study adopted qualitative research methodology and an embedded case study strategy to accomplish the aim and objectives of the research. The data collection comprised a literature review, documentation, and semi-structured interviews. The participants were purposefully selected based on their expertise in water management and being the most representative individual(s) from the water institution. Data from the interviews were collected from 11 experts employed by the Water Institution selected for this study. Thematic analysis was used to analyse the data. The findings were categorised and presented thematically, bringing together and shedding light on the reasons for the slow adoption of SWMSs in Nigeria.

Findings reveal that the selected Water Institution is constrained by numerous factors, including technological, organisational, environmental and economic aspects as well as a knowledge gap. These challenges include internet network failures in Nigeria, associated costs, a lack of service provider support to maintain a SWMS, poor electricity supply, limited government support, government water policies, security concerns around SWMSs, the lack of a SWMS framework and logistics, structural constraints and environmental challenges, and the lack of awareness and understanding of smart water metering (SWM), among others. These factors hinder the use of a SWMS among stakeholders, resulting in the reasons behind slow SWMS adoption.

A Smart Water Meter System Framework and recommendations are proposed to motivate the widespread adoption of smart water meter systems for the sustainable conservation of water resources in water institutions in Nigeria. This framework can be used to improve and support existing IS/IT theories, particularly in developing countries facing similar challenges to Nigeria. Three new constructs were added to the theory used, namely economic factors, a knowledge gap among stakeholders in terms of using a SWMS, and trialability, that is, the need to conduct a pilot study with the new system before large-scale adoption is considered. The long-term benefits of SWMS adoption can significantly benefit society in future, both environmentally and economically. Furthermore, this research offers valuable insights for the Nigerian government and developing countries facing similar challenges to create clear stringent water policies and regulations in response to issues such as water scarcity, demand management, water efficiency and drought relief plans, while water use reduction targets should promote smart water meter system adoption.

Keywords: Water utility, water management, smart water meter system, SWMS, smart water technology, Internet of Things, IoT, sustainable water management, water policy, government water policy, adoption.

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DEDICATION

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“It is a testament to perseverance and the power of believing in oneself: the unexpected twists, the moments of frustration, and the exhilaration of finding answers.”

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ABBREVIATIONS AND ACRONYMS

Acronym	Term
AI	Artificial Intelligence
API	Application Interface
CPUT	Cape Peninsula University of Technology
CSS	Cascading Style Sheets
DOI	Diffusion of Innovation
ESP32	Espressif Systems Microcontroller
ESP8266	Espressif Systems Wi-Fi Microcontroller
FID	Faculty of Informatics and Design
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
Hz	Hertz
ICT	Information and Communications Technology
IoT	Internet of Things
IS	Information Systems
IT	Information Technology
Kbps	Kilobits per second
kHz	Kilohertz
KM	Kilometre
LoRa	Long Range
LoRaWAN	Long Range Wide Area Network
LPWAN	Low Power Wide Area Networks
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution Machine Type Communication
Mbps	Megabits per second
MHz	Megahertz
ML	Machine Learning
MPX5700	Pressure Sensor
MQTT	Message Queuing Telemetry Transport
MSP 430	Mixed Signal Processor Microcontroller

MySQL	Structured Query Language
NB-IoT	Narrow-Band Internet of Things
NodeMCU	“Node” and “Microcontroller” (microcontroller unit)
NRW	Non-revenue water
P1 – P11	Pseudonyms for Participants used in this research
PHP	Hypertext Preprocessor
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDGs	Sustainable Development Goals
SWM	Smart Water Metering
SWMS	Smart Water Meter System
TAM	Technology Acceptance Model
TOE	Technology-Organisation-Environment
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
UN	United Nations
USA	United States of America
WAP	Wireless Application Protocol
Wi-Fi	Wireless Fidelity
YF-S201	Refers to a water flow sensor
ZigBee	Zonal Intercommunication Global standard
1G, 2G, 3G, 4G & 5G	Five Generations of Cellular Communication
3D	Three-dimensional
Smart Water Meter System, IoT-based Smart Water Meter System, Smart Water Metering, and Smart Water Meter (E.g. SWMS or SWM)	In this study, these keywords refer to the same thing. It means meters that integrate modern technology to gather data on water use; and communication systems that can gather and transmit information on water usage in real-time.

CHAPTER ONE: INTRODUCTION AND RESEARCH BACKGROUND

1.1 Introduction

Back in 1926, Nikola Tesla noted that, “when wireless is perfectly applied, the whole earth will be converted into a huge brain” (Shaikh et al., 2017). Traces of Tesla’s philosophy are already evident in society, where water management corporations or governments use Internet of Things (IoT)-based systems to manage their water. The IoT is a physical device that comprises sensors, processors, actuators, and network connections objects. These characteristics enable the connection and transfer of data by devices such as home appliances (Brown, 2016; Mekki et al., 2019). It is expected that IoT technology will offer solutions to many homes and environmental problems such as water leakage. This will help with water resource management, lessening the impact of water scarcity. Basic IoT technology, that is, Wireless Sensor Networks (WSN), may be used to identify, detect, and collect the environmental parameters needed for exact applications to achieve beneficial goals (Whitmore et al., 2015).

One of the applications of IoT is smart water meter systems (SWMSs), which encompass two precise elements, namely: meters that employ modern technology to gather data on water use, and communication systems that can gather and transmit information on water usage in real time (Stewart et al., 2010). Further, the United Nations (UN) approved the 2030 Sustainable Development Agenda in September 2015. The agenda has global indicators for international corporations to attain sustainable development between 2015 and 2030. This study aligns with Goals 6, 12 and 13 of the 2015-2030 UN Sustainable Development Goals (SDGs). These goals focus on the need to implement an integrated water management system to help manage water and address water scarcity at all stages (United Nations, 2015).

Environmental sustainability has grown exponentially to include considerations of climate change. Climate change is a fact and perhaps one of the greatest lasting threats people have ever faced. Climate change threatens our capacity to achieve social, economic, and environmental goals to promote sustainable development (International Telecommunications Union, 2014; Jordan et al., 2018). There is an increasing international concern about addressing the implications of climate change in cities, especially in developing countries where cities are expanding fast. Many people living in cities are poor or prone to climate-related disturbances. Developing countries are more in danger because of their low adaptive capacity and high resource scarcity (Mumtaz et al., 2019; Nahayo et al., 2019). The number of international urban networks involved in the issue of climate change has grown and the membership is diverse.

Simultaneously, some actors, including national governments, the United Nations and the World Bank, have deployed various activities to address climate change issues (Bulkeley &

Castán Broto, 2013; United Nations, 2015). Climate change causes several health risks, including increased vector-borne diseases, heat strokes, air pollution, food insecurity, and water scarcity (Abel et al., 2018).

1.2 Research background

Several nations depend heavily on traditional analogue water metering systems and manual formats for the management of water supply and use (Mudumbe & Abu-Mahfouz, 2015; Hudiono et al., 2021; Sani, 2021). These analogue water meters have dials that display the total water consumption of a consumer (Kainz et al., 2021). In some countries such as India, Indonesia and Nigeria, an employee reads the water meters once a month, and the consumer's bill is calculated using approved rates based on the volume of water consumed (Michael et al., 2019; Sani, 2021). When customers' premises are not easily accessible for these meter readings, consumption estimations are done to calculate the water bill in some countries such as Nigeria (Sani, 2021). These readings are labour intensive, frequently inaccurate because of time lag, and projections are based on historical data or deliberate manipulation. Furthermore, there is a practical challenge that stares consumers in the face. Current water resource management continues to follow 'traditional, manual or analogue' water management solutions. For example, in the City of Cape Town, water leakages in homes or properties are checked manually.

Figure 1.1: How to check your property for leaks (Source: City of Cape Town, 2018)

Figure 1.1 is a guide on how to detect a water leak in a home or on a property. The occupant needs to close all taps and avoid flushing the toilets. He/she then needs to examine and take record of the meter reading, wait for 15 minutes, and read the meter again. If there is a difference, then there is a leak. It is important to note that one leaking tap can waste approximately 400 to 2,600 litres a month. One leaking toilet wastes about 2,600 to 13,000 litres of water a month. This is subject to the leak flow rate (City of Cape Town, 2018). Additionally, increased water wastage may occur for people who cannot take accurate meter readings or the difference between meter readings to ascertain leaks. Hence, there is a need for smart water metering (SWM) to help curb this type of issue as well as the manual checking of leaks.

IoT-based SWMS implementation in developing countries is limited while developed countries leverage and implement IoT innovations (Whitmore et al., 2015; Amadin et al., 2017). Extensive and well-documented evidence shows that emerging technologies play an important role in water management (Salam et al., 2014; Ntuli & Abu-Mahfouz, 2016; Suresh et al., 2017; Srivastava, 2018). The SWMS, an innovation enhanced by IoT, have the potential to address the challenges of traditional, manual and analogue water management solutions.

Here are some potential societal and environmental benefits of SWMSs:

- Decrease in residential household water consumption (Britton et al., 2013).
- Residential leak reduction – better water management practices such as fixing water leakages promptly can lower the cost of fixing water infrastructure/facilities (Muhammetoglu et al., 2020).
- Updates on daily water consumption to users and water distributors (Gosavi et al., 2017).
- Address the challenge of tampering with pre-paid water meters, such as unauthorised top-up to pre-paid meter smartcards using malicious software (Suresh et al., 2017).
- The ability to see the water tariff, making people responsible for their water use (Ray & Ray, 2020).
- IoT SWM could offer a feasible opportunity to save water (Beal & Flynn, 2015).

Further, the access to frequently updated information on water consumption allows engineers to detect pipe leaks and water quality incidents faster than traditional water systems that still use manually read meters (Arregui et al., 2018). One area that requires attention is sustainable access to water. For instance, in Nigeria, one of the reasons for water scarcity is attributed to water corporations not repairing broken down distribution lines and water leakages promptly (Ezenwaji et al., 2016; Chukwuma, 2017). In South Africa, the Western Cape has a semi-arid climate. Forecasts of climate change show that the province may experience more water scarcity with escalating temperatures, evaporation and incidents of dangerous events such as droughts. The impact of water scarcity needs crucial changes and adjustments across society (Harris et al., 2018).

Water plays a fundamental role in creating social structures and sustaining life throughout the entire existence of people. Climate change and an increasing population have presented possible threats to the sustainability of water resources (Yang et al., 2017; D'Ambrosio et al., 2020). The availability and sustainable management of water as well as the right to access adequate safe water for both domestic and personal use has been documented as a basic human right by the United Nations (Yang et al., 2017). There is a need for excellent monitoring of water resources, regular maintenance, and prompt replacement of parts.

According to Ali (2019), people are sceptical of using a SWMS, especially when there is no motivation for using it. Much focus has been on the system design (Gosavi et al., 2017; Suresh et al., 2017; Anandhavalli et al., 2018; Srivastava, 2018; Hasibuan & Fahrianto, 2019; Ray & Goswami, 2020), security architecture (Ntuli & Abu-Mahfouz, 2016; Ray & Ray, 2020), monitoring (Muhammetoglu et al., 2020), and system feedback (Britton et al., 2013; Visser et al., 2021). To date, researchers have failed to propose an IS framework for the coherent adoption of a SWMS. Environmental monitoring helps in identifying short- to long-term indicators of environmental health such as water leakage or wastage. Monitoring and assessing the state of our water supplies, sustainable environmental planning, and strategic policy making are needed (Abraham et al., 2017). It is important that SWM becomes part of current and future strategic planning discussions, whether in research institutions or in corporation discussions, to reap the benefits IoT offers (Coetzee & Eksteen, 2011).

1.3 Research problem statement

There is a practical challenge staring water consumers in the face. Current water resource management continues to follow traditional, manual or analogue water management solutions, and thus has been challenged with time-lag, errors in meter readings, additional labour force to process water bill, water leakage, and wastages. Despite the continuous growth and documented benefits of SWM based on IoT, the uptake of SWMSs has been slow because of a lack of understanding, and an Information Systems (IS) framework to guide the widespread adoption of the system. It is important to design a sustainable IS policy framework for the adoption of a SWMS and the management of the associated technologies is needed. The solution holds both economic and environmental benefits.

1.4 Research aim

The aim of this study is to explore the reasons behind the failure of institutions to adopt an IoT-based Smart Water Meter System (SWMS) to improve the efficiency of water management for a sustainable future. This exploratory study endeavoured to obtain a better understanding of the identified barriers as well as additional factors that influence institutional SWMS adoption. The findings and emergent themes were used to develop an IS framework, and a set of IS adoption guidelines is proposed to motivate widespread adoption of SWM.

1.5 Research question

The following primary research question is posed for this study: **What are the adoption challenges for institutions in the use of an IoT-based smart water meter system?** The primary research question is further divided into research sub-questions to successfully answer the primary question.

1.6 Research sub-questions, objectives and method(s)

Table 1.1 displays the seven research sub-questions, their objectives, and the methods utilised in answering the questions.

Table 1.1: Research questions, objectives and methods for this study

Research question	**What are the adoption challenges for institutions in the use of an IoT-based smart water meter system?**	
Research sub-questions	**Objectives**	**Method(s)**
1) What are the factors influencing the use and adoption of an IoT-based smart water meter system?	To identify and understand how these factors create challenges that institutions must overcome before adopting an IoT-based smart water meter system.	Semi-structured interviews Literature review
2) How do people feel about using a smart water meter system to manage their water?	To determine people's perception towards adopting an IoT technology that can manage water usage.	Semi-structured interviews
3) How can the Water Institution adopt a smart water meter system as part of their water management method?	To identify ways in which a smart water meter system can be adopted.	Semi-structured interviews Literature review
4) What is the role of government in facilitating and engaging the institution proactively in the use and adoption of a smart water meter system?	To establish the role that government plays as a stakeholder in providing support to encourage institutions to actively participate in the use and adoption of an IoT-based smart water meter system.	Semi-structured interviews
5) What practical evidence exists regarding the adoption of a smart water meter system by water utilities?	To review existing practical evidence on smart water meter system adoption by water utilities.	Literature review
6) What are the current smart water application technologies for water management?	To identify the current smart water application technologies used in managing water.	Literature review

Research question	What are the adoption challenges for institutions in the use of an IoT-based smart water meter system?	
Research sub-questions	**Objectives**	**Method(s)**
7) What framework can be developed for the adoption of a smart water meter system?	To develop an efficient and sustainable framework for smart water meter system adoption.	Research findings

1.7 Delineation of the research

This study focuses on the Nigerian water sector, and the embedded case study concentrates on a water utility provider in Southeast Nigeria. The institution was chosen for its outstanding achievements in its water utility service and having the potential to use a smart water meter system. The researcher did not have access to opportunities and resources to include additional cases in this study. Understanding how a government-owned water utility provider staff perceive SWMS can help inform broader policy changes that encourage adoption across regions.

1.8 Theoretical underpinning

Theoretically, to understand the reasons behind the failure of institutions to adopt an IoT-based smart water meter system to improve the efficiency of water management for a sustainable future, the study adopted the following frameworks:

- Concepts present in the Technology-Organisation-Environment (TOE) framework as it considers external factors such as technological, organisational, and environmental factors when thinking about how to appropriate, use, and create value from innovations (Azadegan & Teich, 2010; Bryan & Zuva, 2021) in an organisation.
- Concepts present in the Technology Acceptance Model (TAM) (Davis, 1989).
- The Diffusion of Innovation (DOI) theory (Rogers, 1995).
- Insights from the participants to develop the research conceptual framework.

1.9 Methodological considerations

The methodology applied in this study are discussed in detail in Chapter Three. The study follows a holistic qualitative design approach based on the research problem. The strategy is based on case study analysis, with a government Water Utility Provider serving as the unit of analysis. The main units of observation were identified water utility managers and an Information Technology (IT) manager employed at the case study institution.

Interviews: In-depth interviews were conducted with members of the selected government Water Institution on precise topics regarding factors that influence the use and adoption of a SWMS, participants' perception on using SWMS for water management, the role of government in facilitating and engaging the people proactively towards using a SWMS, and how a SWMS could be adopted as part of their water management method (Saunders et al., 2009; Wahyuni, 2012). Understanding how government-owned water management staff perceive SWMS can help inform broader policy changes that encourage adoption across regions.

Documentation and literature review: A review of academic publications on the subject was conducted to gain a better understanding of related constructs and theories, and to keep record of previous studies. To account for actual local practice, available documentation from the researched government Water Institution was also consulted (Kothari, 2004). Figure 1.2 presents an overview of the research philosophy and methodological choices for this study.

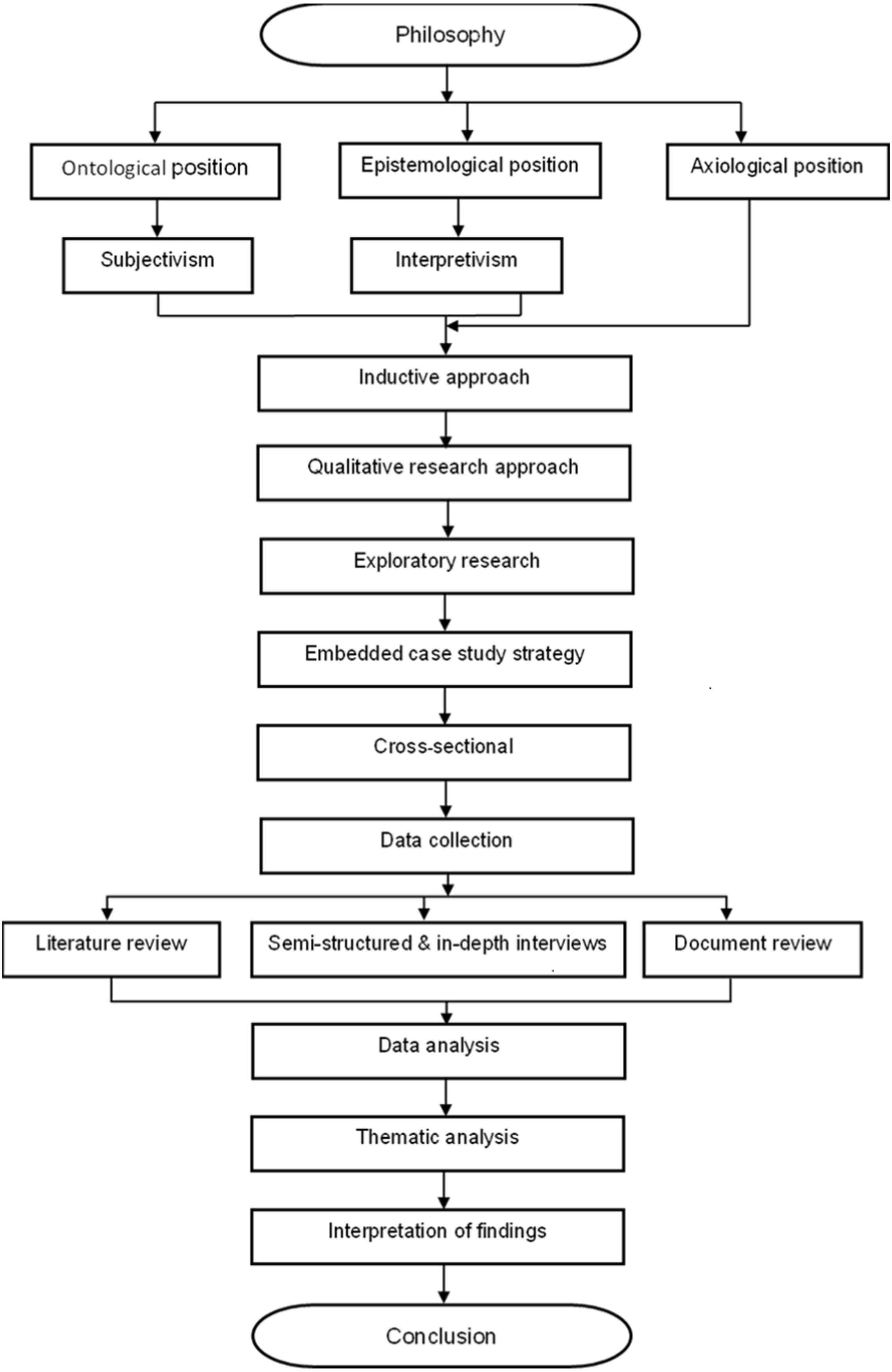


Figure 1.2: Research design and methodology

1.10 Contribution of this research

Theoretically, the study contributes to the existing scientific body of knowledge in the field of information systems (smart water meter systems), particularly from a Nigerian perspective. Nigeria is a developing country where there is little literature on the phenomenon studied. The contribution of this research was accomplished by inferring empirical findings to support and extend existing theories. A Smart Water Meter System (SWMS) conceptual framework was designed to motivate the widespread adoption of SWM for the sustainable conservation of water resources in water institutions in Nigeria. This framework can be used to improve and support existing IS/IT theories, particularly in developing countries facing similar challenges to Nigeria (see Figure 6.1).

Practically, water institutions in Nigeria and other developing countries using traditional analogue water meters can use the findings and Smart Water Meter System conceptual framework to better understand the challenging factors to SWMS adoption. The framework serves as a proposed guide for the adoption of a SWMS. Adoption could benefit society in future, both environmentally and economically, by reducing the carbon footprint of water supply systems through water conservation and cost-saving.

Methodologically, the application of an embedded case study strategy and qualitative data collection techniques in this study is a way to better understand complex phenomena to generate knowledge and/or inform policy development for water institutions in a developing country.

1.11 Thesis structure

The remaining portions of the research report are divided into seven chapters. Each of the remaining chapters are structured as follows:

Chapter Two – Literature Review: This chapter is a formalisation process that builds on previous and current research. The review of related literature provided context for the subject matter and identified gaps, thereby allowing this study to be placed within the existing literature on smart water meter systems. Chapter Two also discusses the theoretical lenses on ICT adoption in Information Systems (IS) research.

Chapter Three – Research Philosophy and Methodological Choices: This chapter covers the research philosophy and the methodological choices, explaining and justifying the choice of interpretivism. The research approach, strategy, data collection techniques, and analytical techniques are considered. The research quality assurance and ethical reflections are also presented in this chapter.

Chapter Four – Fieldwork Report and Data Analysis: This chapter presents an overview of the study area, including the selected Water Institution and participants. It provides an overview of the fieldwork and data analysis process.

Chapter Five – Research Findings: In Chapter Five, the findings on the state of smart water metering in Nigerian organisation are presented. The presentations are organised around themes and categories identified during the data analysis phase. The conclusion of this chapter presents the key finds.

Chapter Six –Discussion of Research Findings: Chapter Six delves into the emerging themes from the findings. These findings are discussed in relation to the literature. The newly emerging constructs are used to build the research conceptual framework.

Chapter Seven – Conclusion: Chapter seven concludes the research with a reflection on the research problem. The chapter summarises the main findings and provides answers to the research sub-questions and the primary research question to address the aim of the study. It presents recommendations, research contributions, limitations, and directions for future research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Chapter Two is an exploration of literature relevant to the study. Thus, this chapter discusses the subjects that form the study's background. This allows readers to gain a better understanding and form a logical picture of the study. The following are the main issues addressed in this chapter:

- Section 2.2. Global perspective on the water crisis
- Section 2.3. Internet of Things (IoT) and sustainable smart cities, an overview of IoT technologies that enable IoT devices to sense and respond in varied conditions
- Section 2.4. Systematic literature review protocol on Smart Water Metering (SWM)
- Section 2.5. Smart water meter and definitions
- Section 2.6. The adoption of SWM
- Section 2.7. The perception of people towards SWM (benefits and challenges)
- Section 2.8. The influence of governmental water policies on smart water meter adoption
- Section 2.9. Theoretical lenses for this study
- The chapter is concluded in section 2.10.

2.2 Global perspective on water crisis

Water is a chemical compound made up of two hydrogen atoms and one oxygen atom; and water is the liquid state of the compound. The gas phase is known as steam and the solid phase is called ice. It is an odourless, tasteless and transparent liquid that is a necessity. It is important for the survival of humans, animals and plants. Thus, water is one of the basic survival needs. Water is also at the centre of social and economic development, serving as a key component in all forms of development and planning. It is essential to preserve health, manage the environment, grow food and create jobs (Emengini & Unigwe, 2016). Water is an essential service for the sustainable development and economic competitiveness of any country.

Global demand for this essential resource has soared substantially because of economic development, climate change and rising population. As the world's population grows, so does the demand for more food, more water for agricultural purposes and thus more household usable water. About 40% of the global population live in areas with medium to high water stress. Two-thirds of the global population (about 7 billion) probably live in areas with such water stress. Ironically, as the world's freshwater system reduces through pollution, water use has increased six-fold over the last century, more than doubling the already precarious rate of population growth (Raimi et al., 2019).

The impact of climate change on water can affect all sectors of the economy, including tourism, agriculture, transportation, recreation, healthcare, industry, forestry and fisheries (Olmstead, 2014). Climate change may have serious implications on water resources in Africa. The United Development Programme (UNDP) estimates that by 2080, about 1.8 billion people will suffer from water scarcity, mainly in Africa and other developing nations (Ford, 2008). Another study predicts that by 2030, water demand will exceed supply by 50% mostly in developing nations (Ahile, 2015).

Many developing nations such as South Africa gets an average yearly rainfall of 492 millimetres while the rest of the world gets 985 millimetres. Thus, South Africa is classified as a water stressed country (Businesstech, 2015). In 2017, “water crises” were classified as the third main risk for performing business in the Republic of South Africa. “Water crises” are also among the top risks worldwide (Reddick & Kruger, 2019). Deteriorating water supply and increasing water demand are not unusual in Cape Town. The 2015 to 2018 drought in Cape Town showed the severity of climate change impacts. Rainfall that fills up the six big dams of the Western Cape Water Supply System (WCWSS) was basically low (Kesson et al., 2018). About three million people residing in Cape Town at the time almost got suspended from piped water supply at some point (Foster et al., 2018). This was because of a combination of extended irregular rainfall since 2015, population growth (Grasham et al., 2019), lack of water resources management and inadequate political intercession to managing water (Muller, 2018)**.** To meet national prescribed water restrictions, water consumption of 50 litres a day per person was mandated at the start of 2018 while ‘Day Zero’ was avoided. “Day Zero” simply means anytime the dams reach a 13.5% limit, the reticulation to most areas of the city is turned off. The previous water scarcity has revealed Cape Town’s vulnerability to increased drought conditions (Kesson et al., 2018)**.**

In Nigeria, practically every urban area experiences water scarcity. The public water supply is intermittent, unreliable, and in most cases inaccessible, resulting in a high reliance on unsafe supplementary water sources, which are prone to water-borne diseases such as dysentery, typhoid fever (Ahile et al., 2015), paratyphoid fever, cholera, diarrhoea, hepatitis and amoebiasis (Ezenwaji et al., 2016). According to a 2008 survey conducted by the Federal Ministry of Water Resources, approximately 80% of Nigerians lacked access to safe drinking water (Ezenwaji et al., 2014). Water scarcity should ideally not be a problem for the country, given the number of surface water bodies and groundwater resources available. Unfortunately, this is not the case.

Enugu state is faced with water scarcity issues. Reports show that water demand is estimated to be at 144,491,774 litres per day (LD), and supply is 67,091,096 LD, satisfying only 44% of the demand. This indicates that water scarcity exists (Ezenwaji et al., 2016). The State Water Corporation uses a strategy called the "administrative method approach" to distribute water to consumers; this method is an estimate of water demand based on historical consumption data, that is, based on records of water consumption for each area. Despite using this method, many areas still experience inconsistent or complete lack of supply, forcing residents to rely on alternative water sources such as wells, rivers, streams and some unhygienic water storage methods (Okpasuo et al., 2020).

The demand for domestic and industrial water is rising, severely stressing the limited water supply available. Water is fundamental for the economy and for our life. Managing water scarcity remains one of the challenges out there to solve these days. Nevertheless, technological innovations such as the Internet of Things (IoT) can help many African countries benefits greatly from information and communications technologies (ICT) and the water resources available. In the next section, IoT is discussed as a means of achieving a sustainable smart city.

2.3 Internet of Things (IoT) and sustainable smart cities

Kevin Ashton originally conceived the phrase Internet of Things (IoT) in the year 1999 (Ashton, 2009). The setting was based on supply chain management (Gubbi et al., 2013). Though as technology advanced, the meaning of "Things" has changed. The principal objective of creating a computer that senses information without a person's intervention remains. However, there is a major development from the present internet to a web of connected things that utilises current internet standards to provide services for information applications, analytics, transfer and communications (Gubbi et al., 2013). Simply put, IoT is when daily physical things are enhanced with sensing, computing, and communication abilities such that they can connect to the internet. These physical things, which communicate with the digital world, produce data and information that were not possible before (Dunko et al., 2017).

The IoT has generally been regarded as an essential platform for achieving sustainable smart cities (Wu et al., 2018). Smart cities have applied IoT to boost the performance and efficiency of urban facilities (Allam & Dhunny, 2019). Different terms such as digital cities (Keegan et al., 2012), information cities (Fietkiewicz et al., 2017), and sensing city (Mone, 2015) have been used in the literature to replace smart cities. The existing definitions of smart cities lean towards distinct aspects, depending on the focus of a study. For instance, most definitions lean towards the role of ICT.

Peng et al. (2017) describe smart cities as towns created to use advanced ICT (innovative technologies) such as smart meters, smart phones, mobile networks, sensors, smart vehicles and data storage technologies. The increased connectivity prompted a remarkable measure of information creation, which made possible a platform that allows data gathering, analysing and distribution in various spheres of life (Allam & Dhunny, 2019). A smart city integrates and monitors the state of every key infrastructure, for example, water, tunnels, roads, bridges, airports, rail, seaports, power and communications. Resources in buildings can be better optimised through planning of preventive maintenance measures as well as monitoring security elements while enhancing services for its citizens (Hall et al., 2000).

Smart city initiatives aim at providing citizens with further well-organised services such as monitoring and enhancing existing infrastructure. Increasing cooperation among diverse economic actors as well as encouraging high-tech business frameworks within private and public sectors (Marsal-Llacuna et al., 2015). Smart cities attempt to increase poor communities' competitiveness through innovation while increasing better amenities and cleaner environment for its citizens (Appio et al., 2019; Ismagilova et al., 2019). Others consider smart cities to be low-carbon or zero localities producing none-to-low greenhouse emissions because of the use of smart green technologies (Yigitcanlar et al., 2019).

Smart cities are a development vision to integrate various ICT solutions securely towards managing a city resource. The definitions of smart city highlighted so far show the importance of integrated information systems playing a significant role in offering high-tech services in smart building, transportation, public safety, e-commerce, security, energy, education, healthcare and environmental monitoring (Schaffers et al., 2012; Guo et al., 2017).

The idea of a smart city can vary depending on the country, technology, lifestyle, culture, environment and society. Therefore, smart city conceptualisation largely differs from city to city and country to country depending on advancement level, willingness to change, residents' desires and resource availability. Furthermore, the meaning of a smart city in Africa can differ compared to Europe (Priya & Rameshkumar, 2017).

Within the literature, different aspects of smart cities have been discussed. Pramanik et al. (2017) identified ten aspects of smart cities as shown in Figure 2.1.

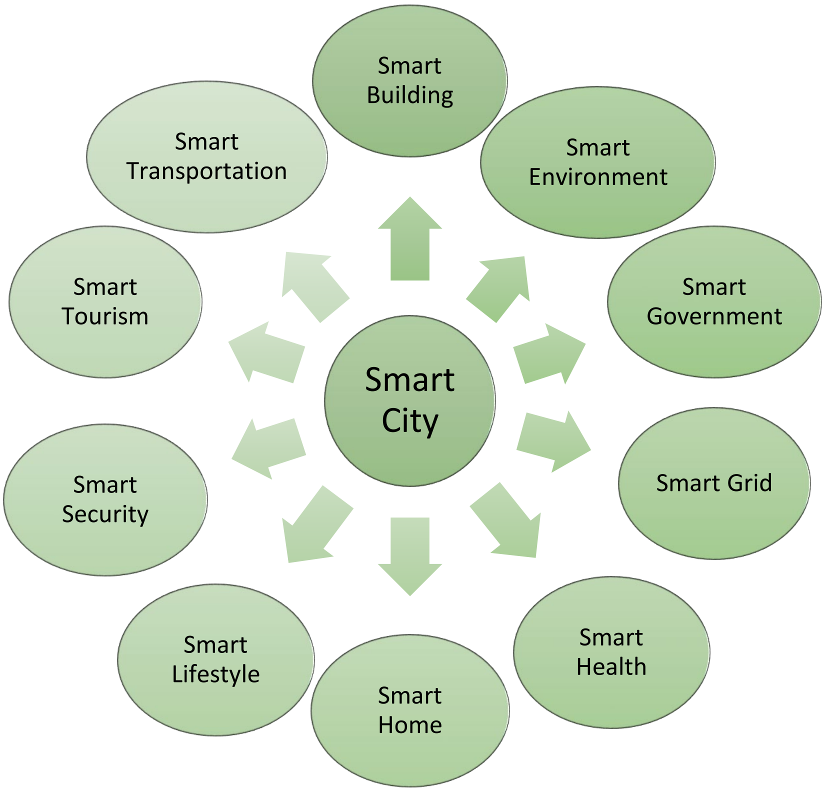


Figure 2.1: Fundamentals of a smart city

This study leans towards the smart environment fundamental. The smart environment comprises water, emission monitoring, green spaces, waste management, energy efficiency, city monitoring and quality of air (Ismagilova et al., 2019). This study is about sustainable SWMSs, which links to the water aspect of a smart environment.

The next sub-sections provide an overview of the various end devices that allow IoT devices to sense and respond in a variety of conditions.

2.3.1 Microcontroller and sensors

A sensor is an input device that provides an output with regard to a precise physical quantity (input). The phrase "input device" means that a sensor is part of the big system that provides input to a key control system such as a microcontroller or processor (Teja, 2021). A microcontroller is a programmable device (Rao, 2017). Sensors are devices that detect and react to specific inputs from the physical world. The input can be pressure, temperature or other types of environmental phenomena. The output is a signal converted to readable format or communicated electronically via a link for humans to read (TechTarget, n.d.). Additionally, data generated from sensors are transmitted over the internet to a cloud server, where it is analysed, processed, and then sent to a terminal for users to consult (Bernard, 2022).

In summary, a sensor is a detector that can sense changes in its environment and send information regarding that change. Different types of sensors exist, such as water flow, ultrasonic, turbidity, flow rate, pressure, temperature, residual chlorine, water PH, water conductivity, Chlorophyll, and soil moisture. These sensors can be installed on pumps or pipes to continuously monitor water flow, levels, temperature, or quality in real time.

2.3.2 Wireless communication technology

2.3.2.1 Short range wireless communication technologies

A wide variety of wireless communication technologies with a transmission range of 1 to 500 m fall under the category of short range. Bluetooth, ZigBee or Wi-Fi are used for short range communication. These wireless communication technologies are mainly used in the vicinity of buildings because of their limited range. For more details, consult the relevant literature (Ding et al., 2020; Lalle et al., 2021). ZigBee is used in industrial monitoring and smart home applications (Ford et al., 2017). Wi-Fi is frequently used in public hot spots to provide mobile devices with a broadband internet connection with high data rates (Ding et al., 2020). Wi-Fi is used to monitor water consumption in buildings (Horsburgh et al., 2017; Gautam et al., 2020).

2.3.2.2 Long range wireless communication technologies

For long-range communication, cellular communication networks are widely used. There are five generations of cellular communication, namely 1G, 2G (e.g., global system for mobile communications (GSM), general packet radio service (GPRS)), 3G (e.g., universal mobile telecommunications system (UMTS)), 4G (e.g., long term evolution (LTE)), and fifth generation (5G) (Abdelwahab et al., 2019; Arshad et al., 2019; Lalle et al., 2021). The 5G network is made to meet IoT requirements for the development of future smart cities by offering high data rates, many connected devices, and lower latency for real-time applications (Arshad et al., 2019). Cellular communication networks have a wide coverage area, making installation in remote areas simple (Quevedo et al., 2010; Salam et al., 2014; Abbas et al., 2017).

Furthermore, other long-range communication networks that promise to solve issues confronted with communication technologies in IoT applications are the Low Power Wide Area Network (LPWAN). In general, there are two types of LPWAN: unlicensed and licensed. The most currently used LPWAN technologies in smart water applications are reviewed below.

i) Unlicensed LPWAN

The unlicensed LPWAN technologies are those that use unlicensed spectrum re-sources in the industrial, scientific, and medical (ISM) bands. Unlicensed LPWAN providers do not have to pay for spectrum licensing because they use the unlicensed band, which lowers the cost of deployment. The two main competitors for unlicensed LPWAN are LoRa and Sigfox (Guibene et al., 2015; Ayoub et al., 2019).

- **LoRa:** LoRa means Long Range. It is a physical layer LPWAN solution created and patented by Semtech Corporation that modulates signals using a spread spectrum technique (Lalle et al., 2019). LoRa uses the chirp spread spectrum (CSS) modulation, which spreads a narrow-band signal over a larger channel bandwidth, allowing for high interference resilience while also lowering the signal-to-noise-and-interference ratio (SINR) needed at a receiver for proper data decoding (Adelantado et al., 2017). The CSS spreading factor can range from 7 to 12, allowing for variable data rates and trade-offs between throughput and link robustness, coverage range, or energy consumption. The data rate of LoRa can range from 50 bps to 300 kbps, depending on the spreading factor and channel bandwidth (Centenaro et al., 2019). The LoRa-based communication protocol known as LoRaWAN networks uses a star-of-stars topology, with gateway devices relaying messages between end devices and network servers. LoRaWAN has three classes of devices (Class A, B, and C) with varying capabilities. Class A LoRaWAN devices have the lowest power consumption and only require short downlink communication, and they use pure-ALOHA RA for the uplink. Class B devices are made for applications requiring more downlink transmission demands. Class C devices, on the other hand, continuously receive slots, meaning they constantly listen to the channel apart from when they need to transmit. Of the three LoRaWAN classes, all the devices need to be compatible with Class A (Ikpehai et al., 2019). Smart water technologies such as sensor nodes and water meters are often installed in harsh environments and rely solely on batteries for power. LoRaWAN provides low power consumption (battery life can last up to ten years), allowing these devices to operate for as long as possible. Furthermore, the LoRaWAN protocol offers long communication ranges (1-5 km in urban areas and up to 15 km in rural areas) and excellent penetration for underground communications. As a result, LoRaWAN offers enormous opportunities. LoRaWAN networks can be used for various smart water applications, including smart water quality monitoring, smart water metering, and leak detection (Lalle et al., 2021).
- **SigFox:** Another popular unlicensed LPWAN solution available is SigFox. SigFox suggests using ultra narrow-band (UNB) technology for transmission with a bandwidth of only 100 Hz for extremely short-payload transmission. Sigfox technology allows for lower power consumption devices and offers wider coverage than LoRA, at a lower cost data rate (Osman & Abbas, 2018). When Sigfox was first released, it could only support uplink communication; but, over time, it developed into a bidirectional technology that has a sizable link asymmetry (Mekki et al., 2018). However, only after an uplink transmission can the downlink transmission be initiated. Furthermore, the number of uplink messages per day is limited to 140, and each uplink message can

only have a maximum payload length of 12 bytes (Mekki et al., 2019). Owing to these rigid limitations and unopened business network model (Centenaro et al., 2016), academia and industry have turned their attention away from Sigfox to its competitor LoRaWAN, which is regarded as being more open and flexible.

ii) Licensed LPWAN

The licensed LPWAN describes LPWAN technologies that make use of licensed spectrum resources. The two most promising standards for licensed LPWAN are Long-Term Evolution Machine Type Communications (LTE-M) and Narrow-Band IoT (NB-IoT). Below is a brief review of the two licensed LPWAN technologies for long-range connectivity.

- **LTE-M:** LTE-M and existing cellular networks are completely compatible (Hoglund et al., 2018). It can be viewed as a simplified form of LTE designed for Internet of Things applications requiring low power consumption and low device cost (Ratasuk et al., 2017). LTE-M technology supports mobile MTC (Machine Type Communications) use cases and voice-over networks (Dawaliby et al., 2016). In the downlink of LTE-M, multi-tone Single Carrier Frequency Division Multiple Access (SC-FDMA) is used, and in the uplink, Orthogonal Frequency Division Multiple Access (OFDMA) is used. To reduce the cost of hardware and complexity, LTE-M has a 1.4 MHz bandwidth and usually supports half-duplex operations (full-duplex operations are also allowed) and one receive antenna chain. New features were proposed for the 3rd Generation Partnership Project (3GPP) Rel-14 and Rel-15 to improve LTE-M performance in terms of positioning, data rate, latency, and voice coverage.
- **Narrow-Band IoT (NB-IoT):** NB-IoT is also known as Long Term Evolution (LTE) Cat NB1. It is an LPWAN technology that coexists with cellular networks, specifically LTE and GSM. When compared to existing cellular networks, NB-IoT has a long communication range, long battery life (up to 10 years), high penetration, and low data rates. NB-IoT uses a frequency bandwidth of 200 kHz, which is equivalent to one physical resource block in LTE and GSM transmission (Boisguene et al., 2017). With a frequency bandwidth of 200 kHz, NB-IoT can function in three different modes: stand-alone operation (the NB-IoT can connect to one or more existing GSM carriers); guard-band operation (using unused resource blocks in the LTE spectrum guard-band); in-band operation (use of resource blocks in an LTE carrier). NB-IoT reuses several LTE functionalities and adapts them to meet the needs of IoT applications. For example, NB-IoT uses the LTE back-end system to broadcast valid messages to all end devices (EDs) in a cell. The data rates for Uplink and Downlink communications are 200 kbps and 20 kbps, respectively (Adhikary et al., 2016). Each message has a maximum payload of 1,600 bytes. Data communication uses quadrature phase shift keying

(QPSK) modulation. Precisely, downlink communication uses OFDMA, whereas uplink transmission uses SC-FDMA modulation. NB-IoT has several advantages for smart water applications, particularly its low power consumption, long communication range, and excellent penetration. NB-IoT has demonstrated benefits in some smart water applications. Huawei and Vodafone used NB-IoT to send data to an end device that was installed in a water meter (Mekki et al., 2018). Finally, NB-IoT is preferred for smart water applications because of its extremely low power consumption. Table 2.1 provides a summary of the discussed technical parameters of LPWAN.

Table 2.1: Summary of LPWAN technical parameters: LoRa, SigFox, LTE-M and NB-IoT (Source: Dawaliby et al., 2016; Chen et al., 2017; Ratasuk et al., 2017; Mekki et al., 2019; Ikpehai et al., 2019)

	LoRa	**SigFox**	**LTE-M**	**NB-IoT**
Topology	Star	Star	Star	Star
Frequency	Unlicensed ISM bands	Unlicensed ISM bands	Licensed LTM bands	Licensed LTM bands
Bandwidth	125 kHz and 250 kHz	100 Hz	1.4 MHz	200 kHz
Bidirectional	Half-duplex	Limited/ Half-duplex	Full/ Half-duplex	Half-duplex
Maximum data rate	50 kbps	100 bps	1 Mbps	250 kbps
Maximum payload length	243 bytes	12 bytes	1000 bits	1000 bits
Link budget	164 dB	156 dB	153 dB	164 dB
Coverage	Urban (5 km), rural (20 km)	Urban (10 km), rural (50 km)	Few kilometres	Urban (1 km), rural (10 km)
Localisation	Yes	Yes	Yes	Yes
Mobility	Yes	No	Yes	Yes
Inference immunity	High	Very high	Low	Low
Battery life	10 years	10 years	10 years	10 years

2.3.3 Real-time data analysis method

This section enables water utilities to reach conclusions through using data provided by sensing devices. It is the foundation of smart water applications because of its ability to make decisions based on collected data.

Researchers are paying more attention to machine learning (ML), which can be used as a data analysis strategy in smart water applications. ML is a field of artificial intelligence (AI) that allows systems to learn automatically from a set of data without explicit programming. ML methods are classified under supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, the learning agent aims to learn a general rule that maps inputs to outputs, using example inputs and desired outputs from the labelled data set. Examples of supervised learning algorithms are Support Vector Machines and K-Nearest Neighbours. Unsupervised learning aims to identify a function that will disclose a hidden structure from unlabelled data. The K-Means Clustering algorithm is commonly used in unsupervised algorithms. Reinforcement learning aims to enhance a long-term goal by interacting with the environment through a trial-and-error process (Sun et al., 2019).

ML can play an important role in smart water applications. Currently, some ML algorithms have been used in smart water management. For more details, consult the relevant literature (Mohammadpour et al., 2015; Rashid et al., 2015; Porwal et al., 2017; Brentan et al., 2017; Saravanan et al., 2017; Chuang et al., 2019).

2.3.4 Software for data management

After data have been transmitted, it needs to be stored, analysed and presented coherently. This data could be stored in the cloud, for example, MySQL database, while data visualisation software such as JAVA platform (Fikejz & Rolecek, 2018), Grafana (Folgado et al., 2023), and Python could be used for data presentation. The next section presents the review protocol for the systematic review.

2.4 Systematic literature review protocol

A systematic literature review of smart water meter systems was performed, adopting the PRISMA statement approach (Moher et al., 2010). The purpose of developing a review protocol is because it decreases the likelihood and risk of research bias during the systematic review. The development of a review protocol is a vital step; it entails defining the fundamental research procedures and practices that will be applied during the systematic review. The review protocol includes search strategy, study selection criteria, quality assessment criteria, data extraction, and data synthesis (Keele, 2007).

2.4.1 Search strategy

The search strategy involves developing search terms, choosing which digital libraries need to be searched, and refining search terms. The systematic literature review was done by basically breaking down the research questions (as shown in section 1.6), using keywords as well as identifying alternative terms. The following search terms were used:

((“Smart water meter” OR “IoT Smart water metering” OR “Smart Water Metering” OR “Digital water”) AND (System OR Technology OR Framework OR Solution) AND (Adoption OR Implementation OR Uptake) AND (Factors OR Issues OR Challenges)).

The databases used are as follows:

- Google Scholar
- Scopus
- ACM Digital Library
- EBSCOhost

Further, a more general search phrase: 'list of countries that have adopted the smart water meter system', was used on Google (with 3,290,000,000 outcomes). After carefully evaluating the outcomes, only one website was relevant. The other websites focused mainly on electricity-based smart meters, and the others displayed websites with the keyword "smart" only, which is irrelevant to this study.

2.4.2 Study selection criteria

Inclusion criteria:

- Empirical studies on smart water meter system and adoption factors
- Empirical studies using IoT techniques for water management
- Empirical studies using ICT and water

Exclusion criteria:

- Studies completed before 2005, or not in English
- Review papers
- Studies that do not align with the inclusion criteria

2.4.3 Quality assessment criteria

Table 2.2 displays eight quality assessment (QA) questions adopted from Malhotra (2015) for the review process. Scores were assigned as follows: 1 for satisfactory, 0.5 if moderately satisfactory, and 0 (no) if study is unsatisfactory. Studies with a quality assessment score of less than 4.0 out of 8.0 were rejected.

Table 2.2: Eight quality assessment questions used for systematic review

Quality Assessment Questions
Are the aims of the research clearly stated?
Are the independent variables clearly defined?
Is the data-collection procedure clearly defined?
Are the techniques clearly defined?
Are the results and findings clearly stated?
Are the limitations of the study specified?
Is the research methodology repeatable?

Quality Assessment Questions
Does the study contribute/add to the literature?

2.4.4 Data extraction

One of the aims of data extraction is to find empirical studies that address the research question of the study. Table 2.3 presents the data extraction form used. Data extraction form entries were filled out by extracting data from studies filtered based on the QA criteria.

Table 2.3: Sample of the data extraction form

Variables
Paper title:
Authors:
Publication type:
Year:
Field of study:
Total quality assessment score (out of 8.0):
SWMS adoption
Factors influencing the adoption of SWMS:
Perception towards using SWMS:
Contribution of government towards SWMS adoption:
Extract information from empirical study that aids in addressing the research questions/subject matter:

2.4.5 Data synthesis

The main goal of data synthesis is to compile and combine data from the chosen primary studies to create a response and answer the research questions (Wen et al., 2012). This study provides key details that were extracted from the selected studies. The report was produced by summarising literature that was chosen based on the QA criteria. The sections that follow hereafter present facts from selected studies in text, diagrams and tables.

2.4.6 Result

Table 2.4 displays the number of studies for each phase of the review process.

Table 2.4: Results from the review process

Phase	Number of studies	Remarks
Initial search using the search terms	3,842	Using metadata
Filtering by title, abstract & keyword	612	
Full text gathered	295	
Included in the systematic literature review	65	High QA score

2.5 Smart water meter and definitions

A consistent and widely accepted set of definitions for smart water meter systems (SWMSs) is crucial. So, the next section covers the definition and research on SWMSs. Implementing smart technologies for water management can help towards realising relevant sustainable development goals.

2.5.1 Definition of smart water meter system

The advancements in metering and ICT have made it possible for household water usage data to be recorded by smart water meters. A SWMS encompasses two precise elements: meters that employ modern technology to gather data on water use; and communication systems that can gather and transmit information on water usage in real time. The idea of smart water metering is to automatically and electronically capture, gather and communicate real-time water usage readings. The data are in the form of electronic signals that can be captured, logged and analysed (Stewart et al., 2010). More precisely, a smart water meter is an internet capable device that monitors water usage in a building or residence (Anandhavalli et al., 2018). A smart water meter can be installed in any application, big or small, residential, domestic, commercial, industrial or institutional (Hauber-Davidson & Idris, 2006). Smart meters can communicate collected information to a wide audience, such as consumers, utility managers and facility authorities (Stewart et al., 2010). Figure 2.2 is an overview of a smart water meter system (SWMS).

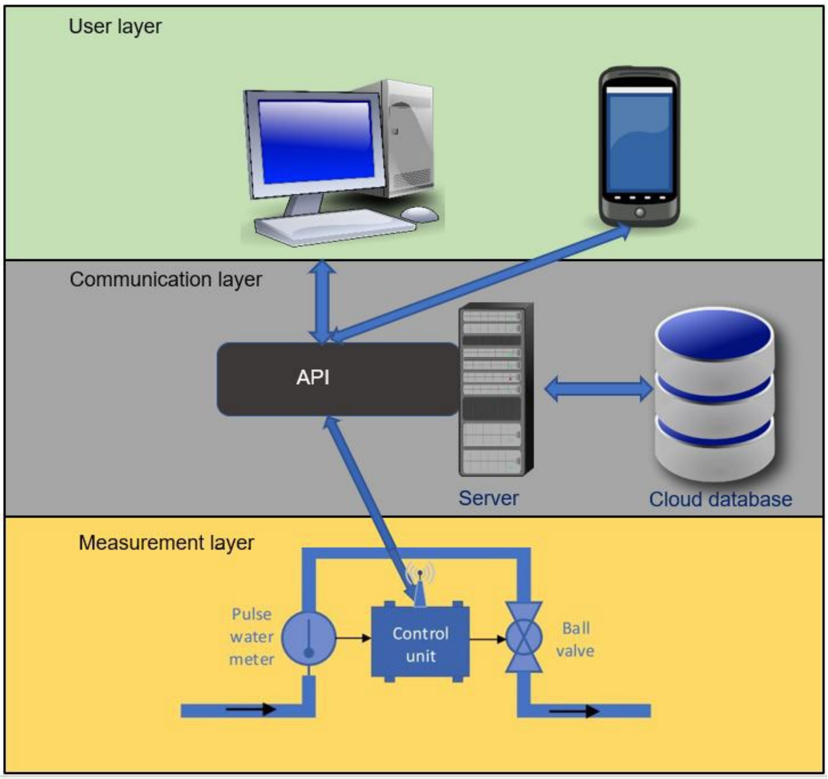


Figure 2.2: Overview of a smart water meter system
(Source: Fikejz & Rolecek, 2018)

The **measurement layer** consists of the pulse water meter, control unit, and ball valve.

The **pulse water meter** provides information on the volume and consistency of water flow. Any pulse water meter may be used (irrespective of the number of pulses per litre).

The **central control unit (CPU)** generally receives information about the water flow rate from the water meter, uses a wireless network for communication within the application interface, evaluates the water flow periodically using established rules in line with application logic, and controls a two-way valve (Fikejz & Rolecek, 2018).

Generally, any microcontroller (environment) can be used, such as Raspberry Pi Zero, which is a single core mini-computer extended by a real-time unit using the Linux Raspbian environment.

The **ball valve** controls the opening or closing of the water flow; which responds to a request from the control unit.

The **backup battery** is a backup power supply in the event of a power outage. The battery needs to be equipped with a suitable capacitor for increased stability when the main power supply is lost.

The **communication layer** provides the application interface (API) with access to the cloud database. The API is implemented as a web service, and it allows communication between the smart water meter and the customer. For the API design, the Representational State Transfer (REST) architecture can be used. There are three parts to the communication interface: communication with the sensor; ball valve; and mobile API.

Two applications exist in the **user layer**. Firstly, the web application enables remote configuration, management of the water meter, and user administration. The second application is designed for mobile devices with a more intuitive and user-friendly experience (Fikejz & Rolecek, 2018).

In the field of smart water management, different terms such as “smart water meter” (Ray & Goswami, 2020), “smart water system”, “smart water supply system”, “smart water network”, “smart water grid” or “intelligent water system”, “internet of water”, “smart water management” (Li et al., 2020), “advanced water meters” and “intelligent water network” and more have widely been used.

Table 2.5 shows definitions of smart water management to help create a better understanding of the concept.

Table 2.5: Various definitions for smart water management

Smart water definitions	Reference list
Smart water system includes smart meters, smart valves, data communication, data fusion, data management, and analysis tools.	(Günther et al., 2015)
Smart water network includes smart meters, smart pumps, and smart valves.	(Mutchek & Williams, 2014)
Smart water grid is founded on the Internet of Things and the structure of a smart water system.	(Ye et al., 2016)
The smart water system demonstrates the different ways in which technology, software and middleware increase the benefit of smart metering data for stakeholders.	(Yu & Hazen, 2010)
Smart water management differs from traditional water management technologies because it integrates ICT and water management technologies.	(Allen et al., 2012)
An innovative smart water supply system that integrates ICT into a water supply network.	(Li et al., 2019)
Smart water grid system incorporates information and communications technologies into a water management distribution system.	(McKenna & Keane, 2016)
Smart water system utilises data driven components to assist in the operation and management of a physical pipe network.	(Kartakis et al., 2015)

The study will henceforth use “smart water meter” as the keyword unless otherwise stated. This covers all efforts of the use of ICT as indicated in section 2.5.1 to positively improve the efficiency of water management for a sustainable future.

2.5.2 Research on IoT-based smart water applications

The study by Salam et al. (2014) proposes a model to identify pipeline leakage via a computerised online system utilising pressure analysis as an element of leakage inside a pipe. Any pressure on an individual node will be the input data. The data were received via EPANET 2.0 software. “A detection system of magnitude and location of leakage with pressure analysis obtained from the EPANET using the method of Radial Basis Function Neural Network produces the accuracy of 98% of the entire existing pipeline on the water distribution network” (Salam et al., 2014:1821).

Ntuli and Abu-Mahfouz (2016) propose a security architecture for water management to ensure secure booting, firmware updates, and communications. Nikhil et al. (2018) propose an IoT system to assist with securing natural environmental water resources. The system reduces the time and costs in identifying the water quality of a reservoir or tank, which forms part of environmental management. Yang et al. (2017) developed a domestic water consumption monitoring system. The system monitors individuals water consumption behaviour. Thus, the time and amount of water consumed by each appliance in the household is recorded remotely and the data are saved in a database, which is a local database system that provides immediate pragmatic advice about saving water and classifies the water consumption behaviour of the individual. Gosavi et al. (2017) published a paper on using Raspberry Pi and Arduino to monitor and forecast domestic water consumption over the internet. The water flow rate is measured by a Hall Effect sensor-based flow meter. The Arduino, a microcontroller, is connected to the flow meter; it collects and sends data to the Raspberry Pi microcomputer. The Raspberry Pi then uploads the data to the cloud infrastructure where a database is created. The web-based technology also shows daily water consumption to users and water distributors. The leakage management, demand management and asset management aspects of the water management system are also covered in this study.

Suresh et al. (2017) propose a system that makes use of low-cost IoT devices and a custom-built smartphone application for water metering. The method allows both domestic and industrial water consumers to perform meter readings and update the database for billing and payment using normal smartphones. The system addresses tampering with pre-paid water meters, which often goes unnoticed because of their standalone nature as well as unauthorised or tampered with top-up updates on prepaid meter smartcards using malicious software. It also addresses connectivity concerns that are common in Data Concentrator Unit (DCU) architectures, when DCUs are installed near meter banks in areas or basements where phone signals are weak or unreliable. A study by Srivastava (2018) proposes an independent system to monitor the water level as well as stop water flow in a tank when it is full. The system (smart home server) receives a signal from the water level detecting sensor placed in the tank. It then switches off the water flow and notifies the user via their mobile phone. Anandhavalli et al. (2018) propose a solution for water consumption using a water flow rate sensor and an interface with a Node MCU microcontroller embedded with Arduino code. The Arduino software is utilised for Arduino coding to find the water flow rate, show the output on a serial monitor, and transfer sensed data to the cloud where consumers can monitor it.

Gupta et al. (2018) propose a solution for water management in households that monitors the water in accordance with basic quality standards. The solution will assist water supervisors in taking the necessary actions if the water level drops below a certain threshold. The system primarily uses a turbidity sensor and an ultrasonic water level sensor. Turbidity sensors monitor basic water quality features, which is useful when selecting water provider services because historical data are presented in the form of a quantity vs. quality graph. The ultrasonic water level sensor constantly monitors the water level and transmits the data to residents over the cloud. Soh et al. (2018) designed a water consumption monitoring and alert system based on IoT Ubidots Cloud. It is designed to monitor water usage in households daily, weekly and yearly in real time using mobile devices. It displays data using the Ubidots Dashboard, and when the data exceeds a limit, an alert is sent to the home user. De Paula et al. (2019) propose a solution that can measure water consumption, detect leakages and water interruptions, and inform users of issues on water systems. The proposed solution can also turn off the water distribution to prevent leakage. Data collected by sensors are made available to devices and users via IoT middleware, which makes use of the Publish/Subscribe architecture and the Message Queue Telemetry Transport (MQTT) protocol. The middleware stores, displays and forwards data to other IoT-based devices that can take automated actions based on collected data from a sensor.

Hasibuan and Fahrianto (2019) propose an innovative low-cost solution that can predict water consumption for household activities. The SWMS uses the IoT concept, where the water flow sensor connects to a NodeMCU 8266 microcontroller. Each water-related activity is transferred to an element termed *dictionary activity* (cloud storage). The dictionary activity analyses the amount of data collected from the smart water system and places each water use activity based on category from highest to lowest amount of water used. One can view the water used on an online portal. The proposed system can inform users of their daily water (litre) consumption for each activity within the household in real time. For example, washing machine, shower, washstand and more. The system is designed and expected to predict water consumption activities correctly. The importance of using the system is to raise an individual’s awareness regarding saving water for the sustainability of water resources.

Patel and Gaikwad (2019) designed a low-cost remote monitoring system based on the IoT. The system distributes equal water quantities based on geographical survey and population density and water quality, and the water flow rate is controlled to help solve water-related problems. Arduino collects data from sensors and sends it to the Raspberry Pi, which then controls the flow of water by changing the position of a stepper motor installed in the shaft of a manually operated control valve. A web-based automatic meter reading system is developed for end users. End users only pay for the water they use, which reduces complaints. Rapelli et al. (2019) focus on water use in large complexes. They proposed a fully automated system capable of performing three distinct tasks, namely, distribution, monitoring and billing. Water wastage is completely controlled by providing a billing system for respective water usage – a cost-effective system that allows the user to save both water and money. An alert on water consumption is occasionally sent. The system helps with meeting the need of protecting future generations from water scarcity.

Jisha et al. (2019) propose a system for domestic sectors and large agricultural fields – an IoT-based technical solution for water management that incorporates various sensors and cloud storage, among others. In addition to decision-making techniques such as automatic electric power cuts, the system generates alert messages for relevant users on their smartphones when there is excessive water usage. As a result, it helps to remotely monitor the water level in both the water tank and the soil. This is an intelligent approach because of the system’s timely alerting mechanism and reliable diagnosis capabilities. The proposed system aims to reduce the user’s burden in monitoring the water level, which makes it a user-friendly system. Herath (2019) focussed on factors that contribute to a cumulatively significant impact on household water use. Water wastage is primarily caused by careless usage, overflow of overhead tanks, and leakages in households. Their “Smart Water Buddy” system uses IoT devices to monitor water use, and it uses ML to detect water leakages and abnormal usage, which aids in optimising the use.

Vithanage et al. (2019) believe that sufficient and regulated water intake is needed for people to stay healthy. However, it is often difficult for many people because of their busy life schedule, and occasionally because of limited access to clean water. An IoT-based smart water bottle termed “SmartOne water bottle” is proposed to help users manage their daily water needs and to ensure they drink good quality water. The water bottle is implemented as a combination of a mobile application and hardware, where the mobile application serves as the interface between the user and the bottle.

Harika et al. (2020) describe a system that uses real-time water consumption data from water flow meters at household level to make useful inferences. The IoT is combined with the ThingSpeak cloud computing platform and with Android Studio to provide an efficient dashboard for consumers. The proposed model is to instil a sense of responsibility in citizens by keeping track of water usage regularly through visually appealing charts laying out monthly water utility costs and providing tips in the form of a compact Android application on their phones. It helps users to know where water is being wasted and consumed, and this aids with users taking proactive decision and saving water resources.

Ray and Goswami (2020) propose an IoT-based smart water meter equipped with machine learning algorithms using a cloud computing platform. The system can be used to distinguish between normal and excessive water usage in households, industry and other sectors that use large amounts of water. With ease of data monitoring and visualisation, the SWMS can be used to detect water leakages and excessive water consumption. Their proposed serverless architecture can easily be adopted on a large scale. Ray and Ray (2020) propose a system that generates authentic data for water use patterns through ML to detect excess or normal water flow via a pipe. The architecture can be scaled up for more functionalities. Collected data are always encrypted end-to-end to ensure the confidentiality and security of water usage patterns. The system is user friendly, with the introduction of a water tariff, making people responsible for their water usage. Sarangi (2020) proposes a system that can help detect water theft and leakages problems faced by the government. The system monitors water leaks in real time and allows the relevant authorities to take the necessary actions to reduce water loss. The proposed approach offers the concept and definition of wireless networking technologies, and the flow sensors help stop water leakage and theft.

Ranjan et al. (2020) present an IoT-based model for smart rainwater harvesting. The model comprises a structure that divides two tanks according to a 60–40 percent ratio. To determine whether it is raining or not, a sensor that detects rainfall is fixed on top of the structure. A pH sensor determines the pH value of the rainwater, and if the pH of the water is greater than 5, the servo motor attached to a hinge rotates clockwise, filling the tank on the right side. If the pH of the water drops below 5, the hinge rotates anticlockwise, filling the tank on the left side. The separation is carried out to separate potable water (pH 5 or higher) from acidic water (pH less than 5). This is all made possible with the NodeMCU Wi-Fi module.

Alves Coelho et al. (2020) propose a system based on a wireless sensor network that detects water leaks with a 75% accuracy, using an autonomous learning algorithm. The ESP32 microcontroller is used, with 32 general purpose input/output ports, 12 analogue ports, and low power capabilities. LoRa is implemented using a RMF95W module, and an aggregation node using Narrowband-Internet of Things (NB-IoT) is used. The MQTT protocol has been selected for its architecture and lower power consumption. Fuentes and Mauricio (2020) present a smart water measurement consumption system with high levels of decoupling and integration of different technologies that enable real-time visualisation of water consumption. The system collects data via a smart meter; the data are pre-processed by a local server (gateway), periodically sent to the cloud to be analysed by a leak detection algorithm and can be viewed on a web interface. The authors note that the system has 100% accuracy, recall and precision to detect leaks and a margin of 4.63% error.

Migabo et al. (2021) propose an IoT-based smart water meter that can operate for the required 10 years using the Long Range Wide Area Network (LoRaWAN). The system makes use of a silicon laboratory microcontroller of which the firmware manages the energy modes and state transitions between them depending on the task at hand. Also included is a LoRa Technology SX1272 Low Power Radio Frequency (RF) Transceiver 860-1000 MHz. The design employs a radio frequency switch to choose between radio frequency communications between the consumer User Interface (UI) and LoRa IoT communications over long distances with a LoRa gateway in its dual radio frequency activities. The authors note that using the device in African municipalities is feasible given that it can last longer than 10 years.

Wong et al. (2021) developed, calibrated and deployed a water quality monitoring system that measures water level and turbidity at two-hour intervals. The low-cost 3D-printed IoT-based near-real-time water quality monitoring system was powered solely by a photovoltaic system for two months in a palm oil plantation on Carey Island, Malaysia. The water quality monitoring system comprises four components: energy, monitoring, time, and communication. To determine the ideal monitoring frequency, the electrical consumption values of the system during operating, data transmission and standby modes were calculated. The proposed system shows successful integration of IoT with 3D printing, low-cost sensors and microcomputers. Further, the study shows the huge possibility of using solar energy as the main source of energy for running low-power water quality monitoring systems in tropical nations.

Alejandrino et al. (2022) propose a SWMS with an IoT platform that provides real-time water consumption and billing reports. During meter inactivity, the system can perform automated data collection and upload phases. Google Application Scripting (GAS) was used to connect the physical prototype, Google Sheets, and the mobile application. A calibrated equation for determining water flow rate and water consumption is generated with the MATLAB Curve Fitting Tool. Ali et al. (2022) developed a water distribution network abstraction prototype. The network has sensors installed to measure the desired physical quantities, such as water flow rates, turbidity and pH level. A sensor network transmits readings to the Firebase platform. IoT-testbed architecture is used to fully connect all IoT modules. Their proposed system enables monitoring of water quality, measurement of consumption and leak detection in smart homes, thereby providing a monitoring platform and an awareness alert for both users and administrators.

Andrić et al. (2022) developed a LoRaWAN-based SWMS for their university buildings. The system identifies peak water consumption hours and water leakage. Frequency and time domain analyses reveal usage patterns and leakage rates for each location. The system provides users with real-time data and cost reduction while allowing for more efficient expenditure.

2.5.3 IoT-based smart water metering technologies

The research review shows that an IoT-based SWMS can be used to manage water in both the private and the public sector. Water leakages or excessive water use can be avoided by using this type of system. Table 2.6 displays various technologies used by researchers to develop smart water applications for managing water resources. The table presents the type of microcontroller, embedded programming language, sensors, communication module, protocol, and the solutions realised.

Table 2.6: Features of various IoT-based smart water applications

References	Microcontroller	Embedded Programming Language	Sensors	Communication Module	Protocol	Solution
Salam et al. (2014)	Arduino UNO circuit board	PHP, HTML, CSS, Java Script, JQuery	MPX5700 pressure	GSM/GPRS	WAP	Accurately detects the degree and location of water leakage.
Yang et al. (2017)	Wi-Fi gateway	Visual Studio, Microsoft SQL server	Flow rate, Temperature	Wi-Fi router		The amount of water consumed by each household appliance is wirelessly recorded along with the exact consumption time and stored in a central database. Real-time water consumption awareness, prompt practical tips for water saving activities, and individual classification of water consumption behaviour may have an impact on people's water consumption habits.
Gosavi et al. (2017)	Arduino Uno, Raspberry Pi	Python	Hall effect flow meter	Wi-Fi build in	HTTP/ WAP	Real-time water consumption data to assist customers save water by real-time asset monitoring, real-time water quality monitoring, and real-time water pressure monitoring.
Suresh et al. (2017)	Electronic Interface Module (EIM)	Android SDK and Java	Build-in tamper flags, Tamper signal from Hall effect	Wi-Fi or Bluetooth	WAP	The system reduces the costs for utilities by handling meter reading and billing for water distribution urban areas.
Anandhavalli et al. (2018)	NodeMCU	Arduino code (Arduino IDE)	Water flow, Flow rate, Hall effect	Wi-Fi build-in Microcontroller	HTTP	The proposed system calculates the water flow rate and quantity consumed by householders and sends it to the cloud to monitor water consumption.
Srivastava (2018)	NodeMCU ESP8266, (Raspberry Pi as home sever)		Water level	Wi-Fi build-in	MQTT	Monitors water levels and stops water flow in tank when full.

References	Microcontroller	Embedded Programming Language	Sensors	Communication Module	Protocol	Solution
Gupta et al. (2018)	Raspberry Pi Zero W model	C Language	Ultrasonic water level, Turbidity	Wi-Fi build-in	MQTT	Allows users to remotely monitor and manage water management systems using their smartphone.
Soh et al. (2018)	Intel Edison	Arduino IDE	Water flow	Ubidots	MQTT	Water monitoring and alert system.
De Paula et al. (2019)	MSP 430	Arduino C	Water flow, Pressure, Solenoid valve	CC2650	MQTT	Detects water leakages, prevents natural water waste, and manages water wastage.
Hasibuan and Fahrianto (2019)	NodeMCU	LUA	Flow rate	ESP8266-12E	HTTP	Increases an individual's awareness regarding saving water for sustainable water resources.
Patel and Gaikwad (2019)	Raspberry Pi Arduino Uno	PYTHON Arduino C	Ultrasonic, Turbidity, Water flow	Raspberry Pi Wi-Fi build-in	HTTP	System designed to distribute same amount of water to each consumer, maintain water level in tank, reduce water wastage, and maintain water quality.
Rapelli et al. (2019)	ArduinoUNO	Arduino C	Ultrasonic, Flow meter	ESP8266	MQTT	Water wastage is completely controlled, resulting in a cost-effective system for saving both water and money.
Jisha et al. (2019)	Arduino UNO	Arduino IDE	Ultrasonic, Soil moisture	Arduino Ethernet Shield	HTTP	System remotely monitors water level in both water tank and soil. Then, sends alert messages to relevant users' smartphones in the event of excessive water consumption.
Herath (2019)	NodeMCU	C language	YF-S201, Solenoid valve	ESP8266	MQTT	A detection model for unusual household water use.
Vithanage et al. (2019)	NodeMCU	Arduino IDE	pH, Turbidity	ESP8266	MQTT	The SmartOne water bottle is designed to ensure users drink good quality water and maintain regularly water intake for proper functioning of the human organs.
Harika et al. (2020)	Raspberry Pi Zero	MATLAB	YF-S201	Build-in microcontroller	HTTP	The system uses real-time water usage data from household water flow meters to make appropriate inferences.

References	Microcontroller	Embedded Programming Language	Sensors	Communication Module	Protocol	Solution
Ray and Goswami (2020)	NodeMCU ESP8266	Lua scripting	YF-S201	Wi-Fi build-in MC	MQTT	Uses machine learning to detect excessive water use.
Ray and Ray (2020)	Node MCU ESP8266	Arduino code (Arduino IDE)	Water flow YF-S201	Wi-Fi build-in	HTTP	Generating water use pattern when implemented, monitoring of urban water resource use pattern, alert system, secure and reliable system, user friendly, proposal of water tariff so people are responsible for their water use, and an architecture that can give room for additional functionalities and computations.
Sarangi (2020)	Arduino Nano, Arduino UNO	Arduino C	YF-S201	Zigbee, LoRa	HTTP	System detects water theft and leakages wherever pipeline connections are used.
Ranjan et al. (2020)	NodeMCU V3 ESP8266	Lua scripting	pH, Rainfall, Ultrasonic	Wi-Fi build-in	MQTP	Collects and retains the quality of precious rainwater in areas with small houses.
Alves Coelho et al. (2020)	ESP32	Machine Learning, Python script, Paho Java MQTT library	YF-B2 Water flow (water rotor & Hall effect sensor)	Wi-Fi and Bluetooth Low-Energy (BLE), LoRa	MQTT (NB-IoT)	The system uses machine learning to monitor water distribution systems, such as irrigation systems, and detects leaks and their locations in pipes in real time.
Fuentes and Mauricio (2020)	NodeMCU ESP8266, Raspberry Pi	Python	Water flow, Motion sensor	Wi-Fi build-in	MQTT	The system covers five aspects of water consumption: measurement, local record process, security of device, storage and visualisation, and leak detection.
Migabo et al. (2021)	Silab EFM32		Tunnel Magneto-Resistance (TMR) sensor	RF radio for CIU communications, LoRaWAN modem for IoT packet transmissions	TCP/IP	Ten-year lifespan battery-powered energy-efficient smart water meter for an African municipal setting.
Wong et al. (2021)	Raspberry Pi, Arduino		Turbidity, Ultrasonic water level	USB Wi-Fi dongle	HTTP	Water quality monitoring system for a palm oil plantation using solar energy as the main source of energy.

References	Microcontroller	Embedded Programming Language	Sensors	Communication Module	Protocol	Solution
Alejandrino et al. (2022)	NodeMCU ESP8266	Arduino code (Arduino IDE), Kodular IDE	Water flow (Hall effect flow meter)	Wi-Fi build-in	HTTPS	Smart water meter that uses mobile application and SMS service to send updates on water flow rate, water consumption, and monthly bill.
Andrić et al. (2022)	Arduino-based boards	JavaScript and TypeScript	Water flow, Ultrasonic	LoRa, Sigfox, NB-IoT, LoRaWAN	MQTT	The system detects water consumption patterns, quantify water loss, and its location.
Ali et al. (2022)	Arduino NodeMCU	C	Flow sensors and water quality sensors (Water flowrate, Water turbidity, Water pH level)	Wi-Fi build-in		Leak detection in smart homes, measurement of consumption, and water quality monitoring.

Table 2.6 shows that the researchers used different types of microcontrollers such as Arduino Uno, Raspberry Pi Zero W model, Electronic Interface Module, NodeMCU ESP8266, Intel Edison, MSP 430, and Silab EFM32. Various embedded programming languages were used, including Python, C Language, LUA, MATLAB, Arduino C, PHP, JavaScript and TypeScript. Furthermore, there are several types of sensors used, such as MPX5700 pressure, temperature, flow rate, water flow, solenoid valve, water level, ultrasonic, turbidity, soil moisture, YF-S201, pH, rainfall, Tunnel Magneto-Resistance, and water quality sensors. The protocols used include WAP, MQTT, HTTP, and MQTT (NB-IoT). Finally, the researchers used the following communication modules: GSM/GPRS, Wi-Fi router, Wi-Fi build-in, Bluetooth, ESP8266, Raspberry Pi, Arduino Ethernet Shield, Zigbee, LoRa, Sigfox, NB-IoT, and LoRaWAN. There is no consensus on the parameters that must be applied to evaluate various water properties.

Future adopters can have an idea of the smart water applications and technologies for managing water resources. Furthermore, system developers can leverage the different IoT components, comparing or integrating systems based on their needs or what works for them in their city.

2.6 The adoption of smart water meter systems

Smart water meters are increasingly being implemented around the world to help save water and combat the effects of climate change. Below is summary of some cities/countries that have adopted the smart water meter system.

2.6.1 Spain

The summary below is based on a report by Johnston (2021).

Aigües de Barcelona is the water service provider for the city of Barcelona in Spain, serving 2.8 million people across 23 municipalities. The company manages a network with over 4,600 kilometres and 1.5 million connections, supplying 524 million litres of water daily. In 2016, the Aigües de Barcelona board accepted a 10-year plan for the adoption of smart water meters after piloting other technologies. Barcelona was experiencing frequent droughts and increasingly unpredictable climate events. The city was looking to cut costs after making significant investments in water production, network automation and control. So, the project was implemented in geographical zones rather than all at once. Each municipality had a unique engagement strategy with all their customers educating them on the value of the smart water meter, and their customers fully appreciate the benefits. By adopting the smart water meter, Aigües de Barcelona achieved operational cost efficiencies that eliminated the cost of 9 million annual manual reading operations as well as the risk of meter fraud. Customers behaviours improved towards supporting water saving because of having access to appropriate water information. It further reduced overconsumption alerts from 9% to 3%. Additionally, network managers now have access to real-time data, enhancing overall network management and billing transparency by daily consumption (Johnston, 2021).

2.6.2 Singapore

The summary below is based on a report by Mutchek and Williams (2014) and Singapore's National Water Agency (PUB, 2022).

One of the reasons for Singapore's aggressive pursuit of the smart water project is insecure water resources. Singapore does not have enough land for water storage, so they are heavily dependent on rainfall to meet its water needs. Extensive research and development funding in Singapore has led to some smart water projects such as the development of a laser-based contaminant sensor and the smart water grid in the Singapore business district. The smart water grid in the business district monitors flow, pressure and disinfectant levels in the distribution system. The data are sent to a computer centre via Singapore's cell network. Modelling software is used on the data at the computer centre to identify problems in the water distribution system. Problems can be identified within 40 meters, and an alarm is sent to the utility if problems are found (Mutchek & Williams, 2014). Furthermore, Singapore conducted a smart water meter pilot trial from 2016 to 2020. In January 2022, they commenced with the installation of smart water meters in residences and businesses across Singapore. For the first phase of its Smart Water Meter Programme, 300,000 smart water meters are installed in residential and business properties. Singapore's National Water Agency (PUB) assured its users that only water consumption data are recorded by smart water meters, which are transmitted directly and securely to PUB (PUB, 2022).

2.6.3 USA

The summary below is based on a report by Jacobs (2022) and Mutchek and Williams (2014).

In 2008, the City of Cleveland's Division of Water (CWD) responded to the challenges of a declining customer base and rising fixed costs by focusing on ways to support sustainability. To meet this challenge, between 2012 and 2016, the CWD installed a cutting-edge SWMS for all water meters belonging to customers across the service area. This increased the accuracy of water bills and decreased the percentage of estimated bills from 18% to less than 1%. Customers can now sign up for proactive leak alerts and track their actual water usage through an interactive customer portal, which will help them manage their water bills and consumption levels. Strong quality controls such as Key Performance Indicator (KPI) reporting, regular communication with project stakeholders, work order management optimisation, and prior lessons learned were used to complete the project. Several important vendor roles were replaced and pro-active contractor management was implemented over the multi-year project period to ensure that the best resources were available to support installations (Jacobs, 2022).

Furthermore, the East Bay Municipal Utility District (EBMUD) provides drinking water and wastewater services to the eastern part of the San Francisco Bay Area. The EBMUD offers innovative programmes such as smart irrigation controller rebates for customers, advanced leak detection device testing and deployment, and smart metering web-based systems for users. Consumers can find leaks on their property using the web-based system (Mutchek & Williams, 2014).

2.6.4 United Kingdom (UK)

The summary below is based on a report by Thames Water (2021).

Thames Water celebrated a key milestone for having installed half a million smart water meters in its region. Thames Water is a large utility company in charge of public water supply and waste water treatment in the UK. The company's smart water meter rollout is the largest in the UK, covering London and the village of Haslemere near Guildford. The data from the SWMS gives customers more control over their water usage and bills.

The SWMS provides detailed insight for Thames Water in terms of where their water supply goes, when customers use water, and how much water customers use. The data also assist Thames Water with reducing leakage and meeting the unprecedented demand for water caused by the coronavirus pandemic. To date, smart water meters have assisted in the detection of over 28,000 leaks on customers' private supply pipes. The leaks are fixed by the property owners or Thames Water, saving a total of 43 million litres of water per day. Customer side leaks account for roughly a quarter of total leakage at Thames Water. Smart meter data was cited as playing a significant role in meeting the company's leakage reduction target in 2019 and 2020. Furthermore, data from smart water meters are used to support Thames' smarter home award-winning programme by highlighting higher-use households that are then prioritised for a visit. During visits, they are given free advice on water conservation and are offered the option of having devices installed in their homes to help them use less water, such as water-saving taps and shower heads. Water savings by smart water metered customers increased by 17% more than those who do not have a meter. By 2025, Thames Water intends to install smart water meters throughout the Thames Valley, and by 2035, hopes to have installed meters in every suitable home (Thames Water, 2021).

Williams (2021) identified challenges on hard to meter properties in London, which include converted buildings and blocks of flats where the water supply is entirely or partly shared, insufficient space for meter installation, and separating pipeline configurations from nearby properties. The author suggests the following: (i) collaborating with smart meter companies on designs for more compact spaces; and (ii) installing bulk supply meters on shared properties to monitor water going in by creating a small supply area inside a larger one that shows any continuous water flow to detect leakage.

2.6.5 Australia

The literature review conducted for this study shows that adoption of smart water metering (SWM) is on the increase in New Zealand and Australia. Also evolving, is the level of service that some customers anticipate from their water utility, including how and when water is used, and how the usage reflects in bills (Beal & Flynn, 2014). Australia is installing a variety of smart water meter and communication networks with the explicit goal of addressing any potential capital and operating expenditure savings that smart water projects may bring.

According to a study by Beal and Flynn (2015), an in-depth interview was conducted with the four largest water utilities, which represented water businesses that completed a smart water project to provide some empirical insight into the project's benefits. The specific water businesses were Water Corporation of Western Australia, TasWater in Tasmania, Mackay Regional Council, Queensland, and City West Water, Victoria. Benefits experienced by them include a reduction in operating costs, increased accuracy, improved customer relations, and gigalitres of water savings.

Furthermore, Sydney Water has successfully adopted a smart water project with its in-house Customer Hub, which actively interacts with citizens to gain valuable insight into how to improve performance. The technology consists of a geo-spatial situational awareness tool (Spatial Hub), online customer portals, automated customer notification and feedback channels, and an IoT sensor, all of which simplify Sydney Water's complex water and wastewater networks and make identifying and scheduling maintenance easier (Ali, 2019).

2.7 The perception of people towards smart water metering

The industry's perception of SWM is divided into two categories. In this study, these perceptions are classified as benefits and challenges of smart water meters and discussed in the sub-sections below.

2.7.1 Benefits of smart water meter systems

When high resolution water consumption data are available for analysis, numerous opportunities for water and capital savings could be realised (Nguyen et al., 2018). The adoption of SWM is significantly influenced by how well users and organisations perceive the benefits of the technology. Here are some significant benefits of SWM.

i) Water conservation by behavioural change

Water conservation can be achieved by implementing a SWMS, thereby giving customers access to more detailed, real-time data on water consumption. For example, two studies looked at how a SWMS can give household consumers access to detailed water use information. Both studies reported improvements in water awareness, concrete behavioural changes, and a decrease in water consumption. The findings show that SWM has a positive impact on water conservation (Erickson et al., 2012; Fielding et al., 2013), implying that advanced feedback can result in several benefits that can lead to more sustainable use of water resources.

Furthermore, a study of more than 85,000 households in the City of Sacramento that was carried out over an 18-month period, noted the water conservation benefit. The study analysed the impact of customer access to real-time data and found a 50% decrease in leak occurrences and a 34% decrease in the time it took to fix the leak. Thus, residents monitored their water consumption level and set an alarm that detected potential leaks. Their findings show that households who logged into the online portal repaired leaks more quickly than households who did not. The study emphasises the importance of customer engagement as smart water meters do not alter consumption patterns on their own. Instead, resident behaviour determines water demand, and changing behaviour results in water efficiency and conservation (Schultz et al., 2018).

ii) Leak detection and repair

The International Water Association (IWA) Task Forces on Water Losses and Performance Indicator recommends using the term "non-revenue water" (NRW) to measure water loss or leakage in water distribution systems (Güngör-Demirci & Lee, 2022). NRW is water leakage from water mains into the surrounding soil – also referred to as "physical losses". Such leakages are difficult to detect and are major sources of water loss that water utilities cannot bill to customers or recover financially. Another source of NRW is commercial losses, which consist of water that enters a water system but is incorrectly accounted for when it leaves the system. Commercial losses are caused by inaccurate or faulty meters, errors in data handling, water theft or leaks (Berger et al., 2016).

In developing countries, real water loss to NRW is approximately 70% to 80%. A high level of NRW typically denotes a water utility that lacks the technical, managerial and governance abilities required to deliver a reliable service (Chawira et al., 2022). These leaks occur on both the customers and the water utility's side (e.g., in water distribution infrastructure). Overall, available empirical literature suggests that leaks can be prevented by using SWM to detect leaks.

On the customer side of leak detection, Britton et al. (2013) in their study emphasise the benefit of SWM for leak detection and repair. Berger et al. (2016) report that in 2009, the City of Sacramento, California, began implementing SWM. The city monitored the performance of 17,600 smart water meters installed between 2010 and 2011. The analysis of the volumetric consumption data collected revealed 1,076 leaks, and 75% of those leaks were confirmed to be in the field. The city estimated that repairing the leaks saved 236 million gallons of water over the course of two years, or about 12.6 gallons for each person per day. Further, Muhammetoglu et al. (2020) examined smart water meters of different sizes installed in 22 different public sites. The study aimed to monitor and identify leakage in public environments such as schools, universities, parks, public toilets and graveyards. The six months real-time monitoring programme measured the flow rates at those sites at 15 minute intervals. The flow occurrence was monitored every two minutes – once a continuous flow was detected, a leak alert message was generated. The authors observed minimum water usage during the minimum night flow (MNF) duration (between 00:00 to 05:00), indicating that close monitoring of MNF at a shorter time interval allowed for accurate leak detection and leakage volume calculation. They found that all sites had high levels of post meter leakages, with an overall leakage exceeding 58% of the total flow. On-site inspections and close monitoring showed that a considerable volume of water leakage occurring in the study sites can be attributed to damaged water connections in taps and toilets.

Water utilities need to take precautions by detecting small leaks before they develop into costly catastrophic pipe failures, although water utility infrastructure side leak detection is more complex than the customer side of detection, largely because water distribution networks have so many inputs and outputs. Studies have shown that better data could significantly improve daily water system operations. Beal and Flynn (2014) suggest in their template for developing a business case for smart metering that it would lead to less wasted time to detect network leaks. This translates to a decrease in network leaks and other NRW causes (like bursts) as well as a decrease in labour costs related to leak detection.

Further, Morote and Hernández-Hernández (2018) report that since the installation of smart water meters in 2011 and increased surveillance by water company employees in Alicante, Spain, the detection of unauthorised domestic water use (theft) has increased. According to their report, water theft decreased by 80% between 2013 and 2017.

iii) Environmental benefits of smart water meter systems

Moldan et al. (2012) note that environmental and natural resource services are mutually connected to people’s well-being. To protect the wellbeing of people, saving the environment and providing natural resource services on a proper standard is important. Simply put, environmental sustainability means maintaining natural resource services at a reasonable standard. SWM could provide environmental benefits such as a reduced carbon footprint of water supply systems because of water savings (Monks et al., 2019). When consumers use less water, the embedded energy required to provide that water is avoided because the water utility needs to extract, treat and distribute less water. This helps in reducing the energy demands of the water utility (Berger et al., 2016). The water company Aguas de Valencia notes that its smart water metering scheme saves about five million cubic meters of water annually, thereby preventing the emission of 600 tons of carbon dioxide (CO_2). Further, replacing paper bills with online bills may decrease the use of paper. Although there are no calculated figures yet, it can be argued that savings in CO_2 emissions may be significant (March et al., 2017). According to Britton et al. (2013), householders identified that environmental motives for conserving water and decreasing loss are stronger than cost-cutting motivations.

iv) Economic and societal benefits of smart water meter systems

Studies have identified key economic benefits of SWM. Some of the economic benefits pointed out by Beal and Flynn (2015) in their study include savings in operating costs, reduced bulk water supply, increased revenues from more accurate meter readings, increased water distribution infrastructure, improved customer relationship, and a decrease in non-revenue water losses. Using the case of Seosan (South Korea), Yi et al. (2018) point out how the SWM project has led to 20% improvement in the revenue water ratio and a 190,000 m^3 reduction in leakage per year. This results in a USD 590,000 benefit over the next eight years, with the cost benefit expected to increase. According to Yi et al., customers' satisfaction has improved because of the switch to smart meters for quality water use. They also noted the potential in responding to complaints quickly and providing additional efficient water management services.

Lastly, SWM implementation has many benefits beyond metering and billing (Gurung et al., 2014; Monks et al., 2019). Monks et al. (2019) reveal 75 benefits associated with SWM. Their study attracted input from various water management experts for stakeholders considering SWM implementation. This demonstrates how an IoT system with precise mapping of data usage can benefit water resource management at the highest level possible.

2.7.2 Challenges of smart water meter systems

While SWM has the potential of providing numerous benefits, there are challenges that need to be addressed. Here are some of the most significant challenges towards adopting smart water metering.

i) Cybersecurity issues

The water and wastewater sector (WWS) is one of the 16 lifeline infrastructure sectors identified by the US Department of Homeland Security (DHS) as a primary target for cyberattacks (White House, 2013). Protecting it from cybersecurity threats is regarded as a national priority (White House, 2017). The truth is that many cybersecurity incidents either go unreported because they are not detected (Walton, 2016) or are not disclosed because doing so could jeopardise the customers' trust, the victim's reputation, and sector's ability to generate revenues (Rubin, 2019).

There are many types of cyber security threats, but ransomware attacks have emerged as the malware threat with the fastest rate of growth in recent years according to the Federal Bureau of Investigation (FBI). For instance, in February 2019, Fort Collins Loveland Water District in the United States was hacked through a ransomware attack. Hackers gained control of technical data and demanded a ransom to unlock the data. The water system declined the ransom demand, and after a few weeks, they were able to regain access to their data (Ferrier, 2019; Sobczak, 2019). Further, In October of 2018, hackers targeted Onslow Water and Sewer Authority, a water utility company in Jacksonville (North Carolina), USA. The attack, which occurred right after Hurricane Florence, speedily developed into a sophisticated ransomware attack, locking out employees and encrypting databases, leaving the utility with restricted computing options. The utility made the decision in this case not to pay a ransom. This complies with federal guidelines because the US Government discourages paying ransom to criminals. Sadly, other instances of ransomware affecting water utilities exist, many of which are protected by advanced cybersecurity measures like antivirus software and firewalls. But their IT system was found to be hackable (ONWASA, 2018; Mahairas & Beshar, 2018).

Given the rise in the use of data-driven systems, protecting historical data is a crucial component of technology integration. Implementing data segmentation and segregation is a crucial safety measure to be taken into consideration (Ferrier, 2019; Sobczak, 2019). The uncertainty that comes with investing in technology is already present and increasing cybersecurity concerns make it worse. Consequently, it is crucial to take cybersecurity issues into account as a potential challenge to any technology adoption.

ii) Cost of smart water metering

SWMS can be more costly than traditional metering devices. The cost of a project varies greatly depending on the chosen metering and communication technologies, the degree of software integration, the state of the metering system prior to the implementation of SWM, and the number of customers. A study on smart water metering projects in Australia and New Zealand found that project costs ranged from $45,000 to upgrade 5,000 water meters to smart water meters, with as much as $36M to install a full SWMS for close to 60,000 residential and non-residential meters (Beal & Flynn, 2015). Because capital costs are high, many water utilities have noted that it is difficult to make a business case for SWM (Zunino, 2015).

iii) Lack of funding

New technology can significantly improve efficiency, although overcoming the initial capital investment can be difficult. Lack of funding seems a major challenge to technology adoption. This idea is supported by survey data gathered by Dodge Data and Analytics. According to the survey, 74% of the respondents believe that a major functional challenge is the lack of funding. Additionally, respondents identified that a lack of funding is the most difficult challenge facing planning, and the fourth-biggest problem in Operations and Maintenance. Lack of funding is a significant problem that has an impact on many aspects of water plant operations. Naturally, this problem leads to several other challenges regarding technology integration (Dodge Data and Analytics, 2020). This is in line with the findings of a survey conducted by Adams (2022), who also identified the lack of funding as a major challenge. Mutchek and Williams (2014) confirm that extensive research and development funding has led to the implementation of smart water projects in Singapore such as the development of a laser-based contaminant sensor and the smart water grid in the Singapore business district. In a similar vein, Yi et al. (2018) noted that the government supported smart water meter adoptions Seosan City with funds.

iv) Social revolution (awareness)

Studies have shown that to achieve success with new technology, stakeholders need to be ready. This includes the institution and the end users, who need to embrace such technology (Ringwood, 2015; Krause et al., 2018; Ali, 2019; Shah et al., 2020). The study by Shah et al. (2020) found that a common challenge to smart water metering is the degree of user awareness and their ability and willingness to pay for the same. The study also notes the importance to convey water efficiency awareness in a way that respects individual and household priorities and preferences. Additionally, their findings show that most people already have a positive opinion of saving water, and awareness levels are relatively high. They note that a high level of awareness suggests that is the right time to implement an environmental policy that emphasises enhanced water saving methods.

According to Ali (2019), social revolution is one of the successes of the 4th Industrial Revolution. Ali notes that government needs to create awareness and more trust-building programmes such as citizen participation, gamification, legal frameworks and government policies to increase the success of digital transformation and adoption.

v) Lack of strong government water policy – smart water metering

It is observed from the literature that water utilities are not compelled by any government water policy to adopt SWM. That is, the majority of countries have no mandatory SWM policy (Hutton, 2019). However, because SWM implementation has many benefits that go beyond metering and billing (Gurung et al., 2014; Monks et al., 2019), many water utilities have been adopting SWM as their water management strategies.

It is also observed that strong water policies imposed in countries such as South Korea and Israel have increased the adoption of SWM directly or indirectly. According to Britton et al. (2013), a policy and related delivery guidelines covering communication protocols, technical standards and incentives for water service providers to end users need to be researched and developed. A SWMS makes it possible for water utilities to regularly identify households or properties with leaks. Legal opinion may hold water service providers legally responsible for informing customers and holding potentially informed customers legally responsible for making repairs within a reasonable time. Further, Britton et al. note that the issues need to be addressed through discussions with water utilities, the government and customers for the policy to be successful.

The lack of a water policy is not the only challenge that can prevent organisational technology integration. One of the key concepts highlighted by the Dodge Data and Analytics study is the lack of alignment with digital goals and issues with organisational structure. The study found that 64% of the respondents believe a lack of alignment of digital goals has a moderate impact on water systems' ability to meet digital priorities (Dodge Data and Analytics, 2020).

To increase the use of SWM across nations, governments need to issue strong water policies and provide funding grants for sustainable water management. Most smart water meter implementations that came to light started after water policy reforms have been put in place. Strong water policies will encourage the adoption of water-efficient equipment, leading to more smart water meter implementations being carried out, thereby reducing the cost of SWM and enhancing the validity of business cases for smart water meter implementations.

2.8 The influence of government water policies on smart water meter adoption

Governments all over the world are applying stringent water policies in response to issues such as water scarcity, demand management and population growth (Liu et al., 2017). Indirect water policy interventions such as water efficiency, drought relief plans, water use reduction targets and water supply tax unintentionally promote smart water meter adoption, whereas direct water policy interventions specify smart water meter installation (Beal et al., 2011; Liu et al., 2017). Given that finding a solution to water insecurity depends on improving policy and water governance (Araral & Yu, 2013), an overview of countries whose water policies influenced the adoption of smart water metering is presented next.

The Korean parliament in 2018 implemented significant changes in water management that marked a paradigm shift. ICT and AI were used for real-time and remote monitoring and setting up SWMSs. Smart water metering aligns with the national policies of South Korea toward a creative economy that seeks to generate employment through innovation and ICT (Choi et al., 2016). Additionally, South Korea established the Environmental Technology Incubator in Korea to encourage the development of smart water meter technology and support venture capital. In a similar vein, the Korean government has been involved in smart water meter adoption. In Take Seosan City, for example, the central government supported the water utilities in a USD 0.4 million project funded by the government drought relief budget. The city saw improvements in customer satisfaction and a decrease in water leakage and errors in the distributing of reservoirs' inflow and outflow. It is expected that smart water meter adoption will continue in the future, based on the number of successful smart water meter implementations that have been carried out in South Korea to date and the ambitious completion targets set by water authorities and the government (Yi et al., 2018).

Nine significant innovations were adopted by the Israeli water sector regarding its water policies. These government innovations had a direct impact on the adoption of water-efficient technologies through the establishment of an amazing connection between the ecosystems of businesses, utilities and universities. The primary forces behind the development of cutting-edge water management technologies, such as smart water meters, include the financial incentives provided by the government to reduce water demand in the agricultural and urban sectors (Marin et al., 2017). The Israeli government approved water policies along with strict water pricing policies such as "tariff reform" (2008) and "surplus use fee" (2009) to promote the use of water-saving technologies. Several policies, including "drinking water regulations" (2013) and "sanitary and quality of drinking water" (2013) (Cahn et al., 2020) imposed in Israel have increased the adoption of SWM directly or indirectly. For instance, water loss fines prompted the development of "dynamic water pressure" and "water loss detection equipment" (Israeli Water System, 2019). In addition, Mei Raanana began utilising the SWMS in 2002 as a sign of consistency with the enactment of a "Parliamentary Investigation Committee" and the empowerment of municipal services (Cahn et al., 2020).

There is evidence that water policies are having an impact on changes in the type of water metering, while traditional metering implementation and smart water metering have been growing in the UK. The "Water Industry Act" was passed in 1991, and it was later modified (by "Statutory instrument 3442") in 1999 to distinguish between non-compulsory and compulsory domestic water metering (Pericli & Jenkins, 2015). In 2018, the Department for Environmental Food and Rural Affairs (DEFRA) published an environmental plan outlining the requirements and steps for England to have a personal water consumption target, and the National Infrastructure Commission (NIC) recommended implementing SWM to increase water efficiency (Department for Environment Food & Rural Affairs, 2018; Rees et al., 2020). The year 2019 saw recommendations from the NIC, the Committee on Climate Change, and the House of Commons Environment, Food, and Rural Affairs (EFRA) Committee urging the UK government to impose compulsory SWM. Though, the UK government still maintains in parliament a non-obligatory water metering policy (Hutton, 2019).

The following section discusses the information systems theories that are reflected in this study for the use and adoption of technology.

2.9 Theoretical lenses

Several theories and models have explained technology adoption. For this study to develop an appropriate and applicable framework for institutional adoption of SWM to help improve the efficiency of water management for a sustainable future, the following models and theory were selected:

- Technology Acceptance Model (TAM)
- Diffusion of Innovation (DOI) theory
- Technology-Organisation-Environment (TOE) framework

2.9.1 Technology Acceptance Model (TAM)

TAM was first proposed by Davis (1986) and later advanced by Davis et al. (1989). TAM's goal is "to provide an explanation of the determinants of computer acceptance that is general, capable of explaining user behaviour across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified" (Davis, 1989:985).

The model was founded on the Theory of Reasoned Action (TRA). The TRA is a well-researched social psychology model that that focuses on the factors that influence consciously intended behaviour. According to TRA, an individual's action of a specific behaviour is determined by his/her behavioural intention (BI) to execute the behaviour, and BI is determined by a person's subjective norm (SN) and attitude (A) toward the behaviour in question (Fishbein & Ajzen, 1975).

TAM employs TRA as theoretical foundation for defining causal relationships with two main constructs: "Perceived Usefulness (PU)" and "Perceived Ease of Use (PEOU)". Other constructs include "user's attitude (A), behavioural intentions (BI) and actual system usage".

- **Perceived usefulness (PU):** is defined as a potential user's subjective belief that using a specific ICT resource will improve his or her performance and productivity level in terms of organisational context.

- **Perceived ease of use (PEOU):** is the extent to which an individual thinks using a system would be effortless in terms of both physical and mental effort (i.e., the potential user expects the target ICT tool to be easy to use).
- Both PU and PEOU predict the user's attitude toward using the system, which refers to the user's desire to use the system. The individual's BI is influenced by A and PU to use the system, and the actual system usage is predicted by BI.
- **External variables:** include all variables that are explicitly not included in the model, such as the actor's personality or demographic characteristics, the nature of the specific behaviour being examined, referent characteristics, previous behaviour, and effective communication. External variables directly impact PU and PEOU, and indirectly impact attitude or behaviour through PU and PEOU.

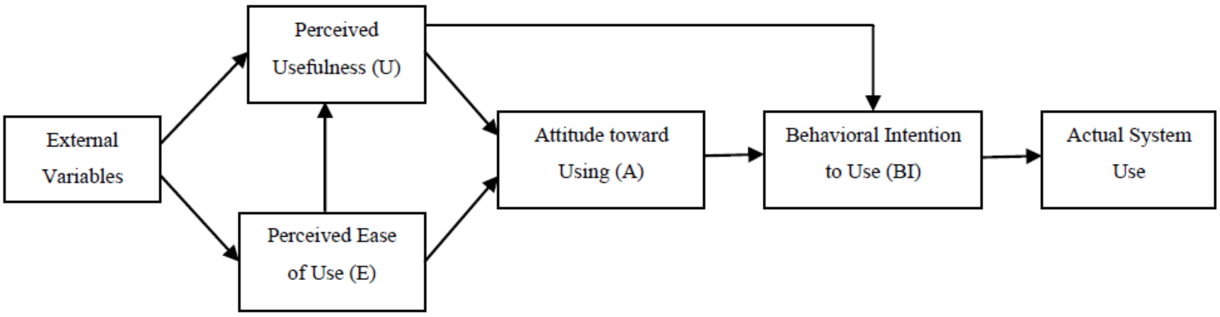


Figure 2.3: Technology Acceptance Model (TAM)
(Source: Davis et al., 1989:985)

TAM is one of the most effective and widely used theoretical frameworks for information technology (IT) and information systems (IS) adoption (Koul & Eydgahi, 2018). TAM's widespread adoption can be ascribed to three main factors: its simplicity in terms of theoretical foundation or attributes; empirical foundation; and general application across a wide range of technologies and systems. TAM's simplicity and validity are the main reason for its popularity and widespread use (Koul & Eydgahi, 2017; Salahshour Rad et al., 2018).

TAM has been applied in different settings, including online learning, media, social networking, the internet and smartphones, to name a few. For instance, a study on factors impacting attitudes toward the adoption of mobile commerce showed that TAM may be applied to the field of mobile commerce, and it adequately explains consumer adoption intentions (Yang, 2005). Also, another study on e-banking adoption validated TAM application by providing a better understanding of how bank customers use e-banking (Carranza et al., 2021). Furthermore, Koul and Eydgahi (2018) explored the use of TAM for driverless car technology adoption, and it showed that the constructs of the TAM framework provide a solid theoretical foundation for predicting the adoption of a driverless car.

2.9.2 Diffusion of Innovation (DOI) theory

Having a new idea adopted is usually difficult even with its advantages. Several innovations need an extended period, mostly years, from the time they are available to when they become generally adopted. Consequently, a widespread problem for most people and organisations is the means to speed up the rate of diffusion of an innovation.

The DOI theory was first formulated to better explain the pace at which new ideas and innovations spread by answering questions such as how, when and why these ideas and innovations spread. Professor Everett Rogers in the field of Communication Studies made the DOI theory popular in his book, "Diffusion of Innovation", first published in 1962 (Rogers, 1995). The book defines DOI as a method where a product or design is conveyed through precise channels for a period between individuals from a social system. The communication is a special type as it has to do with new innovative ideas. Diffusion is a social change that happens when innovative ideas are created, and they are widely spread, and adopted or rejected. The theory embodies four key elements that have an impact on the dispersion of a new developed idea.

These four elements are:

- The "innovation,
- communication channels,
- time, and
- social system"

Based on these elements, its dependence on human capital and self-sustaining of the innovation lie primarily in the size and extent of adoption, which at one point is subject to innovation spreading to a fair population. The theory has five categories of adopters, presented below in figure 2.4.

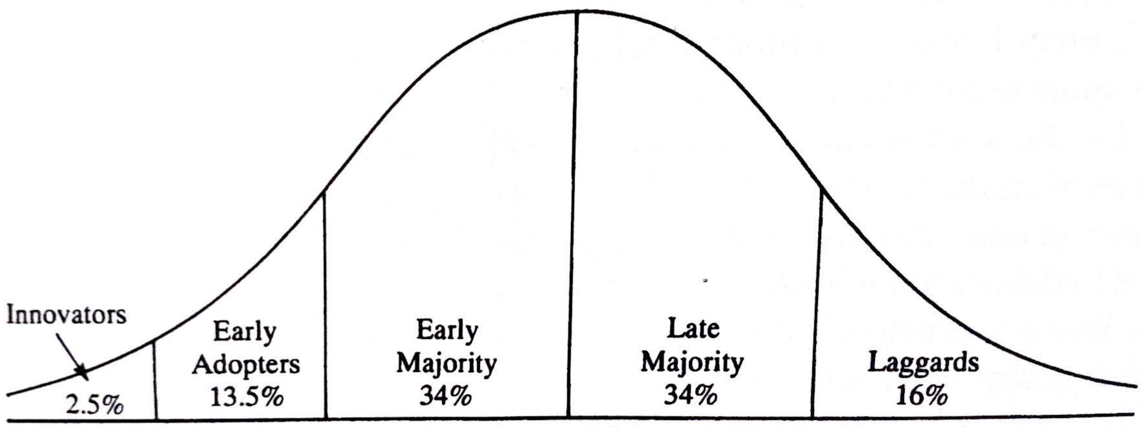


Figure 2.4: Adopter categories of innovation (Rogers, 1995:262)

These five adopter categories of innovation—"innovators, early adopters, early majority, late majority, and laggards"—can be described as technology innovation adoption and its impact on innovative and adoption procedures. Simply put, DOI is the procedure that happens when individuals accept a new idea, practice, product or theory. Rogers notes that most often, only a few people are initially happy to embrace, adopt and use the new idea. As early innovators create awareness, more individuals are comfortable with embracing the innovation, which prompts its advancement. After some time, the product or innovative idea gets diffused amongst people until a saturation point is reached.

DOI in several ways passes through diverse cultural groups and is subjectively inclined to the innovation decision-making process and the person planning to adopt it. Rogers (1995) identified two types of factors that explain the decision that could be taken:

- "Is the decision free of cohesion, and is it made and implemented voluntarily?
- Who is accountable for making the decision?"

The *social system* has one more significant type of influence in the diffusion of innovative ideas. As mentioned earlier, innovations may be adopted or rejected (a) by a person from a social system (b) or by the whole social system. Considering this reason, Rogers (1995) identifies three types of innovation decisions, namely:

- *Optional innovation decision* – a decision taken by a person to reject or adopt novel ideas that is separate from the decision taken by other people within a social system.
- *Collective innovation decision* – a decision taken by the entire group of people in a social system to reject or adopt novel ideas or innovation. Simply put, the decision taken is done in agreement with all the people in a system.
- *Authority innovation decision* – a decision taken by a few people who have technical knowledge or power to reject or adopt novel ideas or an innovation within a social system. A person belonging to this social system has almost no influence on the decision taken by the authority. He/she just implements the decision.

Diffusion of innovation has *five process stages* as shown in figure 2.5, which is basically the innovation decision process that happens through various channels of communication between a specific social system normally over a specific timeframe to evaluate a new idea/innovation and to decide whether or not to integrate the idea/innovation into an existing process.

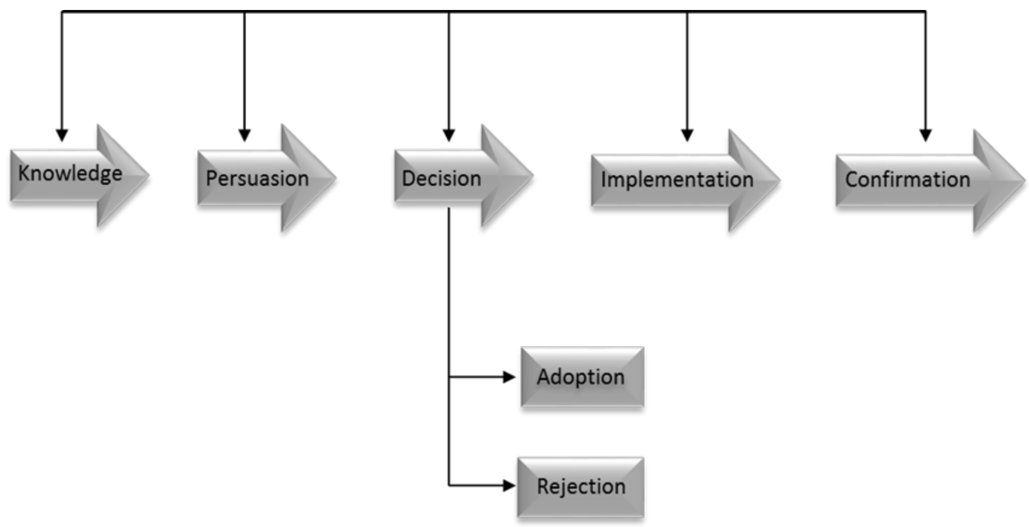


Figure 2.5: Five stages of the Innovation Decision Process for Technology Adoption (Adapted from Rogers, 1995:163)

The five process stages by Rogers (1995) are further explained as follows:

- *Knowledge* is the stage when a person is exposed to existence of a new idea or an innovation. It is the first contact or communication the person has with the innovation. This is when the person gains knowledge about the innovation, which can be through advertisements, exhibitions, a network, or media, among several others. Information such as what the innovation is about, how it works, and why it works is a person's main concern. Formal knowledge of the innovation needs to be absorbed to create motivation for adoption.
- *Persuasion* is the stage where a general perception of an idea or innovation is developed. The person (or group of people) becomes more involved, he/she actively seeks detailed information such as designs, features, cost and user reviews regarding the innovation or new idea. This is when the individual develops a negative or positive attitude towards that innovation.
- *Decision* is the stage where person participates in activities that lead to the choice of adopting or rejecting a new idea or innovation. The person may take into consideration the risk, cost, advantages, disadvantages, etc., and ponder over them. Rogers (1995) notes that this stage of decision-making is critical because of the difficulty to collect pragmatic data and the subjective nature of the person taking the decision.
- *Implementation* is the time a person puts the new idea or innovation into use. Implementation includes explicit behavioural change because the innovation is put into practice. Despite the decision made previously to adopt the innovation, during this stage, the person wants to know the applicability, adaptability, compatibility and ability of the innovation. The new idea or innovation is examined and measured to ascertain if it performs well. Information seeking such as where to get the innovation, how to use

it, how it works, what operational problems are likely to surface, and how the problems can be solved usually takes place at this stage. Additional information may be needed to enhance usage and stability of the innovation. If the innovation does not perform as expected, re-invention may be considered. Re-invention is the process of modifying the innovation so that it is compatible within its system of operation and meets the needs of the person or user.

- *Confirmation*: At the confirmation stage, the decision to reject or adopt an innovation is determined. The person or group of people looks for support to back up the decision previously taken or withdraws the previous decision based on exposure to conflicting messages regarding the innovation. An innovation can likewise be rejected in diverse ways, for instance, if the innovation becomes outdated or has completed its cycle and outlived its usefulness, or if the innovation fails to meet expectations or malfunctions, it needs to be replacement with an advanced version. The most controversial aspect is that it is unsuccessful when a person gets and uses the product less often such that it becomes abandoned because of dissociation. Then, the time, effort and money spent in choosing the innovation have been wasted. Each stage can be a potential rejection point during the process of decision making, for example, it is possible to reject a new idea/innovation during the knowledge stage by just overlooking it after the initial awareness knowledge has been gained.

According to Rogers (1995), one significant explanation of innovation adoption rate is the perceived attributes of the innovation. It is necessary to examine and understand why certain innovations become successfully accepted and others not. Rogers suggests five innovation characteristics that influence rate of adoption, with some attributes implicit to innovation, while others are concerned with the real innovation usage and the person adopting it. These characteristics include:

- *Relative advantage* refers to the advantages of an innovation over others. An innovation needs to demonstrate the features and why it is better than other advances being assessed. The degree of relative advantage is frequently identified as economic wellbeing, reduced cost, social prestige, etc.
- *Compatibility* shows how much a technology is seen as being compatible or reliable with existing experiences, standards and needs of potential adopters. A potential adopter may likely adopt an idea that is more compatible and fits his/her life situation. Compatibility may be technological in nature, for example, software or hardware devices. Such compatibility helps the person give meaning to and appreciate the new idea.
- *Complexity* refers to how hard it is to comprehend and use an innovation. Some innovations are comprehensible in their meaning to possible adopters while some are

not. New ideas or innovations can be grouped into a complexity-simplicity range. The more complex an innovation is, the less likely it will be adopted.

- *Trialability* means the person or potential user can experiment with the innovation on a limited basis before taking a decision. This enables the person to test the innovation through a demonstration or simulation without adopting the innovation. Trials are frequently part of the persuasion and implementation stages because it helps the person to create an accurate and good impression of the innovation.
- *Observability* is the degree to which the result of an innovation is noticeable by people. Results of certain ideas or innovations are effortlessly observed and reported to others, whereas some innovations or ideas are hard to notice and describe to other people. The more an innovation is observable and seen to be used within a social system or among friends, the higher the interest and motivation will be toward adopting the innovation. Rogers (1995) notes that this factor is the most silent embodiment of DOI.

2.9.3 Technology-Organisation-Environment (TOE) framework

Many studies use the Technology–Organisation–Environment (TOE) framework as a research model to examine how innovative technologies are adopted at organisational level (Kim et al., 2015).

The TOE framework was proposed by Tornatzky et al. in 1990 (cited in Oliveira et al., 2014) to explain the innovation process within an organisation. The theory considers three organisational characteristics—technology, organisation, and environmental—that influence the adoption of innovations.

The three contexts forming the basis of the TOE framework are:

- *Technology context* describes both internal and external technologies that are pertinent to the organisation as well as technologies that could be adopted.
- *Organisation context* describes the organisation’s characteristics (e.g., its size, business focus and management structure), resources (both human and slack), communication process (both formal and informal) among employees.
- *Environment context* describes elements associated with the business environment such as competitors, market elements, the governmental regulatory body (Oliveira et al., 2014), and other institutions both near and far that can impact on the adoption decision (Azadegan & Teich, 2010).

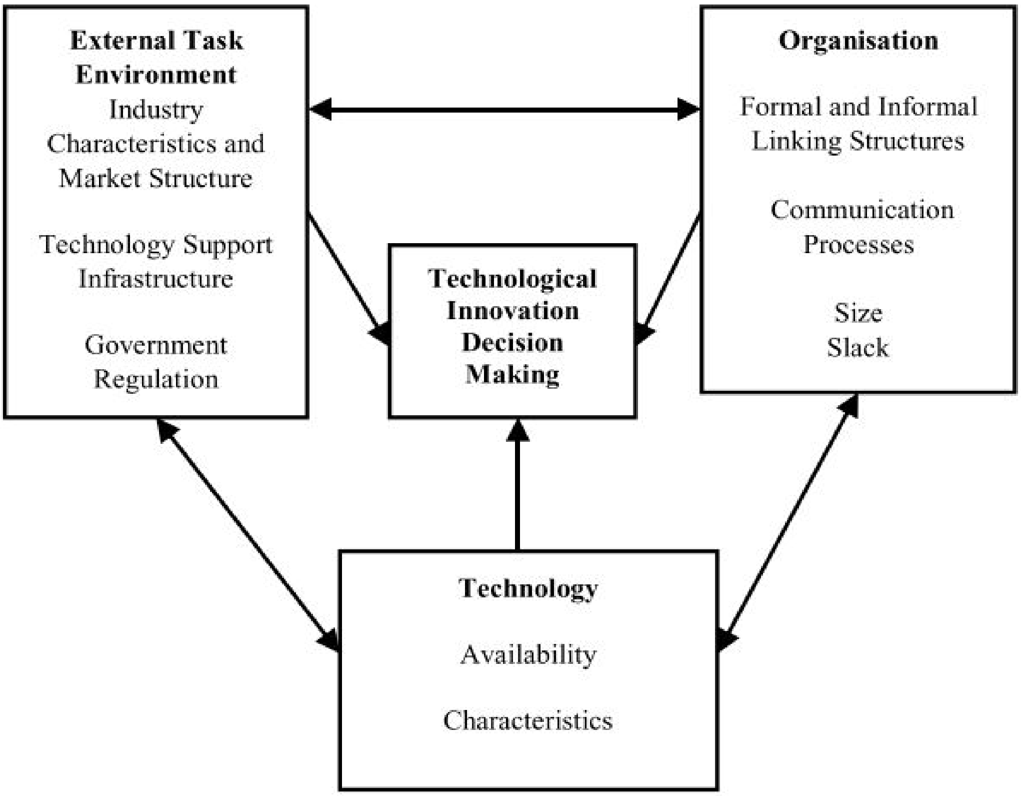


Figure 2.6: The Technology-Organisation-Environment Framework
(Tornatzky et al.1990, cited in Bryan & Zuva, 2021)

Figure 2.6 presents the TOE framework. The strength of TOE is that it considers external factors such as technological, organisational and environmental factors when thinking about how to appropriate, use and create value from innovations (Azadegan & Teich, 2010; Bryan & Zuva, 2021).

2.10 Conclusion to Chapter Two

Chapter Two discussed the systematic literature on smart water meter systems. The review was done to find practical evidence of SWMS adoption by water utilities. Furthermore, it identified the current smart water application technologies used in managing water and discussed the influence of stringent government water policies on smart water meter adoption.

The study adopted the TOE framework (Figure 2.6) as a guide. The TOE theoretical framework explains technology adoption in organisations and highlights how the adoption of technological innovations are influenced by various factors: technology, organisation, and environment. The study found the adopted theory to be constrained; consequently, some features of TAM and DOI were adapted to offer a thorough description and conceptualisation of the features of evaluation and adoption of smart water metering. The conceptualised framework for the study is presented in Chapter Six. The next chapter (Chapter Three), discusses the research philosophy and methodological choices.

CHAPTER THREE: RESEARCH PHILOSOPHY AND METHODOLOGICAL CHOICES

3.1 Introduction

Chapter Three focuses on the philosophical foundation, methodological choices and research processes used for this scientific research. The techniques were selected to meet the aim and objectives of the study. The aim of this study was to explore the reasons behind the failure of institutions to adopt an IoT-based smart water meter system (SWMS) to improve the efficiency of water management for a sustainable future. The study aimed at gaining a better understanding of the factors influencing and limiting institutional adoption of Smart Water Meter Systems (SWMSs); perceptions of using SWMS for water management; how SWMSs can be adopted as part of the water management method; and the government's role or support towards using and adopting a SWMS.

Methodology is the science of discovering; it refers to the techniques used in scientific research (Babbie, 2013). According to Silverman (2017:190), methodology is a "general approach to studying research topics". On this basis, the choice of methodology in this study influenced the methods selected and how each method was used. Additionally, research ethics were carefully considered, thereby serving as guiding principles throughout the research process.

Saunders et al. (2019) uses the metaphor of an onion to explain the general research process. According to Saunders et al., a research project starts with the outer layer and progresses to the inner layer**.** Accordingly, this chapter is organised in the following order:

- Section 3.2. Research philosophy
- Section 3.3. Research approach
- Section 3.4. Methodological choice
- Section 3.5. Research strategy
- Section 3.6. Time horizon
- Section 3.7. Techniques and procedures
- Section 3.8. Qualitative data collection techniques
- Section 3.9. Qualitative data analysis technique
- Section 3.10. Research quality assurance
- Section 3.11. Ethical reflections
- Section 3.12. Chapter three conclusion

The methodology and design used in this study are commonly employed in Information Systems (IS) research.

3.2 Research philosophy

The phrase “research philosophy” refers to how knowledge is developed and the nature of such knowledge. The research philosophy a person selects comprises significant assumptions on how the person sees the world. These assumptions support the research strategy and methods selected (Saunders et al., 2009). This implies that different researchers can have different assumptions about an idea or nature of truth, knowledge and its realisation (Cohen et al., 2007). The philosophical assumptions upon which a study may be based includes, but are not limited to, ontology, epistemology and axiology. Each of these philosophical assumptions has important differences that influence the research process. The following subsections discusses these set of assumptions, which underpins the methodological choice, research strategy, data collection techniques and data analysis.

3.2.1 Ontological assumptions

Ontology refers to the nature of existence or reality or social entities (Bryman, 2012). It is about “interpreting the nature of reality, and gaining clarity on understandable forms of reality, under the assumption of how the world operates in relation to each particular viewpoint, it can be of static nature or constant change” (Bhattacherjee, 2012). Ontology is also described as “the way the investigator defines the truth and reality” (Antwi & Hamza, 2015). The goal of ontology is to provide an answer to the question: “What is there that can be known?” or “What is the nature of reality?” (Lincoln & Guba, 2013:39). Two concepts influence ontological position: ***Objectivism*** and ***Subjectivism*** (Scotland, 2012).

Objectivism is completely free from a person’s perception because it is culture-free, value-free, universal and completely certain (Saunders et al., 2009). Objectivism holds that knowledge gained from reality is independent of social actors (Gruber, 1995). This assumption generally accords with the positivist or natural sciences approach to knowledge claims (Wahyuni, 2012).

Subjectivism holds that social phenomena are created from perception and conscious activity of those social entities who are interested in their existence. Furthermore, this is a continuous process, as these social phenomena are constantly revised as a result of social interaction (Saunders et al., 2009). Thus, it corresponds to the field of social sciences (Bhattacherjee, 2012). A researcher with a subjectivist ontological view needs to observe the conditions, situations and interactions to gain a better understanding of their reality (Burrell & Morgan, 1979).

This study adopted the ***subjectivist view,*** which suggest that a situation observed can only exist as a result of human action in creating and recreating the observed phenomena (Orlikowski & Baroudi, 1991). Subjectivism was selected because it is consistent with the interpretivist epistemological paradigm of reality knowledge. The knowledge of reality and the issue under investigation are socially constructed or created in this study, based on interactions with the water utility professionals.

The interpretivist epistemology that this study followed is contextualised within this philosophy of subjectivism. The epistemology (philosophy of knowledge) is discussed below.

3.2.2 Epistemological assumptions

Epistemology aims to answer questions such as, "What counts as knowledge", and "What are the limitations of epistemology?" Epistemology then means the study of knowledge, or the science of knowing, or the nature of knowledge (Du Plooy-Cilliers et al., 2014). Chia (2002) defines epistemology as "how and what is possible to know", and the necessity of considering the methods and criteria by which verifiable and reliable knowledge is formed. Simply put, epistemology is concerned with how we acquire knowledge in the world (Bhattacherjee, 2012). Researchers adopting an objective ontological stance usually support a positivist epistemology. A positivist will choose a research design that enables them to measure the phenomena they are studying because they believe that phenomena are precise (i.e., measurable) and real. For researchers with a subjectivist view, that is, those who prefer a close engagement with the research phenomenon, their epistemology is interpretivism (Remenyi et al., 1998) or social constructionism (Easterby-Smith et al., 2008).

Other philosophical paradigms are acknowledged, but this study focuses on the three dominant epistemologies generally adopted within the IS field, namely, positivism, critical realism, and interpretivism (Orlikowski & Baroudi, 1991). Each philosophy has a significant difference that influences an individual's thinking about research processes, not just in assumptions and concepts, but also in terms of the considered importance of research problems (Bailey, 1982). To demonstrate awareness, these main philosophical paradigms are briefly explained in the next section.

3.2.2.1 Positivist paradigm

Positivism holds that knowledge is only valid if it is based on empirical and verifiable means of evidence. Positivism holds that knowledge is formed only through observation. The researcher's experience and beliefs are insignificant to the output as the researcher is regarded as being excluded from the research process (Burrell & Morgan, 1979). Furthermore, positivism acknowledges the importance of theory. It centres on finding patterns in observable events and describing them as laws, with the focus on finding causal relationships and offering explanations.

The positivist researcher looks for knowledge through measurement and observation (Collis & Hussey, 2009). They frequently create and test hypotheses using techniques known as hypothetico-deductive methods. In hypothetico-deductive research, a theoretical statement is developed, for instance, from a literature review. The statement is then broken down into hypotheses that are tested. The testing frequently comprises the measurement of variables, and the researcher is looking for data to support or disprove the hypothesis. Positivists maintain that when attempting to understand and explain natural and social phenomena, only objective, observable and verifiable facts should be considered (Du Plooy-Cilliers et al., 2014).

This study was not intended to test theory or hypotheses or to generalise findings in a predictive manner (deductive research technique). Rather, this study seeks to infer relationships and patterns discovered through data analysis to the theory to produce a better understanding of the study phenomena.

3.2.2.2 Critical realist paradigm

Critical realism is a philosophy that focuses on explaining what we see and experience in terms of the fundamental realities that form observable events. Critical realists see reality as independent and external to us; it cannot be directly observed or known. Instead of actual 'things', what we experience is 'empirical', or sensations, which are manifestations of phenomena in the real world. Critical realists emphasise how frequently we are deceived by our senses (Saunders et al., 2019). According to Orlikowski and Baroudi (1991), critical realist researchers are not interested in interpreting views from a social context; rather, their goal is to actively criticise phenomena with the intention of influencing social status.

This study did not employ critical realism as the foundation of the research philosophy because, according to Du Plooy-Cilliers et al. (2014), to change social relations, critical realist researchers must critique, expose and change any unfair social practices. The aim is to expose myths, change society, liberate people from all forms of oppression, while also empowering people to create a better world for themselves. The philosophical paradigm is different from the aim of this study, in that this study seeks to understand the phenomena being investigated within a subjective setting.

Furlong and Marsh (2010) state that ontology advances into epistemology. Ontological and epistemological positions are enlaced with different value systems. Therefore, the subjectivist view is compatible with the interpretivist epistemological paradigm of knowing about reality. Knowledge is gained by understanding the meaning of different experiences.

3.2.2.3 Interpretivist paradigm

Interpretivism aims to gain a subjective understanding of the phenomena through the empirical observation of human activities (Saunders et al., 2009). It is based on the philosophical doctrines of humanism and idealism, and it holds that our perception of the world around us is a product of our minds. This means that we can only experience the world on an individual basis through our perceptions, which are shaped by our beliefs, principles and values (Walliman, 2011). Interpretivism refers to how people create and communicate knowledge in their own subjective meanings and is founded on their unique insight and experiences about the phenomena (Neuman, 2011a; Burrell & Morgan, 1979). So, the interpretivist researcher creates his/her own meaning of the phenomena by subjectively interpreting the meanings and experiences of others.

The interpretivist researcher's goal is to provide a better understanding of how people acquire knowledge in a specific social setting, and not to generalise the population (Neuman, 2011a). Interpretivist research can assist IS researchers with better understanding human thought and action in organisational and social contexts. It also has the potential to reveal deep insights into a variety of IS phenomena, such as IS development, and management (Klein & Myers, 1999).

This study adopted the **interpretivist paradigm** because the researcher endeavoured to study reality subjectively, understanding and explaining human perceptions in relation to the study phenomenon (i.e., research questions), and the fundamental meanings attached to SWMS. According to Hitchcock and Hughes (1995:21), "ontological assumptions will give rise to epistemological assumptions which have methodological implications for the choice of particular data collection techniques". Furthermore, the study adopted a set of principles suggested by Klein and Myers (1999) for conducting and evaluating interpretive research in IS. Table 3.1 illustrates how the principles were applied to the study, and the emergent relationships that resulted from the application of the principles.

Table 3.1: Summary for the principles of interpretive research
(Source: Klein & Myers, 1999)

No.	Principle	Explanation	Application to the study
1.	The hermeneutic circle principle	This principle proposes that all human understanding is achieved by iterating between considering the interdependent meaning of parts and the whole they form. This principle of human understanding is the foundation for all other principles.	The interview transcript was coded and classified by identifying similar meanings and translations in individual cases in comparison to others in an iterative circle, as well as by examining the overall pattern of emerging relationships.

No.	Principle	Explanation	Application to the study
2.	The contextualisation principle	Requires critical reflection on the social and historical background of the research setting so that the intended audience can understand how the current situation under investigation came to be.	To establish previous and current research done in the field of IS. This provided the study with a rich historical context and application, allowing the study to relate previously established constructs to current conditions and happenings.
3.	Interaction between researcher and subjects	Requires a critical reflection on how the research materials or data were socially constructed through interaction between the researcher and the participants.	The interview questions were based on the research assumption and theoretical data. Responses from the interviewees were used to determine whether the premise on which the research assumption and impressions were based was supported or disapproved. Consequently, the interpretation aided in establishing cognitive findings.
4.	Abstraction and generalisation	Requires relating the idiographic details revealed by data interpretation to theoretical general concepts that describe the nature of human understanding using principles 1 and 2.	The study adopted the principle of interpretive research, connecting existing theoretical propositions and philosophical constructs with the reality of findings observed from the collected empirical data. To ensure a good interpretation of the data collected, analysis was performed by synchronising the current data collected with historical data from previous research studies.
5.	Dialogical reasoning	Requires sensitivity to potential contradictions between theoretical preconceptions guiding the research design and actual findings (or 'the story that the data tell'), with subsequent cycles of revision.	The conclusion of the study followed an iterative process of several reflections. This validated some theoretical ideas from previous literature while also highlighting unexpected variations and possibilities of conclusions.
6.	Multiple interpretations	Requires sensitivity to potential differences in participants' interpretations, which are normally expressed in multiple narratives or stories of the same sequence of events being studied. Much like multiple witness accounts even if they all accurately describe what happened.	Individual responses based on personal experience and narration of events were treated with caution by capturing the true meanings of their answers in their natural subjective environment. Efforts was made to uncover the underlying meanings and present them in their originality. Responses were carefully summarised and developed into themes that comprised the various interpretations.
7.	Suspicion principle	Requires sensitivity to potential systematic 'distortions' and 'biases' in the participants' narratives.	A great deal of care was taken to ensure that the narrative was free of bias and personal agendas by carefully presenting questions that provoked real-life experiences. And the respondents who are professionals in the sector demonstrated a genuine interest in the topic.

3.2.3 Axiological assumptions

Axiology is a discipline of philosophy concerned with value judgments. The role of axiology is to provide an answer to the question, "What role do our values play in the research decisions we make?" (Saunders et al., 2009). The interpretivist researcher believes that values influence what are considered facts and the interpretations drawn from these facts (Farquhar, 2012).

The researcher acknowledges that biases in research can exist, especially in an interpretivist study. However, insights from inferences provides a way of dealing with this challenge. Thus, the rich experiences of managers and IT managers who participated in this study are valued. Integrating a SWMS into water management differs from one person to another, therefore related experiences will also vary. This study draws on the expertise and experiences of managers from the water provider institution regarding the impact of technology on water management. Again, literature also contributed to the world views of the reasons why institutions fail to adopt a SWMS to improve the efficiency of water management. This study's research approach is discussed below.

3.3 Research approach – inductive

According to Saunders et al. (2012) deduction, abduction and induction are the three main research approaches. With **deduction**, a hypothesis and/or theory is developed, and a research strategy is designed to test the hypothesis. The **inductive** approach emphasises on collecting empirical evidence and developing a theory based on the findings. The **abduction** approach moves back and forth effectively, combining deduction and induction. It starts with the discovery of a surprising fact, followed by the development of a reasonable theory as to how it may have occurred (i.e., deductive reasoning) (Creswell, 2009).

Given that this study's research philosophy is subjective in nature, an inductive approach was followed. According to Walliman (2011), ***induction*** continues to be the most popular type of scientific activity today. We use it daily to learn from our environment and experiences. We draw conclusions based on our experiences or observations and then generalise them, establishing them as a norm or believe (Walliman, 2011). Inductive reasoning progresses with specific comments, experiences or opinions and then leads to general statements based on the given events (Babbie, 2013). Qualitative researchers typically work inductively by creating patterns, categories and themes using the bottom-up approach by organising data into more logical units of information (Creswell & Creswell, 2018). Research has discovered that a qualitative inductive approach is beneficial in exploring a phenomenon where researchers are aiming to understand organisational experience (Gioia et al., 2013).

The research is exploratory. Exploratory research is frequently carried out in new areas of inquiry with objectives being to: scope the extent of a problem, behaviour or phenomenon;

generate initial ideas about the phenomenon; test the feasibility of conducting a more extensive study about that phenomenon; or to create precise contextual frameworks (Bhattacherjee, 2012). An exploratory research design is a useful tool for discovering what is happening, seeking new insights, asking questions, and assessing phenomena in a new light. It is especially useful for clarifying one's understanding of a problem (Saunders et al., 2009).

3.4 Methodological choice – qualitative research

Qualitative research offers the methods needed to achieve the aim and objectives of this study, as qualitative research in Information Systems (IS) is intended to assist researchers in better understanding people's behaviour in their social and cultural environment (Myers, 1997). It is an approach primarily used for collecting, analysing and interpreting data in a non-numerical setting. It focuses on exploring voluminous detail to accomplish depth instead of breadth (Saunders et al., 2012).

The qualitative research approach comprises the interpretation of participants' experiences and the meanings they associate with the phenomena (Du Plooy-Cilliers et al., 2014). Research is qualitative if the primary aim is to describe, understand or explore the 'what', 'why' and 'how' of a phenomenon or condition (Fouché & Delport, 2011). Qualitative research is a procedure where the researcher frequently makes knowledge claims founded on constructivist views, that is, individual experiences and their multiple meanings; meanings that are historically and socially constructed with the goal of creating a pattern or theory. The fundamental goal of the researcher is to build themes from open-ended, emerging data (Creswell, 2009).

Qualitative researchers perform research in a natural setting; they do not intervene in the situation except perhaps by their presence. Qualitative researchers typically collect data in the field, at the location where the problem is being studied. The researchers interact with people face-to-face and observe how they behave and act in their environment (Creswell & Creswell, 2018). This study was conducted in a natural environment on the premises of the researched institution, with face-to-face interaction centred on the research topic. Furthermore, the researcher is a key instrument for data collection in qualitative research. Thus, the researcher collected the primary data by conducting interviews and examining documents, with the interviews being the key source of data collection (Creswell & Creswell, 2018). The next section presents the research strategy used for this study.

3.5 Research strategy

The case study strategy was used in this study. The following sub-sections provide discussions on it.

3.5.1 Case study as the strategy of inquiry

According to Yin (2014), case study refers to “an empirical inquiry that investigates a contemporary phenomenon (the ‘case’) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident”. Creswell et al.’s (2007:245) definition captures the full range and depth of case study descriptions and concepts as follows:

> “Case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audio visual material, and documents and reports) and reports a case description and case-based themes”.

Case study research can be used to investigate a variety of topics and objectives (Stewart, 2014), but the primary requirement for using case study research is a desire to better understand complex phenomena (Yin, 2014), topic, policy, programme, professional practice, institution or system to generate knowledge and/or inform policy development (Thomas, 2021). Case studies are mostly exploratory and explanatory in nature, and they are used to address research questions such as ‘how’, ‘why’, or ‘what’ (Flyvbjerg, 2011; Stewart, 2014; Yin, 2014).

Case studies are another form of qualitative research. They differ from other types of strategies as they are intensive studies and descriptions of a single unit or system that is bounded by space or time. The phenomenon under investigation is examined in its natural context, which is defined by space and time (Hancock et al., 2021).

Case study research aims to understand the factors that influence a specific circumstance. It can produce research with new framework, demonstrating for instance how a SWMS may be adopted into institutions successfully (Koranteng, 2012). Furthermore, case studies are generalisable to theoretical propositions. In this instance, the researcher’s goal in conducting case study research is to expand and generalise theories, that is, analytical generalisations (Yin, 2014).

Table 3.2 below shows the elements of case study research. These elements distinguish case studies from other types of research and guide the research design and execution process.

Table 3.2: Summary of the major elements of case study research
(Adapted from Creswell, 2014; Yin, 2014; Harrison et al., 2017)

Element	Description
The case	❖ The object of the case study identified as the unit of analysis or entity of interest. ❖ Phenomena, topic, policy, programme, professional practice, group, individual, social situation, event, organisation or process.
A bounded system	❖ Bounded by space, time and/or activity. ❖ Includes a system of connections. ❖ Uses frames to control contextual variables. ❖ The boundaries between the case and the context may be unclear.
Studied in context	❖ Study done in its natural environment or real-life setting. ❖ The case's context (background) is crucial for comprehension. ❖ The contextual variables comprise social, historical, cultural, political, economic and/or organisational factors.
In-depth research	❖ For in-depth analysis of a problem. ❖ Fieldwork is an essential part of the research process. ❖ Subjectivity is a consistent thread. Depending on the philosophical orientation, aim and methods. ❖ Reflexive approaches are critical to the research process and reliability.
Selecting the case	❖ Based on the study's intent and conditions; it includes decisions about phenomena, topic, policy, programme, professional practice, group, individual, social situation, event, organisation or process. ❖ Broad: includes ordinary things, unique, accessible and/or varied. ❖ Methods: methodical and purposive, specified criteria, replication. ❖ Logic: theoretical or literal replication.
Multiple sources of evidence	❖ For a thorough scope and breadth of inquiry, multiple sources of evidence are needed. ❖ Data collection methods: interviews, internal or external documentation, observation, focus groups, questionnaires, artefact, or surveys. ❖ Data analysis methods differ and are dependent on data collection methods and cases; they must be systematic and rigorous. ❖ Triangulation is highly regarded and commonly used.
Case study design	❖ Descriptive, explanatory, exploratory, evaluative, illustrative. ❖ Single or multiple cases. ❖ Holistic or embedded.

3.5.2 Embedded case study as the design

This study adopted an embedded case study design. Firstly, the case study design implies choosing one case (such as an institution) to study. The single case studies are a typical design for conducting case study research. The single case study can make an important contribution to theory and knowledge building by challenging, confirming or extending the theory. A study like this can help in refocusing future research in a field. Secondly, embedded in this case implies that the case study involved multiple units of analysis or sub-units of observation (which included key informants such as the ICT manager, billings manager and commercial manager, among others) from the researched institution. Finally, the phenomenon being studied and the research questions motivated the decision to use this design (Yin, 2018).

3.6 Time horizon

Time horizon refers to cross-sectional or longitudinal research. Cross-sectional means the study of a phenomenon at a specific time, whilst the longitudinal research has the capacity to study change and develop a phenomenon.

Cross-sectional research was selected as this study only investigated a phenomenon at a specific time, that is, to understand reasons for institutional failure to adopt a SWMS for efficient water management. Longitudinal research takes a long time in terms of investigating change and development. Thus, for this research, no form of changes was observed in the studied phenomenon (Saunders et al., 2012).

3.7 Techniques and procedures

This section covers the sampling technique, data collection and data analysis. The decisions taken in the previous sections influenced the techniques and procedures discussed in the sections to follow.

3.7.1 The study population

Population is the people a researcher is interested in. Though, not all the people typically participate in the study (Gravetter & Forzano, 2009). Study population includes individuals, institutions, companies, groups, movements, artefacts or countries (Neuman, 2011a). Population means all items or people (unit of analysis) with the features one needs to study (Bhattacherjee, 2012), i.e., people from whom you would obtain needed information to answer your research questions (Kumar, 2011). This study's population (unit of analysis) was a government water utility provider corporation recognised as using ICT within their institution and with the potential to use a SWMS.

3.7.2 Sampling technique for the study

A research sample is a "small sub-set from the research population that has been chosen to be studied", or carefully chosen individuals from the general population (Lunsford & Lunsford, 1995). Bailey (1982) emphasises that it is necessary to use the smallest sample size that accurately represents the population being sampled, else, there will be an error. Also, samples in qualitative research that are selected in a deliberate manner is referred to as ***purposive sampling***. The goal is to obtain samples that yield generally abundant and the most applicable data about the study (Yin, 2011).

Sampling techniques enable a researcher to collect less data by considering only data from a smaller group instead of all possible elements or cases (Saunders et al., 2012). In sampling, two broad techniques exist: ***probability sampling*** and ***non-probability sampling***. ***Probability sampling*** is also referred to as chance or random sampling. In this type of sampling, each item in a population has the same chance of being selected (Kothari, 2004). It is suitable for a study that aims to generalise its findings numerically to the entire population — although barely used in qualitative studies. ***Non-probability sampling*** is a technique wherein some items in a population has zero chance of being selected, or where the probability of selection cannot be precisely decided. Selection is non-random, calculation of sampling errors is not permitted, and the sampling might be biased. Thus, information from the sample cannot be generalised to the entire population (Bhattacherjee, 2012).

For this study, ***non-probability sampling*** was used as it is ideal for qualitative studies, and it uses a non-numerical mode of generalisation (Yin, 2011). Furthermore, the ***expert sampling*** of non-probability sampling was used. In the ***expert sampling***, respondents are selected in a non-random manner based on their expertise of the phenomenon being researched. For example, to understand the reasons for institutions failing to adopt a SWMS for efficient water management, a sample of managers from different departments who have knowledge on the study phenomenon were selected (Bhattacherjee, 2012). The sample selection was based on the premise that, as managers, they are most expected to provide insights from which the researcher can build an understanding (Saunders et al., 2012).

3.8 Qualitative data collection techniques for this study

Data collection is the systematic process of gathering information for appropriate variables; it can take the form of primary or secondary data, and it may include words, pictures or numbers that help the researcher to answer the research question (Yin, 2011). Different data collection techniques such as documentation collection, interviews, direct observation, participant observation, archival records, and physical artefacts may be used during the data gathering process (Yin, 2018). Each of these techniques depends on the study as well as the methodology chosen (Fox & Bayat, 2007). Data for this study were obtained from interviews and documentation (primary data). Other appropriate data were obtained from the literature (secondary data source).

The sub-sections that follow discuss the data collection and analysis techniques used for this study.

3.8.1 Interviews

Interviews are two-way communication between an interviewer (researcher) and an interviewee (respondent) with the aim of gathering answers, perspectives and experiences on research questions (Yin, 2014). According to Bhattacherjee (2012), the most common type of interview is the face-to-face or personal interview as the interviewer can clarify issues raised by interviewees through asking follow-up questions.

Interviews are useful in providing explanations for major events and insights that reflect participants' perspectives. Interviews are a vital source of case study evidence. The questions are mostly fluid rather than rigid as the researcher needs to follow a consistent line of inquiry. This type of interview is referred to as an "in-depth interview", "intensive interview" or "unstructured interview". The researcher has two responsibilities during an interview: (A) following the line of inquiry as reflected in the interview protocol. The interview protocol may be viewed as a guide for the interview, which includes what to say at the beginning to introduce yourself and the topic, how to obtain participant consent, interview questions, and what to say at the end. (B) Expressing in words the actual interview questions in an unbiased way that is relevant to the research (Yin, 2018).

There are three types of interviews frequently mentioned, namely, structured, unstructured, and semi-structured interviews. The semi-structured interview contains both structured and unstructured (in-depth interview) sections with standardised and open-ended questions (Walliman, 2011). This type of interview involves the interviewer and interviewee in an active symbiotic interaction of knowledge and analysis of the issue (Simons, 2009).

Semi-structured, in-depth interviews were used during the primary data collection phase. With the semi-structured interview, a list of themes and questions to cover during interview was compiled, although this varied from one interview to another. Some questions were omitted given the flow of conversation and participant's responses. The in-depth interview helped in probing participants to elaborate on initial responses and to ask follow-up questions to clarify issues raised by the participants (Saunders et al., 2009). The use of an in-depth interview is considered suitable for case study research as in-depth questions cannot be answered briefly. The researcher is expected to ask for explanations and examples of the given answer to deepen the understanding on the subject (Wahyuni, 2012).

The next sub-section is a guide by Myers and Newman (2007) for conducting a successful qualitative interview.

3.8.1.1 Interviewing guidelines for qualitative research

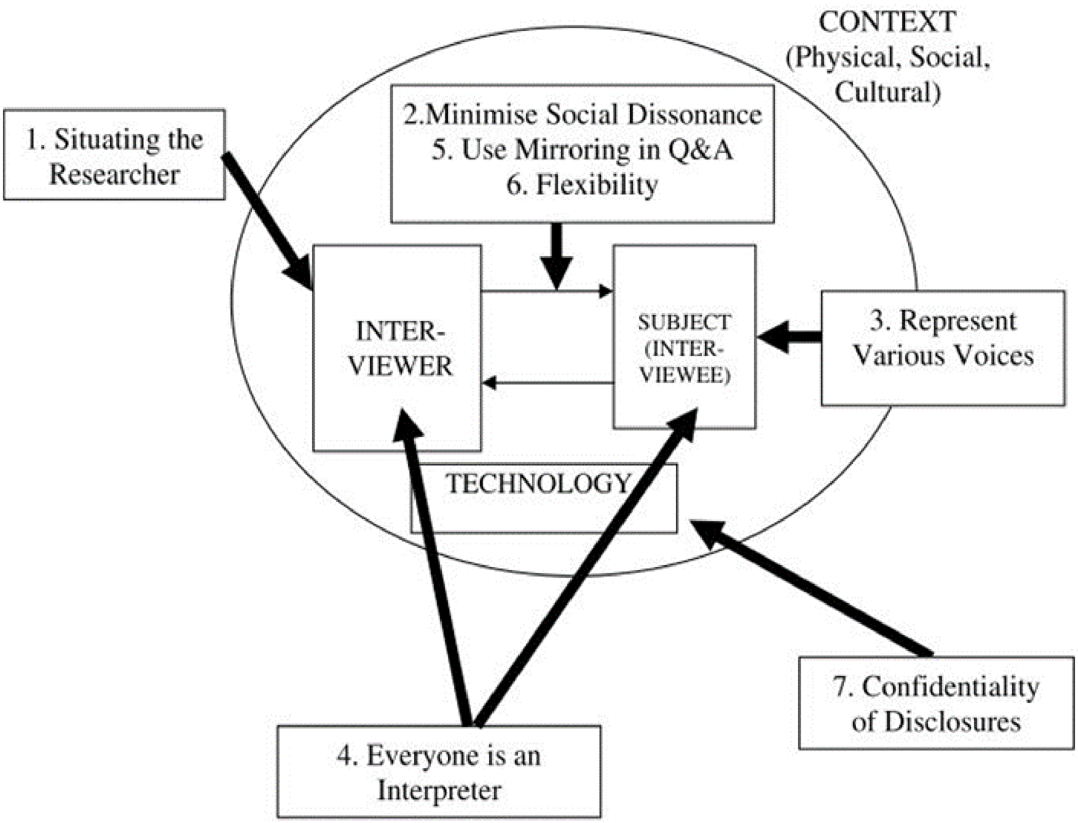


Figure 3.1: Interviewing guidelines for qualitative research
(Source: Myers & Newman, 2007:16)

To apply the prescribed interviewing guidelines, the following steps were taken:

i) **Situating the researcher:** The interviewer and the interviewee need to comfortably position themselves for the interview to be more at ease. The interviewer can start by asking the following questions: "Who are you?" "What role are you playing?" "What is your background, age, gender, experience, and nationality?" These questions help the researcher familiarise him or herself with the interviewees, and the information obtained may become useful in validating the findings from secondary data sources.

ii) **Minimise social dissonance:** Since the interview is held in a social setting, it is important to minimise any distractions that may make the interviewee feel uncomfortable. It includes making a first good impression, wearing appropriate clothing, and using the proper language to communicate. This is generally a method to improve the quality of disclosure and may be relevant to consider depending on the research topic, culture, gender and age.

iii) **Represent various "voices":** In most cases, qualitative research requires interviewing different people within a company to contribute to the study. The process of interviewing different people or subjects is known as “triangulation of subjects”, and the aim is to avoid forcing one voice to emerge. All respondents are not the same, so it is significant to try and avoid any form of elite bias.

iv) **Everyone is an interpreter:** This implies that subjects, like us, are creative interpreters of our worlds. For most subjects, interviews are a rare event. Thus, the interview leads to the creation and reading of one or more texts where the initial text is the interview transcript.

v) **Use mirroring in questions and answers:** Mirroring entails creating follow-up questions using words and phrases from the responses of a previous question. This allows the researcher to concentrate on the subject’s world and communicate with them in their own language instead of imposing one’s own. The aim is for the interviewees to explain and describe their world using their own words. Using open questions are preferable to concentrate on common events and stories while progressing from broad to more specific. The interviewer’s role includes listening, encouraging, prompting and directing the discussion.

vi) **Flexibility:** The use of an incomplete script in semi-structured and unstructured interviews necessitates flexibility, openness and improvisation. The researcher should be ready for unexpected surprises and pursue similar interesting lines of research. The researcher should also be aware of the subjects’ differing attitudes to questions and reply accordingly.

vii) **Confidentiality of disclosures:** It is important that researchers keep records, transcripts and the technology used in collecting data secure and confidential. In some circumstances, it might be appropriate to provide early feedback to organisations and subjects, and to double check facts with them if necessary.

The above interviewing guidelines for qualitative research were used during the study. The interviewer and the interviewees were properly situated in a friendly and comfortable environment. The interviews were mostly situated in the interviewees’ offices at the researched organisation. This helped to reduce social dissonance while also improving data quality.

The interviewer’s clothing was carefully considered, and the interview was conducted in a language that the respondents fully understood and could relate to, with no jargon used. Questions such as the organisation and background of the business, the interviewee’s role in the organisation, and their experiences were part of the questions asked.

During the data collection process, various departmental managers in the organisation were interviewed. Some of the interviewees are experienced in interview sessions, while for some, the interview was a rare occasion outside of their normal workday. Interviewees were encouraged to express themselves in a charismatic and relaxed manner. The researcher posed follow-up questions to produce depth and gain more content on the study phenomenon. A verbatim transcription of the interview was compiled. To ensure that the correct wording was transcribed, careful listening and multiple replays of tracks were performed. The audio and text versions were saved to a cloud storage facility with access control.

The interview protocol was designed using qualitative exploratory research. A semi-structured interview approach was followed to explore participants' knowledge and perceptions of the subject matter, while openness was ensured, and similar interesting lines of research were pursued. An interview guide was developed consisting of a list of predetermined questions to address the research problem statement. An introduction of the study topic, aim, objectives and interview questions was done before the interview process commenced, and this created a relaxing environment for an open discussion.

The ethical considerations of the study were presented to consenting participants in the form of a consent letter. The interviews were digitally recorded with the interviewees' permission, and observations of the surroundings were noted. The interview sessions lasted between 20 and 50 minutes. Participants were thanked for taking part in the study at the end of the interview.

3.8.1.2 Limitations and mitigation measures of interviews

Interviews are time consuming and expensive (Bhattacherjee, 2012). "Clustering" was one method of avoiding this problem. The researcher proposed certain dates when more people from the organisation could be interviewed. The dates were arranged in a way that individual interviews would not be scattered.

Since there is no specific sample size for a semi-structured in-depth interview, the mitigation measure was to reach data saturation. So, each interview "cluster" was arranged once data saturation was achieved. According to Creswell and Creswell (2018), one should stop collecting data when the themes or categories are saturated, which implies that collecting new data no longer reveals new properties nor does it generate new insights. This is when suitable sample size is reached.

3.8.2 Documentation and literature review

Yin (2018) notes that the primary purpose of documentation is to augment and corroborate evidence from other sources. Firstly, documents can be used to verify the correct titles and spelling of individuals and organisations mentioned during an interview. Secondly, documents can provide precise details that may be used to corroborate information obtained from other sources. Finally, documents can be used to make inferences. Though, inferences should be treated as clues rather than conclusive findings, as they may later turn out to be false. Creswell and Creswell (2018) note that researchers make use of private or public documents related to the study phenomenon obtained from participants or a website. The following are different types of documentation:

- Emails, letters, memoranda and other private documents such as calendars, diaries and notes.
- Agendas, minutes of meetings, announcements, official reports and newspapers.
- Administrative documents such as progress reports as well as other internal records.
- Formal studies or evaluations related to the study/research (Yin, 2018).

The main source of documentation for this study was documentation from the researched Water Institution website as well as reports and ICT implementation documents from the institution related to the study to account for actual local practice. A review of academic publications on the subject were conducted to gain a better understanding of related constructs and theories, and to keep record of previous studies.

3.9 Qualitative data analysis technique – thematic analysis

Data analysis is all about breaking up data into smaller parts and then examining these parts for better understanding (Schiellerup, 2008). Qualitative analysis refers to the analysis of qualitative data like interview transcripts (i.e., text data). The importance of qualitative analysis is to make sense or understand the study phenomenon (Bhattacherjee, 2012). Qualitative data analysis comprises content analysis, grounded theory, narrative analysis, discourse analysis, conversation analysis (Silverman, 2017), and thematic analysis (Braun & Clarke, 2006). To analyse the data for this study, thematic analysis was used. Thematic analysis is appropriate for emerging qualitative studies with textual data from semi-structured interviews and observation notes (Kondracki et al., 2002). Thematic analysis is a technique for identifying, analysing and reporting data patterns (themes). It organises and describes the data set in detail. It often goes beyond this, interpreting different aspects of the research topic (Braun & Clarke, 2006). According to Clarke and Braun (2013), thematic analysis is suitable for a wide range of research interests and theoretical perspectives, and it is useful because:

- It is applicable to a wide range of research questions, including those involving people's understanding or experiences and the representation and creation of specific phenomena within specific contexts.
- it can be used to analyse a variety of data, from primary data such as transcripts of interviews or focus groups to secondary data such as media.
- It is effective for both large and small data sets.
- It can be used to perform data-driven or theory-driven analyses.

The interviews with participants were digitally recorded and reproduced verbatim in writing. It was then subjected to qualitative thematic analysis where categories and themes were identified from the data. Saldana's (2016) coding manual assists researchers in understanding the coding process and concepts, and how it develops into categories and themes.

With the diagram in Figure 3.2, the author illustrates "a streamlined codes-to-theory model for qualitative inquiry". Miles and Huberman (1994, cited in Neuman, 2011b:510) note that "…codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study. Codes usually are attached to chunks of varying size-words, phases, sentences or whole paragraphs, connected or unconnected to a specific setting".

Qualitative thematic analysis was employed with meaningful, interpretive and descriptive tools to organise and analyse appropriate data obtained from the interview. A thematic coding system can be used to analyse qualitative data by reading through all data thoroughly, summarising all data gathered, noting all categories that appear in the data, grouping important concepts into themes, and identifying important themes based on how they appeared in the groups. This method allows the researcher to examine documents and text to detect themes that emerge and identify similar and recurrent themes (Quinlan, 2011).

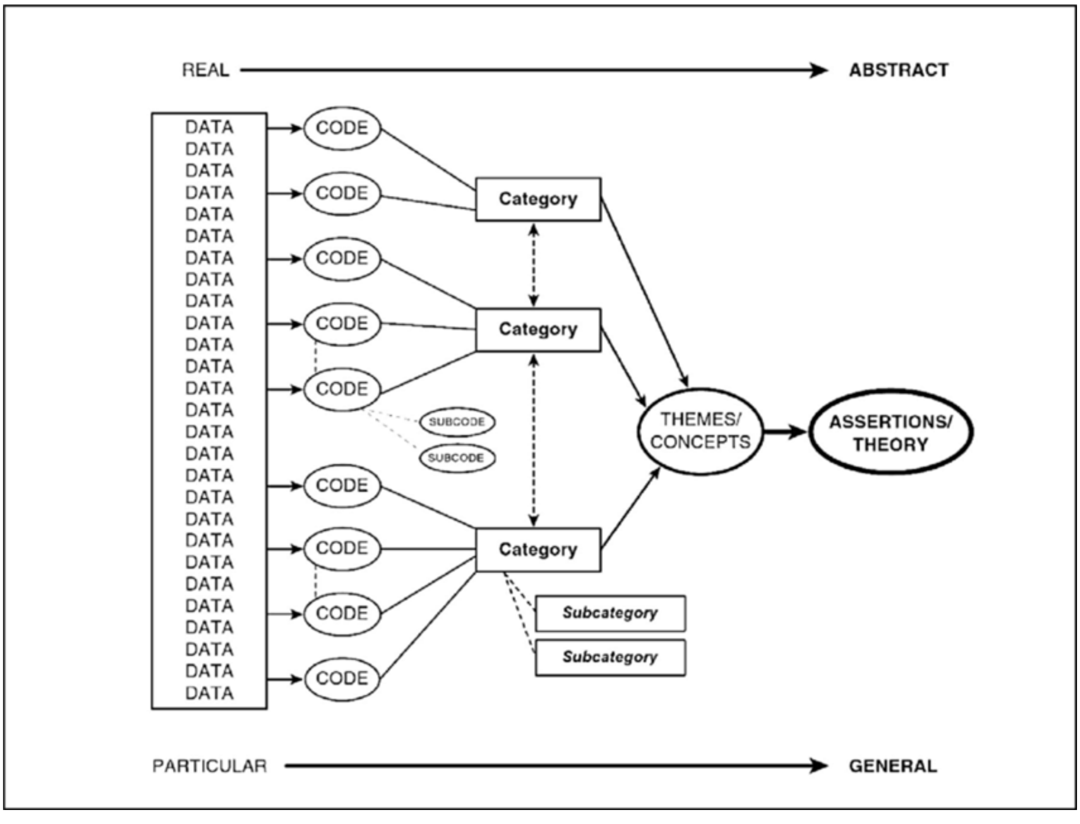


Figure 3.2: A streamlined codes-to-theory model for qualitative inquiry
(Source: Saldana, 2016:14)

3.10 Research quality assurance

Research quality was considered by adhering to the quality standards of validity and reliability (credibility). ***Validity*** refers to the credibility of research interpretations, and ***reliability*** means the research procedure needs to be documented to ensure consistency and dependability (Silverman, 2017). Credibility can also be enhanced by providing participants with relevant information prior to the interview. A list of themes will also promote validity and reliability, because the participants are allowed to prepare and assemble supporting institutional documents (Saunders et al., 2009). Furthermore, a valid study collects and interprets data in a way that the conclusions properly reflect and represent the real world under study (Yin, 2011).

3.10.1 Validity and reliability

The interview questions measured what they were supposed to measure as the researcher provided participants with insights on the information requested. Participants were given information regarding the study, such as the title, aim, data collection methods and interview protocol of the study. This gave them insight into the study and enabled them to prepare (e.g., assemble supporting documents) for the interview. The following steps were taken to ensure the validity and reliability (credibility) of the research:

- A **pilot study** was conducted with a volunteer manager in the field to validate the interview protocol. A debriefing in the form of comments was requested from the participant. Including a volunteer assured that the interview questions were suitable and would capture the correct data. The volunteer suggested that certain protocols be followed, such as a thorough introduction to the study before moving on to the actual interview, and the company's business and culture should be known. Minor modification was made to the data collection instruments where necessary (Saunders et al., 2009).
- The researcher strictly adhered to the design methods and interview protocol during the data collection process.
- The interview date and time were carefully selected to ensure that the data collection process was not influenced by events.
- The collected data came from precise and trustworthy sources.
- Interviews were digitally recorded, and verbatim transcriptions were compiled.
- Different data sources were triangulated by examining evidence from the sources, and themes were established (Creswell & Creswell, 2018).
- Monette et al. (2014:443) note that efforts should be made to validate research findings in qualitative research with existing theories and valid facts to justify the implication of the findings. Thus, this study adopted the inductive approach, and the findings from the study were inferred back to existing constructs and theories in the literature.

3.10.2 Confirmability and dependability

According to Bradley (1993:437), *confirmability* is "the extent to which the characteristics of the data, as posited by the researcher, can be confirmed by others who read or reviewed the research results". And *dependability* is "the coherence of the internal process and the way the researcher accounts for changing conditions in the phenomena".

The main method of showing dependability and confirmability is by reviewing the research processes and findings. So, dependability was assessed by examining the coherence of the research processes, while confirmability was determined by examining the internal consistency of the research product, such as the data, findings, interpretations and recommendations.

3.11 Ethical reflections

According to the Merriam Webster Dictionary, ethics refers to "a set of moral principles, a theory or system of moral values" (Silverman, 2017:59). Alternatively, it means adhering to a group's set of beliefs. This study was conducted in an entirely ethical and reflective manner. The data were presented without any manipulation of the findings in accordance with the Research Ethics Committee of the Faculty of Informatics and Design at the Cape Peninsula University of Technology. Furthermore, research ethics were applied throughout the study. Presented below are the accounts of the ethical reflections in this study.

3.11.1 Approval and permission

Approval and permission for this study started at the Research Ethics Committee (REC) established by the Cape Peninsula University of Technology (Silverman, 2017). Firstly, the research title was subjected to a thorough title search. Secondly, the proposal went through a double-blind review, whereafter a public defence was done. Approval was granted by the Faculty's REC after permission approval for data collection from the identified institution was submitted to REC. Data collection was only permissible if the identified institution granted that privilege to the researcher. So, the research title, aim, objectives and data collection methods were explained to the researched institution. Permission was granted by the institution through an official letter (Appendices B & C).

3.11.2 Informed consent

Information about the study, the researcher, interview protocol, data to be collected, how data are to be used, and how participants rights will be protected, was provided. For instance, participants were informed that the requested information was needed for academic purposes (Doctoral thesis, conferences, and articles) and that such information would not be used against them. Although the research is intended to inform decisions and policy makers, the information may be used by affected government sectors and organisations to advise developmental strategies.

A form (i.e., informed consent) that clearly explains the participants rights to take part in the research as well as the right to withdraw was signed by all participants before their responses were recorded (Bhattacherjee, 2012). The signed form shows an agreement to participate in the study (Appendix E).

3.11.3 Anonymity and confidentiality

Two main constructs (anonymity and confidentiality) were applied to protect the identities and interests of both the firm and the subjects. Anonymity implies that participants stay nameless. Confidentiality implies that the identity of participants will not be made known, but their responses can be identified (Berg, 2001; Bhattacherjee, 2012). Therefore, a pseudonym (fake or false name) was used where possible throughout in the study to maintain the subjects'/institution's anonymity. In terms of confidentiality, no personal information of the subjects/institution was revealed. Data protection and storage in secure locations all ensured anonymity and confidentiality. The collected data (voice or documentation) were encrypted and kept in a password-controlled environment. Furthermore, the data were only used for this study.

3.11.4 Voluntary participation and harmlessness

Participation was completely voluntary as participants were not required to sign away their rights when they agreed to participate as subjects. Subjects were informed of their rights to refuse participation or withdraw from the study at any time and for whatever reason. Subjects were not coerced to participate in the study as consent was freely given. The study excluded potential subjects who could not provide informed consent. The interview process did not cause any arguments or harm to the participants. Respect was shown to all the participants (Silverman, 2017). Lastly, the study did not involve any processes or materials that could harm the environment.

3.11.5 Literature sources

It is ethical to build on the work of others. Therefore, all literature sources were properly cited and acknowledged as the present study rests on previous studies. Literature sources were accessed and considered with regard to relevance to this study.

3.12 Conclusion to Chapter Three

Chapter Three presented an overview of the research philosophy and methodology used. The ontology and epistemology the study followed were presented, and the research paradigm was highlighted. The ontological stance was identified as subjectivism, which holds that phenomena exist because of social interaction and decisions based on actors' perceptions. The epistemological view was identified as interpretivism, which holds that reality is determined by the observer's subjective interpretation. The study was therefore founded on the philosophical paradigm classification of interpretivism, with the aim to understand the reasons behind the failure of institutions to adopt a smart water meter system to improve the efficiency of water management for a sustainable future. This interpretivist paradigm underpinning the study informed the research approach, methodological choice, research strategy and data collection techniques.

The study adopted an inductive approach to theory inference and was designed based on qualitative research. The embedded case study strategy was selected to provide answers to the research questions. The data collection techniques of this exploratory study were semi-structured, in-depth interviews, document review and literature review. Further, the research quality was accomplished by addressing validity, reliability, confirmability and the ethical concerns related to the study.

Chapter Four presents the fieldwork report and data analysis of the study.

CHAPTER FOUR: FIELDWORK REPORT AND DATA ANALYSIS

4.1 Introduction

Chapter Four reports on how the fieldwork progressed. It demonstrates that standards were followed, increasing the dependability of the findings. The chapter presents the institution used as a case in the study. The institution was selected based on the following criteria: (i) it is a government-owned water provider recognised as using ICT within their institution and with the potential to use a smart water meter system (SWMS); (ii) willingness to participate in the study; and (iii) outstanding achievements in its water service in the southeastern part of Nigeria.

The main source of documentation for this study was available documentation from the researched Water Institution website, reports and ICT implementation documents from the institution related to the study to account for actual local practice. Interview data also provided information about the institution.

The following are the main issues addressed in this chapter:

- Section 4.2. Overview of the study area, with a description of the institution and governing body.
- Section 4.3. Participant sampling
- Section 4.4. Performing qualitative thematic analysis to data collected
- Section 4.5. The conclusion of the chapter

4.2 Overview of the study area

This study took place in a water provider institution located in the southeastern part of Nigeria. The institution is located in an urban area of the state. The urban area of the state has a population density of about 1,741 people per square kilometre. In most parts of the city, pipe-borne water supplies are rare.

The seasonal pattern of rainfall has some effects on the urban area’s water supply. Many streams and rivers dry up from November to March when the region receives almost no rainfall, and the water sources that do survive during this time experience a low stage. This "low stage" implies that the volume of water in surviving water sources has decreased significantly, affecting the environments and human activities that rely on these resources. As the rains fall, the river waters start to rise until they reach a peak discharge in mid-October. Additionally, rainfall has a significant influence on the amount of water available in wells and rivers for water supply.

4.2.1 Description of the institution

The institution was purposively selected for this study. Pseudonyms are used to identify the research institution and participants. Vogt et al. (2012) note the challenge associated with “anonymity in the case of institutions”. Although some of the participants gave consent for their names to be used, pseudonyms promote protection and easy writing.

This institution, referred to as the **Water Institution** hereafter, was established in the 1990s. It is a licensed state-owned business in the water sector, with the government as the main shareholder. The Water Institution is granted ownership of all current and future state-owned water infrastructures in the urban areas of the state. This Water Institution was chosen for its outstanding achievements in its water utility service in the southeastern part of Nigeria and for having the potential to use a SWMS. The objectives of the Water Institution include, but are not limited to, the provision of adequate, safe and affordable water services to residents within urban areas of the state and ensuring that the supply of water for domestic use takes priority over the supply for any other use.

The core functions of the Water Institution are to: deliver water services in urban areas and to maintain facilities owned by the institution; develop, operate, control, construct, maintain and expand new waterworks and equipment as the institution may deem necessary to provide clean, potable water for public consumption as well as water for commercial, scientific, industrial, and domestic uses; produce water and create customer interfaces such as metering, revenue collection, billing and customer service; and provide an enabling environment, management, and internal support.

4.2.2 The Water Institution’s governing body

The governing body of the Water Institution is appointed by the Governor of the State. The board of directors consists of a Chairman with a minimum of five years proven experience, Managing Director, secretary, Executive Director Finance, Executive Director Commercial, and Executive Director Engineering. These officials are ex-officio members. The Board makes strategic decisions regarding the Water Institution’s mission and activities, and approves and monitors the implementation of business plans, performance, and the budget. Further, the Board provides the Water Institution with leadership and vision to enhance shareholder value and achieve growth, sustainability and competitiveness.

The Managing Director/Chief Executive Officer is responsible for the implementation of the policies and decisions of the Board, overall administration of the Water Institution, and staff matters. The Managing Director creates other technical and administrative departments as deemed necessary in accordance with current national and international standards in water sector administration for the proper discharge of the Water Institution's functions and the accomplishment of its objectives.

4.3 Participant sampling

The participants for this study were staff members of the researched Water Institution. Participants were selected purposively based on their expertise in water management and being the most representative individual(s) from the water institution, as shown in Table 4.1. This exploratory study aimed at gaining a better understanding of the factors influencing and limiting institutional adoption of Smart Water Meter Systems (SWMSs); perceptions of using SWMS for water management; how SWMSs can be adopted as part of the water management method; and the government's role or support towards using and adopting a SWMS.

4.3.1 Participant description

Eleven (11) individuals were selected to participate in the research process. The participants are experts in the operations of water management, that is, they are managers from the **Water Institution** in the southeastern part of Nigeria. The sample selection was based on the premise that, as managers, they are most expected to provide insights on which the researcher can build understanding (Saunders et al., 2019). Table 4.1 presents the participants' respective departments, positions and pseudonyms used to maintain their anonymity.

Table 4.1: Participants' profile from the Water Institution

Department	**Position (Rank)**	**Participant Code P= Participant**
Monitoring and Evaluation	Assistant Chief Scientific Officer	Participant 1
Billing	Head Billing Unit	Participant 2
Operation/Distribution	Consultant	Participant 3
Geology	Chief Hydrology Geologist	Participant 4
Monitoring and Evaluation	Monitoring and Evaluation Officer	Participant 5
Production	Manager (in charge of water scheme production)	Participant 6
Operation/Distribution	Operation/Distribution Manager	Participant 7
Commercial	Head of Department Commercial	Participant 8
Engineering	Manager (in charge of repairs)	Participant 9
ICT	ICT manager (also in charge of smart meter prepayment – prepaid meter)	Participant 10
Monitoring and Evaluation	Chief Monitoring and Evaluation	Participant 11

During the interview sessions, the researcher observed that there were desktop workstations in the offices. There were a few interruptions during the interviews partly because some of the participants shared offices, and because participants were managers; as a result, their attention were needed at intervals. All interviewees said they use traditional water meters in their homes, and they speak English, albeit as a second language.

4.3.2 Transcribing the interview

This sub-section explains how the researcher used the data after it was gathered. The first step after completion of the data collection process was to present the data in written form in accordance with Saunders et al. (2009). This was accomplished through a transcription process where the researcher listened to the recorded interview sessions and typed them verbatim in Microsoft (MS) Word. Some recorded interviews were so lengthy that it took days to type them in MS Word. To accurately record conversations and interviews, transcriptions calls for tremendous patience.

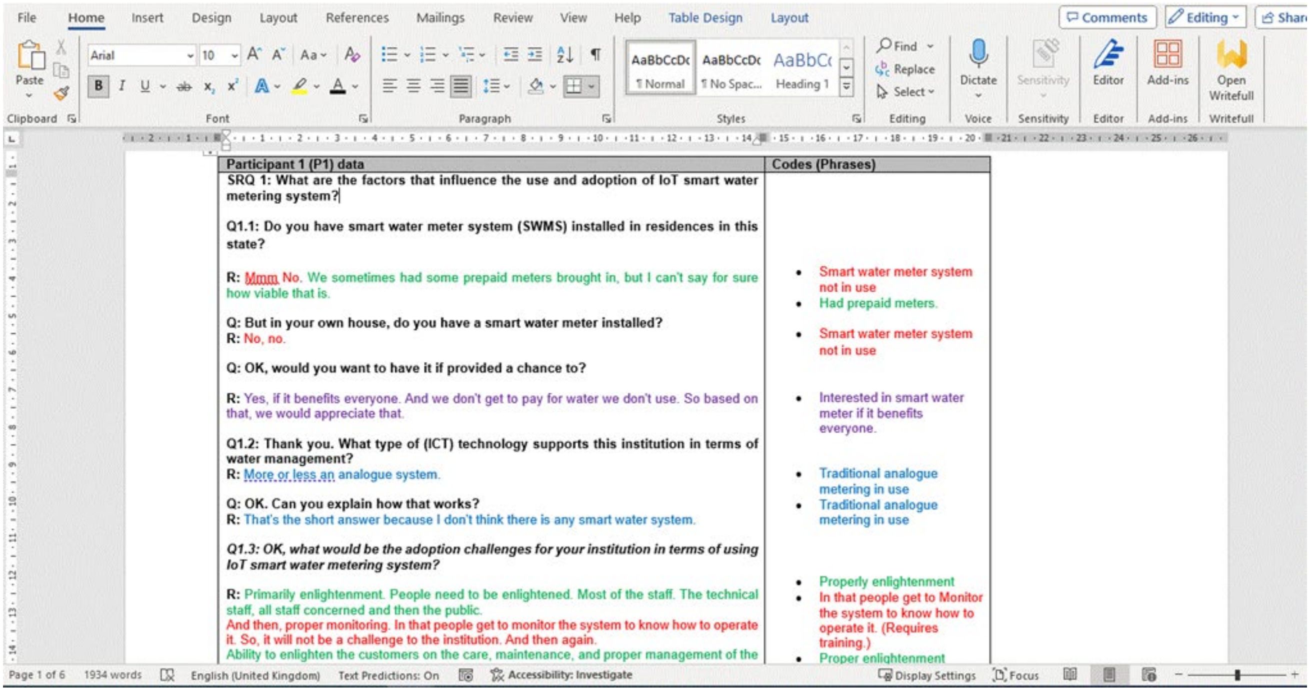
4.4 Performing qualitative thematic analysis

A variety of coding methods were used during the analysis. Firstly, the researcher took some time to digest and reflect on the data before starting the initial coding process. The *initial coding* provided the researcher with analytic leads to determine the path the study should take. During the initial coding process, *in vivo coding* was employed whereby codes (phrases and concepts) were taken from the participants' own words. This enabled the researcher to capture the meanings that are ingrained in people's experiences. Furthermore, *values* coding was used to reflect on participants' attitudes, beliefs and values, representing their worldviews or perspectives. *Value* is the importance we place on ourselves, another person, an idea or a thing (Saldana, 2016). "The greater the personal meaning of something to someone, the greater the personal payoff; the greater the personal payoff, the greater the personal value" (Saldana, 2016). The participants' emotions were also coded. The codes were combined and aggregated to create categories.

4.4.1 The analysis process

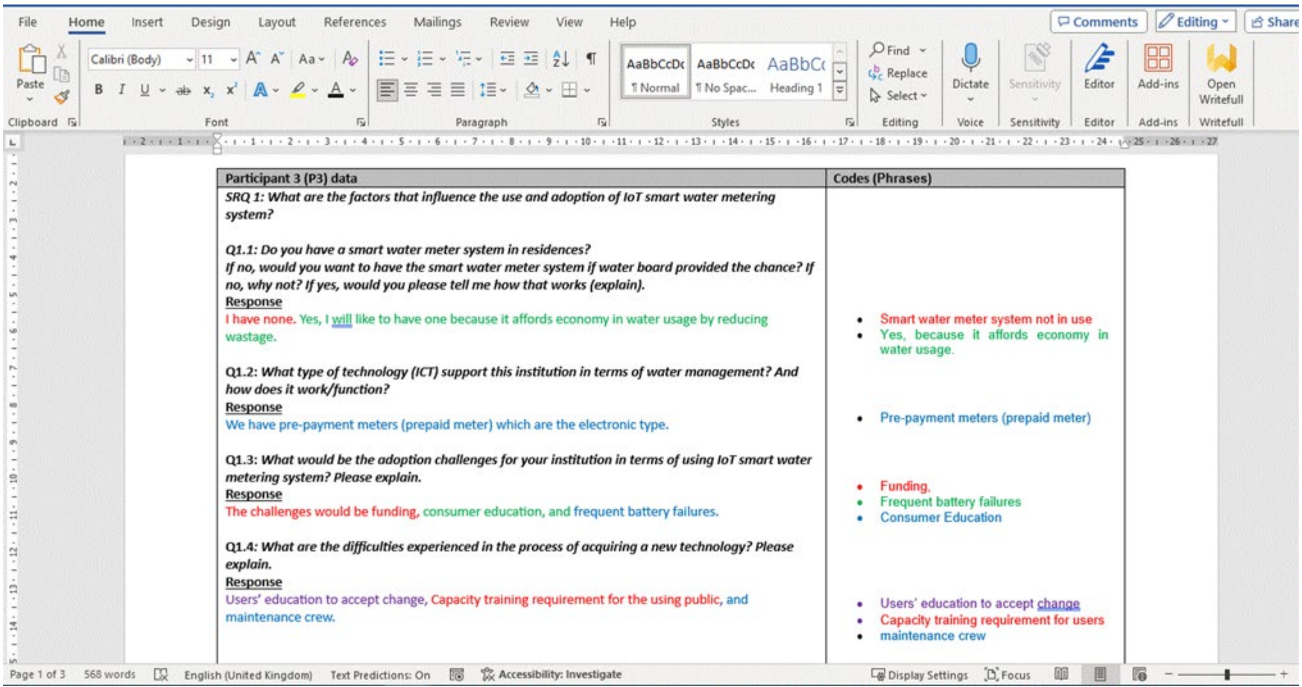
Several coding steps were involved during the interview data analysis process before the categories and themes reported in this study were determined. The following steps were taken:

- The transcribed interview data served as the units of analysis during the analysis process.
- Several readings of the transcriptions were made to ensure that the texts were fully absorbed and understood.
- Figures 4.1, 4.2 and 4.3 show text highlighted with font colours and identified with codes (i.e., phrases and keywords) as the text suggested meanings.



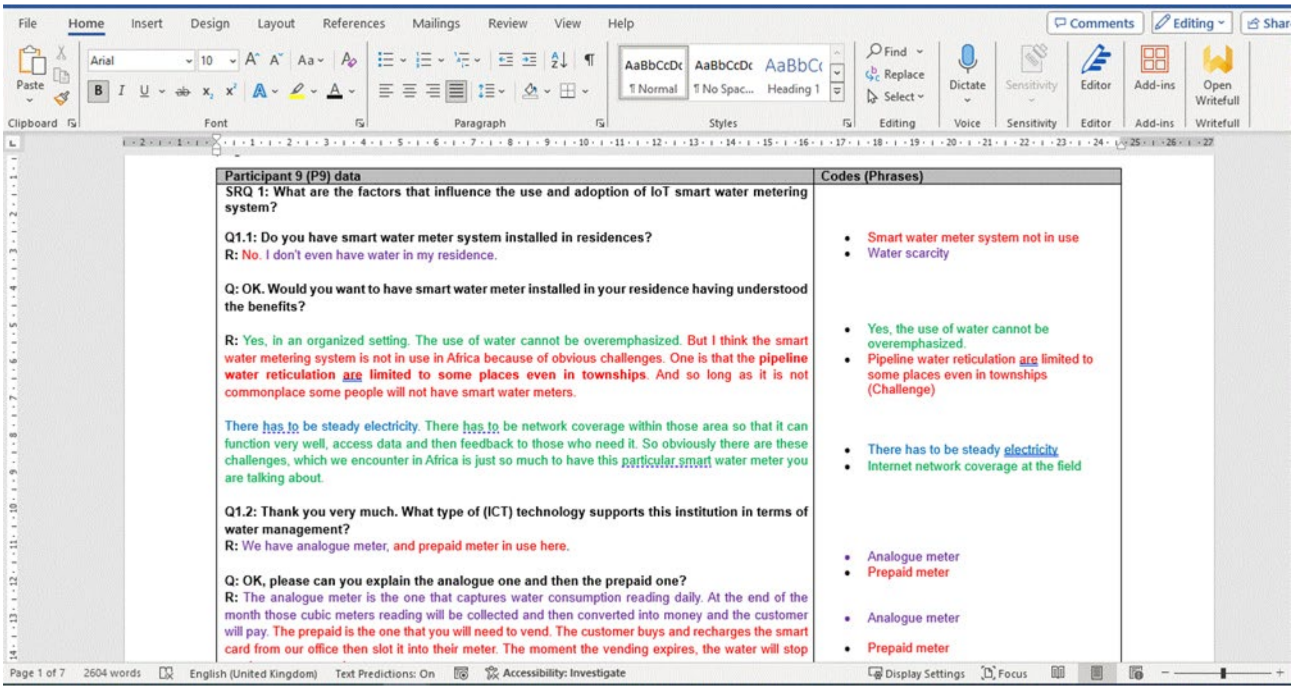
Participant 1 (P1) data	Codes (Phrases)
SRQ 1: What are the factors that influence the use and adoption of IoT smart water metering system?	
Q1.1: Do you have smart water meter system (SWMS) installed in residences in this state?	
R: Mmm No. We sometimes had some prepaid meters brought in, but I can't say for sure how viable that is.	• Smart water meter system not in use • Had prepaid meters.
Q: But in your own house, do you have a smart water meter installed? **R:** No, no.	• Smart water meter system not in use
Q: OK, would you want to have it if provided a chance to?	
R: Yes, if it benefits everyone. And we don't get to pay for water we don't use. So based on that, we would appreciate that.	• Interested in smart water meter if it benefits everyone.
Q1.2: Thank you. What type of (ICT) technology supports this institution in terms of water management? **R:** More or less an analogue system.	• Traditional analogue metering in use
Q: OK. Can you explain how that works? **R:** That's the short answer because I don't think there is any smart water system.	• Traditional analogue metering in use
Q1.3: OK, what would be the adoption challenges for your institution in terms of using IoT smart water metering system?	
R: Primarily enlightenment. People need to be enlightened. Most of the staff. The technical staff, all staff concerned and then the public. And then, proper monitoring. In that people get to monitor the system to know how to operate it. So, it will not be a challenge to the institution. And then again. Ability to enlighten the customers on the care, maintenance, and proper management of the	• Properly enlightenment • In that people get to Monitor the system to know how to operate it. (Requires training.) • Proper enlightenment

Figure 4.1: Sample of data coding for Participant 1 (P1)



Participant 3 (P3) data	Codes (Phrases)
SRQ 1: What are the factors that influence the use and adoption of IoT smart water metering system?	
Q1.1: Do you have a smart water meter system in residences? If no, would you want to have the smart water meter system if water board provided the chance? If no, why not? If yes, would you please tell me how that works (explain). **Response** I have none. Yes, I will like to have one because it affords economy in water usage by reducing wastage.	• Smart water meter system not in use • Yes, because it affords economy in water usage.
Q1.2: What type of technology (ICT) support this institution in terms of water management? And how does it work/function? **Response** We have pre-payment meters (prepaid meter) which are the electronic type.	• Pre-payment meters (prepaid meter)
Q1.3: What would be the adoption challenges for your institution in terms of using IoT smart water metering system? Please explain. **Response** The challenges would be funding, consumer education, and frequent battery failures.	• Funding, • Frequent battery failures • Consumer Education
Q1.4: What are the difficulties experienced in the process of acquiring a new technology? Please explain. **Response** Users' education to accept change, Capacity training requirement for the using public, and maintenance crew.	• Users' education to accept change • Capacity training requirement for users • maintenance crew

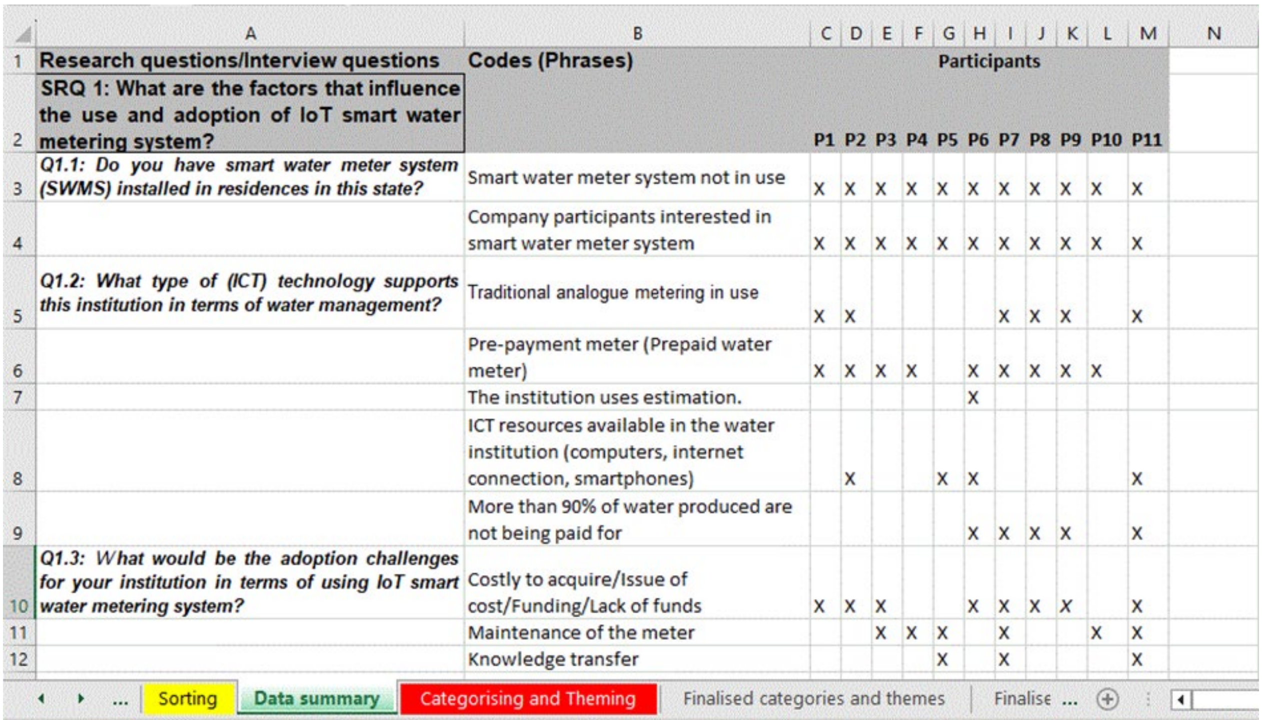
Figure 4.2: Sample of data coding for Participant 3 (P3)



Participant 9 (P9) data	Codes (Phrases)
SRQ 1: What are the factors that influence the use and adoption of IoT smart water metering system?	
Q1.1: Do you have smart water meter system installed in residences? **R:** No. I don't even have water in my residence.	• Smart water meter system not in use • Water scarcity
Q: OK. Would you want to have smart water meter installed in your residence having understood the benefits?	
R: Yes, in an organized setting. The use of water cannot be overemphasized. But I think the smart water metering system is not in use in Africa because of obvious challenges. One is that the **pipeline water reticulation are limited to some places even in townships**. And so long as it is not commonplace some people will not have smart water meters.	• Yes, the use of water cannot be overemphasized. • Pipeline water reticulation are limited to some places even in townships (Challenge)
There has to be steady electricity. There has to be network coverage within those area so that it can function very well, access data and then feedback to those who need it. So obviously there are these challenges, which we encounter in Africa is just so much to have this particular smart water meter you are talking about.	• There has to be steady electricity • Internet network coverage at the field
Q1.2: Thank you very much. What type of (ICT) technology supports this institution in terms of water management? **R:** We have analogue meter, and prepaid meter in use here.	• Analogue meter • Prepaid meter
Q: OK, please can you explain the analogue one and then the prepaid one? **R:** The analogue meter is the one that captures water consumption reading daily. At the end of the month those cubic meters reading will be collected and then converted into money and the customer will pay. The prepaid is the one that you will need to vend. The customer buys and recharges the smart card from our office then slot it into their meter. The moment the vending expires, the water will stop	• Analogue meter • Prepaid meter

Figure 4.3: Sample of data coding for Participant 9 (P9)

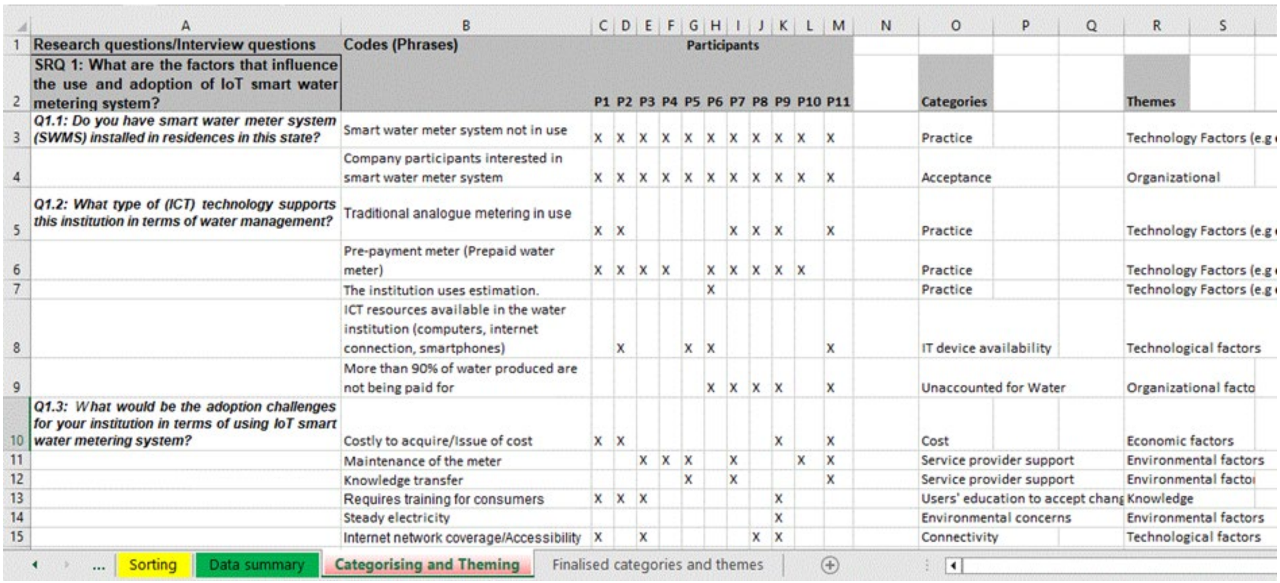
- Codes were then summarised by finding similarities and dissimilarities between participants as presented in Figure 4.4.



	Research questions/Interview questions	Codes (Phrases)	Participants										
2	**SRQ 1: What are the factors that influence the use and adoption of IoT smart water metering system?**		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
3	*Q1.1: Do you have smart water meter system (SWMS) installed in residences in this state?*	Smart water meter system not in use	X	X	X	X	X	X	X	X	X	X	X
4		Company participants interested in smart water meter system	X	X	X	X	X	X	X	X	X	X	X
5	*Q1.2: What type of (ICT) technology supports this institution in terms of water management?*	Traditional analogue metering in use	X	X					X	X	X		X
6		Pre-payment meter (Prepaid water meter)	X	X	X	X		X	X	X	X	X	
7		The institution uses estimation.						X					
8		ICT resources available in the water institution (computers, internet connection, smartphones)		X			X	X					X
9		More than 90% of water produced are not being paid for						X	X	X	X		X
10	*Q1.3: What would be the adoption challenges for your institution in terms of using IoT smart water metering system?*	Costly to acquire/Issue of cost/Funding/Lack of funds	X	X	X			X	X	X	X		X
11		Maintenance of the meter			X	X	X		X			X	X
12		Knowledge transfer					X		X				X

Figure 4.4: Data summary for participants

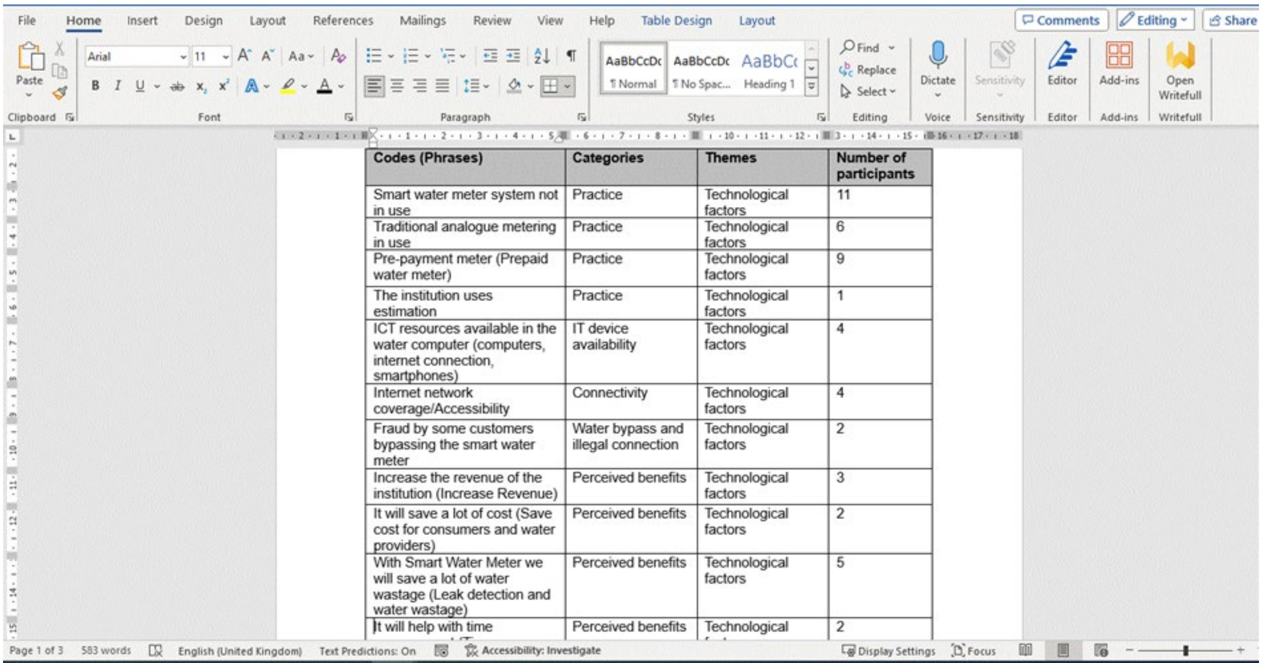
- Figure 4.5 shows the categorising and theming of codes process.



	Research questions/Interview questions	Codes (Phrases)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Categories	Themes
2	SRQ 1: What are the factors that influence the use and adoption of IoT smart water metering system?														
3	*Q1.1: Do you have smart water meter system (SWMS) installed in residences in this state?*	Smart water meter system not in use	X	X	X	X	X	X	X	X	X	X	X	Practice	Technology Factors (e.g
4		Company participants interested in smart water meter system	X	X	X	X	X	X	X	X	X	X	X	Acceptance	Organizational
5	*Q1.2: What type of (ICT) technology supports this institution in terms of water management?*	Traditional analogue metering in use	X	X					X	X	X		X	Practice	Technology Factors (e.g
6		Pre-payment meter (Prepaid water meter)	X	X	X	X		X	X	X	X	X		Practice	Technology Factors (e.g
7		The institution uses estimation.						X						Practice	Technology Factors (e.g
8		ICT resources available in the water institution (computers, internet connection, smartphones)		X			X	X					X	IT device availability	Technological factors
9		More than 90% of water produced are not being paid for						X	X	X	X		X	Unaccounted for Water	Organizational facto
10	*Q1.3: What would be the adoption challenges for your institution in terms of using IoT smart water metering system?*	Costly to acquire/Issue of cost	X	X							X		X	Cost	Economic factors
11		Maintenance of the meter			X	X	X		X			X	X	Service provider support	Environmental factors
12		Knowledge transfer					X		X				X	Service provider support	Environmental factoı
13		Requires training for consumers	X	X	X						X			Users' education to accept chang	Knowledge
14		Steady electricity									X			Environmental concerns	Environmental factors
15		Internet network coverage/Accessibility	X		X					X	X			Connectivity	Technological factors

Figure 4.5: Categorising and theming of the codes

- Figure 4.6 displays the categories and themes for this study. Appendix G contains the complete classification of these codes into categories and themes. Appendix G was considered too lengthy to be included in the main body of the thesis.



Codes (Phrases)	Categories	Themes	Number of participants
Smart water meter system not in use	Practice	Technological factors	11
Traditional analogue metering in use	Practice	Technological factors	6
Pre-payment meter (Prepaid water meter)	Practice	Technological factors	9
The institution uses estimation	Practice	Technological factors	1
ICT resources available in the water computer (computers, internet connection, smartphones)	IT device availability	Technological factors	4
Internet network coverage/Accessibility	Connectivity	Technological factors	4
Fraud by some customers bypassing the smart water meter	Water bypass and illegal connection	Technological factors	2
Increase the revenue of the institution (Increase Revenue)	Perceived benefits	Technological factors	3
It will save a lot of cost (Save cost for consumers and water providers)	Perceived benefits	Technological factors	2
With Smart Water Meter we will save a lot of water wastage (Leak detection and water wastage)	Perceived benefits	Technological factors	5
It will help with time	Perceived benefits	Technological	2

Figure 4.6: Finalised categories and themes

4.4.2 The categories and themes after analysis

A total of nineteen (19) categories emerged after following the process of aggregating and concatenating codes from interview data. These categories were largely derived from interview data, interview protocol questions, and common-sense constructs. The categories were then themed, resulting in a total of six (6) themes. These themes also came from common-sense constructs and theoretical literature explaining the phenomenon under study (Ryan & Bernard, 2003; Bhattacherjee, 2012). A summary of the categories and themes that emerged from this study is presented in Table 4.2.

Table 4.2: Summary of categories and themes

Categories	**Themes**
Practice IT device availability Connectivity Water bypass and illegal connection Perceived benefits	Technological factors
Acceptance Experts and technicians Logistics/adoption framework Unaccounted-for water	Organisational factors
Service provider support Environmental concerns Government support Government policy	Environmental factors
Cost and funding	Economic factors
Technology awareness Users' education to accept change	Knowledge
Pilot scheme	Trialability

The study produced six themes, three of which fit into the Technology-Organisation-Environment (TOE) framework (Tornatzky et al., 1990). The TOE framework themes are: (i) Technological factors; (ii) Organisational factors; and (iii) Environmental factors. The other three themes are: (iv) Economic factors; (v) Knowledge; and (vi) Trialability. These themes are based on how categories are interpreted. The findings were used to create a recommendation and an inductive inference to supplement related theories. This was done to contribute to a sustainable IS framework for SWMS adoption.

4.5 Conclusion to Chapter Four

The fieldwork was challenging and exciting because the researched Water Institution is in the southeastern part of Nigeria. The chapter described the researched Water Institution and the governing body. Data were collected from available relevant documents, and from the eleven participants.

The chapter presented information about the participants, the interview data transcription process, and the thematic analytical process where different coding methods were employed. Finally, the categories and themes were presented after a conclusive induction.

Chapter Five provides a comprehensive thematic presentation of the research findings.

CHAPTER FIVE: THE RESEARCH FINDINGS

5.1 Introduction

This chapter presents the detailed findings of the embedded case study on adopting an IoT-based smart water meter system (SWMS). The findings are founded on the analysis of the empirical data gathered from the Water Institution located in Nigeria and used as a case study. The findings report on SWMS, bringing together the Technology-Organisation-Environment (TOE) framework elements (section 2.9.3) such as technological factors of an institution towards SWMS adoption.

Thematic presentation of findings

The following section provides a thematic presentation of the SWMS findings:

- Section 5.2. Technological factors
- Section 5.3. Organisational factors
- Section 5.4. Environmental factors
- Section 5.5. Economic factors
- Section 5.6. Knowledge
- Section 5.7. Trialability
- Section 5.8. Conclusion of the chapter

The themes are connected to the corresponding categories (Appendix G), which are the result of aggregating and concatenating codes that were determined to share characteristics during the analysis stage. The categories and themes presented here largely emerged from interview data, interview protocol questions, common-sense constructs and theoretical literature explaining the phenomenon under study.

The **Technological factors** theme is discussed in the following section. The findings are based on in-depth interviews with participants (described in Table 4.1).

5.2 Technological factors

The ***Technological factors*** theme includes internal and external variables that affect an organisation's willingness to accept innovation. Internal technologies are practices and technologies in the organisation, while external technologies are those available on the market but not yet in use by the organisation. The theme includes findings on the challenges the researched Water Institution may have regarding SWMS adoption.

There are five categories for this theme:

i) *Practice*
ii) *IT device availability*
iii) *Connectivity*
iv) *Water bypass and illegal connection*
v) *Perceived benefits*

5.2.1 Practice

The **Practice** category describes the actual practices of water management by the researched Water Institution. This category was created with significant sub-categories, such as:

- *No smart water meter system* – indicates that a SWMS is not in use by the researched Water Institution.
- *Traditional analogue metering* – indicates one of the technologies in use for water management and how it works.
- *Prepaid water meter* – indicates another technology in use for water management and how it works.
- *Estimation* – indicates one of the practices used by the researched Water Institution for water billing.

5.2.1.1 No smart water meter system

All the participants (11 in total) (100%) from the researched Water Institution noted that a SWMS is not in use or installed in customers' residences in the state. The following responses demonstrate this when participants were asked whether a SWMS is installed in residences:

Participant 1 said: "Mmm No". Participant 4 stated: "I do not have a smart water meter system in my house". Participant 6 indicated: "No. We do not have it… that smart water meter is what we do not have, and some other things that are associated to it". Participant 9 stated: "No. I don't even have water in my residence". The lack of a SWMS in residences for water management is further demonstrated by Participant 11 who said: "Of course not, because I am just hearing about it now". Participants 2, 3, 5, and 7 also noted that they do not have a SWMS installed in residences (Appendix F: pages 1, 5, 9, 11, 13, 16, 17, 21, 25, 32, 37 & 44).

Interestingly, 27% of the participants just heard about the SWMS during the fieldwork data collection as is evident in the responses of Participants 8, 10 and 11 who described the prepaid water meter as a SWMS (Appendix F: pages 25, 37, 38 & 44). It was brought to their attention that the prepaid water meter is not SWMS, that the characteristics differ. As a SWMS is not adopted or in use, determining the type of technology used for water management by the researched institution is essential. Findings show that various water management practices exist in the researched Water Institution, such as traditional analogue water metering, estimation, and prepaid water meter.

5.2.1.2 Traditional analogue water metering

Six of the eleven participants (55%) stated that the researched Water Institution uses the traditional analogue water meter. Participant 2 said: “We have an analogue meter that one is postpaid. We have it in our homes… The reading from the analogue, that’s what we have now” (Appendix F: page 5). Participant 8 stated: “The other meters we have here are analogue, which is subject to manual reading. So, when we go to the field, we have analogue meters” (Appendix F: page 26). Participant 11 indicated: “It is … analogue. It is not robust to communicate information as the smart water meter” (Appendix F: page 44). Participants 1, 7 and 9 also noted that they have the analogue water meter in their homes (Appendix F: pages 1, 21 & 32). Interestingly, Participant 2 noted that the dominant meter in homes is the analogue water meter. On cost, Participant 9 indicated that “the analogue meter doesn’t come with any cost, just that at the end of the month, you take the reading and convert it to money”.

On how the analogue water meter works, Participant 8 explained that they go to the field (e.g., residences, hotels, institutions, etc.) with their notebook (logbook) to read and record meter readings. They record the meter reading together with the people working there. So, both parties will confirm that what is written down is the correct record of the meter reading and meter rate for clarity purposes. The present reading of the meter minus the previous meter reading determines how many cubic meters the person consumed within a time frame, which is then multiplied by calculation per cubic meter. Participant 8 further said: “For example, now we are having a new tariff of N230 Naira per cubic meter. When you compute the difference between the initial meter reading and the final reading, you multiply by N230 to get the charge. That is the volume of consumption at the rate of N230 per the cubic meter. That’s the amount that person will pay, and that is done manually” (Appendix F: page 26). Participant 11 summarised this by saying that “the analogue water meter does give the previous reading and the current reading. The difference between the two readings provides the consumption of water over time. You can now use that to determine the rate for that period by multiplying it with our tariff rate” (Appendix F: page 44).

On the challenges of analogue water meters, Participant 7 indicated that the analogue water meter increases manpower. Participant 7 explained that monthly, they must go to the field (e.g., residences, hotels, institutions, etc.) and pick up readings; then go back to the office to prepare a bill for the customer. For that timeline, there is a challenge of delay to push their bill in time (Appendix F: page 21). Participant 8 noted that the analogue water meter is at risk on the premises where it is installed because they do not have control of the meter as an organisation. In terms of the security of the meter, it is dependent on the place where it is located. Whether it is a hotel or school, they do not have direct daily control/monitoring of the meter. Secondly, Participant 8 explained that if the analogue water meter is located where there is a flood, the meter quickly spoils, and it becomes difficult to read as a flood can destroy elements of the meter; or it becomes difficult to visit the flooded area to take record of the meter reading. Thirdly, Participant 8 noted that during repairs (maintenance) of pipes, at times, some debris (dirt, tiny stones) goes through the pipe network and enters the fan belt of the analogue water meter because the meter has fan. It destroys some elements of the meter, which is the fan. It may cause the meter to stop moving. And when the meter stops moving, water passing through is no longer calculated. Participant 8 continued by saying that the speed of the fan depends on the pressure of the water. If the pressure of the water is high, it will increase the speed of the fan. Then, if the pressure of the water carries objects such as plastic and small stones that block the fan, the pressure will decrease and the fan will no longer work; thus, only a small quantity of the water will pass through, and the customer will be enjoying the water for free. The meter will no longer reflects a reading, and the customer will be enjoying some level of water supply (Appendix F: page 27).

5.2.1.3 Estimation

Only one of the participants (9%) stated that the institution uses estimation for water billing. According to Participant 6, the institution uses estimation in the sense that if a customer stays in a three-bedroom flat, he pays a fixed amount of money. If a customer stays in a one room apartment, he pays a fixed amount of money. If a customer resides in a bungalow, a certain amount is paid. It is fixed, irrespective of how much water the customer uses within a month or the period of billing. Participant 6 further explained that the water bill will still be paid even if a customer locks up his/her apartment and travels. The customer will still pay the same amount of money allocated to the apartment. Even if a customer wastes water, the same amount of money is paid (Appendix F: page 16).

5.2.1.4 Prepaid water meter

This sub-category is one of the water management practices in the researched Water Institution. The sub-category is thus not included in the discussion in Chapter Six as it does not fall within the scope of this study. However, nine of the eleven participants (81%) stated that there is a prepaid water meter in use, although only few customers have it in their homes. Findings also show that the prepaid water meter is being used as a pilot study in a mapped-out location. This is demonstrated by the responses of Participants 1, 2, 3, 4, 6, 7, 8, 9 and 10 (Appendix F: pages 1, 6, 9, 11, 16, 17, 21, 25 & 26).

Participant 2 noted: “Here we have prepaid meter” (Appendix F: page 6). Participant 3 stated: “We have pre-payment meters (prepaid meter) which are the electronic type” (Appendix F: page 9). Participant 4 said: “We have prepaid water meter that you can recharge” (Appendix

F: page 11). Participant 6 said: “In water management. Yeah, we do not have that high technology except some people have a prepaid meter. But it’s few people, less than 1% of the water users that have the prepaid meter” (Appendix F: page 17). Participant 7 noted: “Then we have prepaid meter. Pay as you use” (Appendix F: page 21). In explanation, Participant 8 said: “We have a pilot case study where we have established some areas like GRA, we are using prepaid meter, but it was provided by a contract agreement. About 500 plus prepaid water meter, we are using it at GRA as a pilot study”. Participant 8 continued by saying:

> *“A contractor supplied a prepaid meter, electronics prepaid meter. So, he installed it for us to know the workability of that prepaid meters, and we use GRA as a pilot area. Those meters were installed in some houses. He brought in about 500 plus. And we are looking at the workability. So that is the first prepaid meter we have had and some of them are still in the field up till now”* (Appendix F: pages 25 & 26).

On billing and functionality of the prepaid water meter, six participants (55%) mentioned that the prepaid water meter works the same as recharging for electricity (prepaid) or the pay-as-you-go system used for smartphones. The customer buys and recharges the smart card from the office and then slot it into the prepaid water meter. The moment the vending expires, water will stop flowing into the premises. This viewpoint is consolidated in the responses of Participants 2, 6, 7, 8, 9 and 10 (Appendix F: pages 6, 16, 17, 21, 25, 32 & 37).

Participant 2 said: “That one you can go to the bank and buy as much as you can and insert the card in your meter as soon as the money finishes, the water will stop” (Appendix F: 6). Participant 6 noted: “Just like you recharge for electricity. You buy credit, you recharge, and the water tap starts rushing” (Appendix F: 16 & 17). Participant 7 indicated that “the prepaid meter helped us because we don’t have any challenges in giving the bill because whenever you recharge, and then slot it in the meter, then when your money is off it will close by itself” (Appendix F: page 21). Further illustration on the prepaid water meter billing was provided by Participant 8 who said:

> “*When you go to the bank with the card then You recharge how much you want to pay. For instance, if you are loading for N2000, then you pay for N2000, automatically the N2000 will reflect in that card. When you get home you slot it into the little machine, that is the meter. The meter will collect the amount in that card and automatically opens your tap for water to run. So as the water runs, the amount recharged is being reduced. It is pay as you go system just like smartphones. So, if that money finishes automatically the water will trip off”* (Appendix F: page 25).

Participant 10 also explained that the prepaid meter component is installed in customers premises while the card reader is installed inside the kitchen:

> *"We install it inside the compound where the customer would take it up to his apartment. And the meter component will be installed there connected to the water that will link to the individual apartment. Then the card reader will be installed inside a kitchen whereby, when the person recharges the card and inserts it inside the card reader that will be installed inside the kitchen, the person can vent. That is, it will enable the person to get water. The moment you remove the card from the card reader, the water stops venting"* (Appendix F: page 37).

Participant 10 furthermore said that the meter saves costs for the customers (Appendix F: page 37).

It has been found that prepaid water meters do not function like a SWMS, for example, providing real-time information to customers on water leakages on the premises. Participant 6 said: "It doesn't give you any information, kind of a signal or whatever such as sending message to your phone or internet devices to tell you this is the quantity you have used. It is just, when you recharge, you have water. When you run out of the credits, you will not have water" (Appendix F: page 17). Participant 10 noted: "it does not communicate to the user". In explanation, Participant 10 said: "it sends signal to the server room of the water provider, and they will send maintenance team to go and fix the leakage" (Appendix F: pages 37 & 38).

Interestingly, the findings also show that the researched Water Institution faced or had challenges with the use of the prepaid water meter. These challenges include cost implications, human resources management in the institution, and maintenance of the prepaid meter. This statement is supported by the responses of Participants 2, 4, 6 and 10. In support, Participants 6 pointed out that their major difficulty is funding (Appendix F: page 17). Participants 10 emphasised that "the prepaid meters are very, very expensive because it's not being produced in Africa. Must be shipped from UK. It's capital intensive" (Appendix F: page 39). Participant 4 noted: "Cost implications in the process of acquiring new technology, funding of the projects, and human resources management in the institution. Some bill payments are not co-ordinated in the prepaid meter". Participant 4 also said that "it is not effective because sometime the maintenance culture is poor" (Appendix F: page 11). Participant 2 explained: "We depend on the people and most of the times, the people who installed it, they will be running short of maintenance parts… when you call them for maintenance, it is not easy for them to come" (Appendix F: page 6).

The batteries of the prepaid water meter only last for approximately six months, thereby affecting water supply to customers. The researched Water Institution would normally get fake batteries to change it because the original quality batteries are not readily available. This statement is supported by the responses of Participants 7 and 8. Participant 7 noted:

"The challenges we have on that prepaid meter right now is in changing the battery always because the prepaid uses battery… it really affected us because from time to time, when the battery fails, the customers will not get water again, and for us to get a spare battery is a problem. We normally get fake battery to change it" (Appendix F: page 21).

Furthermore, Participant 8 explained this as follows:

"If the battery goes down, the possibility of getting new batteries to replace them becomes difficult. And we suffer this most in the COVID period because those batteries are overseas. To import those batteries took long time. And for somebody whose meter battery is down, how long will he wait till it gets replaced; so, it becomes a serious issue. So, because of the battery issues, some of these meters are no longer working, so they were demobilised, and they were uninstalled and taken away from the field. But some fields are still using their own whose battery is still effective" (Appendix F: page 26).

Fake batteries are produced with inferior components and materials which affect their lifespan and performance. They are often made to look like genuine brand-name batteries. They can result in issues such as overheating and fast draining.

Findings shows that dust has a negative effect on the sensor of the prepaid meter, which can happen due to the environment where it is installed. Participant 10 explained this by saying: "For example, the prepaid meter unit communicates with the card reader and dust used to have a negative effect on such communication. Dust is a challenge". Participant 10 also said that external forces such as children, users and flood affect the prepaid meter based on the environment (Appendix F: page 39).

5.2.2 IT device availability

The **IT device availability** category denotes the ICT technologies that are available in the researched Water Institution. Four of the eleven participants (36%) identified computer and internet connection as the ICT technologies available in the researched Water Institution that can support the use/adoption of a SWMS. This view is demonstrated in the responses of Participants 2, 5, 6 and 11 (Appendix F: pages 7, 13, 14, 17, 44 & 46).

Participant 6 noted: "We have IT section here, they have Internet, computers, and other things" (Appendix F: page 17). In explanation, Participant 5 said: "1). Computer technology installed in designated offices for data processing and information storage, and 2). Internet for sourcing and/or transferring of information locally and globally". Participant 5 further explained that it is possible for their institution to use a SWMS as a water management approach "because of the digital operations of the corporation which is an integral part of the global world" (Appendix F: pages 13 & 14). In support, Participant 2 stated that "the possibilities of having SWMS are there because they are using the Internet. So is as good as adding to what they have been using". When asked whether the users have a smart device for a SWMS, Participant 2 said: "You know, about 80% of the people are using smartphones. So, it will be easier for them" (Appendix F: page 7). Participant 9 made the following statement about the use of computer and internet connection in their institution:

> *"We have computer. We are in a jet age and every organisation that wants to move with the speed is changing over to computer, so our organisation is not left out. We have computers in designated offices. And that has been helping us a lot in data processing, and we have our staff who are good at that. They gather data, they process it, they come up with information that enhance decision making as the need arises. We also have internet connection which is also technological improvement that everybody is taking advantage of. There is a lot that is being provided through the internet and we are not left out in its benefits"* (Appendix F: page 44).

5.2.3 Connectivity

The **Connectivity** category denotes that ICT resources are needed for a SWMS, such as the availability of an internet connection that is available and reliable, with sufficient network coverage.

The findings reveal that there are many limitations or challenges in IT in Nigeria, such as internet network failures. Four participants (36%) stated that sufficient network coverage is needed for a SWMS to be adopted. This view is supported by the responses from Participants 1, 3, 8 and 9 (Appendix F: pages 4, 10, 29, 32, 33 & 36).

Participant 1 said: "There is a need to put certain things in place, like the Internet… Exactly, internet has to be available" (Appendix F: page 4). Participant 3 stated that the SWMS adoption "may prove initially difficult as internet access is presently limited among water consuming public" (Appendix F: page 10). Participant 8 supports the above claim by saying that "Internet enabling meter requires network… thus, network failures may affect water, even the meter if it is Internet enabled. Internet is something that happens using network. And I know in Nigeria, this area, at times when you want to log on your system and do some certain things. You would notice there is no network (smiles)" (Appendix F: page 29). Furthermore, Participant 9 pointed out:

> *"There are a lot of limitations in information technology. And what I mean by that is, for areas that you would wish to have this kind of smart water meter system, there must be sufficient network coverage there". He noted that "to adopt this smart water meter, you will need to maybe link up with a telecommunication company such as MTN for internet connections to help power the smart water metering or it will be a flop (smiling)"* (Appendix F: page 32 & 33).

Interestingly, Participant 10 said that Nigeria does not have the same network capacity than overseas for SWMS adoption. For example, the participant stated: “Even at times when you go to the bank. They say there is no network. So, I do not think that we have same network capacity as the overseas. The network capacity to execute all these functions is not the same here” (Appendix F: page 29). In support, Participant 9 argued that: “I think certain things are peculiar, this technology can work well in an advanced country where all the technologies are already in place. Then the analogue meter and the prepaid will work in here (Africa)” (Appendix F: page 36).

5.2.4 Water bypass and illegal connection

The **Water bypass and illegal connection** category denotes the fraudulent activities that the researched Water Institution experiences.

When participants were asked what their perception is towards using a SWMS for water management, it was found that some water customers engage in fraudulent activities such as water bypass and illegal water meter connections. This view is illustrated by responses from Participants 4 and 9 (Appendix F: pages 11, 33 & 35). Participant 4 said that some customers perform fraud through bypassing the water meter, which leads to lost revenue (Appendix F: 11). In explanation, Participant 9 said: “There are lot of fraudulent activities that people involve themselves in, such as water bypass, illegal connection and they use it to do all sort of things”. Participant 9 further explained that “some people may want to default the system so that it does not keep sending them updates, so they will have opportunity of manipulating or manoeuvring bills” (Appendix F: 33). The participant further emphasised that cost of water is a “big thing especially in Africa, they want everything manipulated” (Appendix F: 35).

5.2.5 Perceived benefits of smart water meter systems

The **Perceived benefits** category denotes the benefits of SWM as identified by participants from the researched Water Institution. During the interviews, participants identified the benefits they believe will accrue if a SWMS is adopted. The findings indicate that a SWMS can benefit water users as well as the researched Water Institution, and it can help maintain a sustainable environment. The benefits noted below are some factors that can drive SWMS adoption.

Three of the eleven participants (27%) believe that a SWMS will help curb the menace of unpaid water bills and increase revenue for the Water Institution, thereby allowing them to better maintain their equipment and increase water production and water supply to more zones in the state. This point is generally consolidated in the responses of Participants 4, 6 and 7.

Participant 4 noted that “it will help to make more revenue for the institution to expand its coverage of water supply to more zones in the state” (Appendix F: page 12). Participant 6 stated: "I think using this technology will help us curb the menace of that unpaid water and increase the revenue of the institution. If we can get this kind of technology, it will help us a long way". Participant 6 continued by saying that a SWMS "will give us enough revenue that can help us to maintain our equipment and the water production will increase, and that increase in production will now amount to increase in supply of the service (water). So, I do not think adoption of smart water meter is a problem" (Appendix F: pages 17 & 19). In support of the above claim, Participant 7 explained:

> *"We will not have a loss of revenue like we have now because now, you can prepare a bill, go to customers' house, and drop it. The person may claim that they didn't see the bill and it will prolong for about six months to a year. But with the smart water meter, it will be automatic. Which is between the customer and the institution"* (Appendix F: pages 22 & 24).

Three of the eleven participants (27%) perceived that a SWMS will make things easier, such as saving cost for water consumers and the Water Institution. They also believe that a SWMS will help their institution manage time. This view is demonstrated in the responses of Participants 2, 4 and 6.

Participant 2 explained: "My perception is it will make things easier. And it will also save costs. Why I'm saying it will save cost is, if you have leakage in your House, you can easily go and take care of it without much wastage. Because once you curtail wastage, you curtail cost". Participant 2 continued by explaining why a SWMS will save more cost than the analogue water meter: "If you are using analogue water meter, assuming the water is passing through your meter, the cost is already there… especially for the consumers. Because most of the time the meter is normally installed well before your house. So, any water that comes into your house is on your cost" (Appendix F: page 6). Participants 4 and 6 generally believe that a SWMS will help with time management for the institution, city, and the state. Participant 6 emphasised this by saying: "Technology in the whole world is a welcome development. It saves time and it saves resources. So, it will save a lot of cost and time even in billing" (Appendix F: pages 11 & 17, respectively).

A SWMS is perceived as an innovation that will help the Water Institution with accountability. Participant 10 noted that a SWMS "helps with accountability. You will be able to know where your water goes. That is, the water you produce, where does it go. Who uses the water" (Appendix F: page 39).

The findings also show that the robustness, dual ability and adaptability of a SWMS are the factors that will drive its adoption. In support of this statement, Participant 5 made the following list:

- "*It's robustness to capture a wide array of vital customer information in real time.*
- *The dual ability of the new technology to transmit such information both to clients (customers), and the service providers in real time.*
- *The adaptability of the smart water meter to the corporation's services*" (Appendix F: page 14).

Participant 11 explains:

> *"It is robust to capture a wide array of vital customer information in real time. Then also we see the dual ability of the new technology to transfer such information both to the clients and to the service providers. And thirdly, adaptability of the smart water meter to the corporation services. I can see that it can be adapted into what we are already doing such as the operational information. I know these are factors that can lead to its adoption"* (Appendix F: page 47).

A SWMS is considered a technology that will reduce manual labour and manpower. This statement is illustrated in the responses of Participants 6, 7 and 10, with Participant 6 saying that "it just needs little or no manpower to operate" (Appendix F: page 17). Participant 7: "It will reduce manual labour" (Appendix F: page 22). Participant 10 said: "It also helps to reduce manpower". In explanation, the participant said that "meter that detects leakage you don't need manpower to run around for leakage detection. So, technology is now doing the work. So, these are the major benefits of using the smart water meter system". Participant 10 further confirmed that these benefits will drive SWMS adoption (Appendix F: page 41).

Five of the eleven participants (55%) recognised that the adoption of a SWMS will help detect and reduce water leakages and water wastages, and help households save water. They believe that smart water metering will prove to be more efficient than the analogue methods. This opinion is supported by Participants 2, 3, 4, 7, 8 and 10. Participant 2 said that the smart water meter "will help to… indicate where there are leakages. And as such, it will help every household to conserve water" (Appendix F: page 5). Participant 3 noted that "it affords economy in water usage by reducing wastage" (Appendix F: page 9). In support, Participant 4 said: "It is a good method because it will help to reduce… water leakage, and water wastage" (Appendix F: page 11). Participant 7 also supported by saying "it will help us to stop leakages and waste of water". The participant explained that "once we can put a system that can checkmate water use, and money. It will make people reduce how they use water … If we have the smart water system, other government institution would use it because we supply water to them. Such as the secretariat, police etc. That way, we will save a lot of water wastage, and the government institutions will use water with care" (Appendix F: pages 21, 22, & 24). The statement also indicates that government agencies waste a lot of water. Additionally, Participant 10 said: "Perhaps you don't need to wait for people to call you before you know that water is leaking. Digital technology will alert you from the server room. These are the benefits of using digital technology to manage water" (Appendix F: page 39).

Findings reveal that a SWMS will save water and when water is saved, it will be available to more people than it is currently. It was also found that water supply is less than the demand in the city currently. This point is illustrated in the responses of Participants 6, 7, 8 and 9 (Appendix F: pages 18, 23, 31 & 35). Participant 6 explained how saving water can build up and travel to high areas with no water. He said:

> *"And when you have this kind of system as it saves water, and we are running short of water. Currently our supply is less than the demand. So instead of the people that have water supply in lower areas frequently wasting it, they will lock up and the pressure will build up to travel to those high areas so they too can have water supply. So, water that was supposed to be wasted in one area can now be used in another area. That will make water available to more people than it is currently"* (Appendix F: page 18).

In support of the above claim, Participant 9 said: "And as you turn off the tap, you save bills and water can get to another location. Thereby helping in proper water supply and distribution. Water will get to almost all the end users" (Appendix F: page 35). Participant 7 made the following statement about a SWMS helping to increase the service of production of water to the customers:

> *"With Smart Water Meter we won't have many losses of water because it will help to manage the water so that the water will go far to others. If you don't pay for water, the water will be wasting, and when you see water wasting in your yard, you don't care because you don't know the value. Some People don't have a reason to save water. If there is SWMS, people will try to manage water wastage in their residences"* (Appendix F: page 23).

Participant 7 also said that some people do not have reason to save water.

In similar vein, Participant 8 emphasised: "Those water that are wasting, will get to other people who are not getting the water, even if that person is getting the water, they will be getting more and paying more" (Appendix F: page 31).

5.2.6 Summary of findings for Technological factors theme

The **Technological factors** theme, which includes all internal and external variables that affect an organisation's willingness to accept innovation, summarises the determining categories—*Practice, IT device availability, Connectivity, Water bypass and illegal connection,* and *Perceived benefits*—of a SWMS.

For the ***Practice*** category, various water management practices exist within the researched Water Institution. The following are the main findings for the *Practice* category:

- All participants (100%) from the researched Water Institution acknowledged that smart water meter systems are not adopted or in use. Interestingly, some participants were unaware of a SWMS before the fieldwork data collection.
- Various water management practices exist in the researched Water Institution, such as using traditional analogue water metering, prepaid water metering, and estimation.

Below are findings for the ***Traditional analogue water metering*** category:

- Analogue water metering is the dominant meter in homes and does not come with cost for installation. Customers only pay for the water consumed within a billing period.
- Findings show that staff members go into the field (residences, hotels, institutions, etc.) with their notebook/logbook to read and record meter readings. This is done together with the customers to ensure that calculated bill is correct.
- The analogue water meter is calculated as the present reading of the meter minus the previous meter reading, giving the quantity of cubic meters a customer consumed within a time frame. The difference between the two readings provides the consumption of water over time, which is then multiplied by the tariff rate for that period.
- Findings show that there are challenges associated with using analogue water meter. One of the participants (Participant 7) noted that the meter increases manpower and also introduces delays in preparing water bills for customers.
- Findings show that the analogue water meter is at risk in the location where it is installed as the Water Institution does not have direct daily control or monitoring of the meter in the field. Further, if the analogue water meter is located where there is a flood, the meter quickly spoils, and it becomes difficult to take readings as a flood can destroy some elements of the meter, or it becomes difficult to visit the flooded area to take record of the meter reading.
- The findings show that debris can destroy the fan of the analogue water meter during repairs of pipes. This debris (plastic, little stones) can cause the meter to stop moving, and when the meter stops moving, the water passing through is no longer calculated.

Below are findings for the ***Estimation*** category:

- The researched Water Institution uses estimation for water billing; estimation in the sense that if a customer stays in a three-bedroom flat, he pays a fixed amount of money. If a customer stays in a room apartment, he pays a fixed amount of money, etc. It is fixed, irrespective of how much water the customer uses within a month or the period of billing.

Below are findings for the *Prepaid water meter* category:

- Eighty-one percent (81%) of the participants acknowledged that their institution uses prepaid water meters, although only few customers have it installed in their homes. Findings also show that the prepaid water meter is being used as a pilot case study in mapped-out areas (GRA, New Heaven, etc).
- About 500 plus prepaid meters were supplied and installed by a contractor after a contract agreement was reached.
- On billing and functionality of the prepaid water meter, six participants (55%) mentioned that the prepaid water meter works similar to recharging for electricity (prepaid) or the smartphone (pay-as-you-go system).
- Findings show that the prepaid water meter simplifies bill payments as it automatically stops water flowing into premises when the money recharged finishes, thus eliminating challenges in billing. It was also found that it helps customers save costs.
- The prepaid meter component is installed on customers' premises, while the card reader is installed in the kitchen.
- Technically, it was found that the prepaid water meter lacks the functionality of a SWMS, such as providing information on water leakages or wastages to smartphone or internet devices. However, it sends signal to the server room of the water provider, and they will send a maintenance team to repair the leak.
- Findings show that there are challenges with using prepaid water meters, such as maintenance of the meter. The maintenance culture is not effective as the Water Institution depends on the contractors for maintenance and parts replacement of the prepaid water meter, and they are usually not available when contacted.
- The batteries of the prepaid water meter only last for approximately six months, thereby affecting water supply to customers. If the battery goes down, the possibility of getting new batteries to replace them becomes difficult. During the COVID-19 pandemic period, replacing batteries was difficult for the institution because of the batteries being overseas. The researched Water Institution would normally get fake batteries to change it, which leads to the uninstallation of some of the prepaid water meters from the field.
- The negative effect of dust on the prepaid meter sensor, influenced by the environment, is a significant concern. Dust can disrupt communication between the meter and the card reader, posing a challenge to the device's functionality. External factors like children, users and floods also have an impact on the prepaid water meter's performance.
- Other challenges faced by the institution in terms of using the prepaid include cost implications such as funding the project and human resources management in the institution.

Below is summary of findings for the ***IT device availability*** and the ***Connectivity*** categories*:*

- Computers and an internet connection are the ICT technologies available in the researched Water Institution, which can support the use/adoption of a SWMS.
- Computer technologies are installed in designated offices for data processing and information storage.
- Internet is used for sourcing and/or transferring of information locally and globally.
- It is possible for the researched Water Institution to use a SWMS as water management approach because of their digital operations, which is an integral part of the global world.
- Water users can use a SWMS as 80% of the people use smartphones. However, internet access is presently limited among the water consuming public.
- The findings reveal that there are many limitations or challenges in information technology, such as internet network failures in Nigeria. As a result, it is believed that an internet connection needs to be available, reliable, and with sufficient network coverage for a SWMS to be adopted.
- To adopt smart water metering, you will possibly need to partner with a telecommunication company such as MTN for internet connections to help power the SWMS, otherwise it will be unsuccessful.
- Finally, two of the participants (18%) believe that Nigeria does not have the same network capacity as advanced countries for SWMS adoption. As a result, it was pointed out that analogue water metering and prepaid water metering will work in Africa.

Below is a summary of findings for the ***Water bypass and illegal connection*** category:

- It was found that some water customers engage in fraudulent activities such as water bypass and illegal water meter connections. As a result, they might want to default the system so that it does not keep sending them updates, so they will have the opportunity of manipulating or manoeuvring bills.
- Findings also show that water cost is a 'big thing' especially in Africa as customers want everything manipulated.

Below is summary of findings for the ***Perceived benefits of smart water meter systems*** category:

- Some participants (27%) believe a SWMS will help curb the menace of unpaid water bills and increase revenue for the Water Institution, allowing them to better maintain their equipment and increase water production, thereby leading to water supply to more zones in the state.

- Some participants (27%) perceive that a SWMS will make things easier by saving cost for water consumers and the Water Institution; they also believe that a SWMS will help their institution manage time even in billing.
- A SWMS is perceived as an innovative tool that will enhance accountability within the researched Water Institution in terms of providing information on where water produced goes, and who uses the water.
- It has been found that SWMS robustness, dual ability and adaptability are the factors that will drive its adoption – robustness in terms of capturing a wide array of vital customer water information in real time; dual ability in terms of transmitting such information both to customers and the service providers in real time, and adaptability of the smart water meter to the Water Institution services.
- Smart water metering is considered a technology that will reduce manual labour and manpower as a meter that detects leakage does not need manpower for leakage detection.
- Some participants (55%) recognise that a SWMS will help detect and reduce water leakages, water wastages, and help households save water. They believe that smart water metering will prove to be more efficient than the analogue methods.
- It was found that water supply is less than the demand in the city currently. As such, findings revealed that a SWMS will save water and when water is saved, it will be available to more people than it is currently leading to revenue increase for the Water Institution.
- Findings consistently revealed that when water is saved by people that have water supply in lower areas, water pressure will build up to travel to high areas so they too can have water supply.
- It is believed that as people do not pay for water as it should be, they waste it; as such, using a SWMS can help people understand the value of water and motivate them to save it in their homes.

5.3 Organisational factors

The **Organisational factors** theme denotes the characteristics and resources that an organisation has for the effective adoption and operationalisation of new technology. There are four categories for this theme:

i) *Acceptance*
ii) *Experts and technicians*
iii) *Logistics/adoption framework*
iv) *Unaccounted-for water*

5.3.1 Acceptance

The **Acceptance** category describes those who are ready to use a SWMS and those who may not want to use SWMS.

All the participants (11 in total) (100%) from the researched Water Institution are interested in a SWMS. The majority identified the benefits that would accrue to them if they used a SWMS, such as, if it benefits everyone, and they do not have to pay for water they do not use. This point is supported by participants 1 to 11 (Appendix F: pages 1, 5, 9, 11, 13, 16, 21, 29, 32, 39 & 44).

Participants 2, 8, and 11 are interested in a SWMS because of its many benefits, such as helping to indicate leaks and conserving water (Appendix F: pages 2, 31 & 44). Participant 1 said: "Yes, if it benefits everyone. And we don't get to pay for water we don't use. So based on that, we would appreciate that" (Appendix F: page 1). Participant 3 said: "Yes, I would like to have one because it affords economy in water usage by reducing wastage" (Appendix F: page 9). Participant 4 said: "Yes, I will like it, if provided by the water Board. It will help to control water usage" (Appendix F: page 11). Participant 5 said: "Yes, I want to have the smart water meter system because of its many attractive benefits" (Appendix F: page 13). Participant 6 said: "Yes! I think it will go a long way in improving the services and the operations of the institution… is a welcome development, and we will adopt it if it is made available to us" (Appendix F: pages 16 & 17). Participant 7 said: "Yes of course… As we don't have smart water meter, people use water any how they like" (Appendix F: page 21). In support, Participant 9 stated: "Yes, in an organised setting. The use of water cannot be overemphasised" (Appendix F: page 32). Finally, Participant 10 concluded that, "yeah, it should be there as an added feature to the existing one" (Appendix F: page 38).

Five of the eleven participants (45%) believe that water users would be happy to use the SWMS, but it should not be costly. This is illustrated in the responses of Participants 1, 6, 8, 10 and 11. Participant 1 explained that: "They will be happy to have it, but it should not be costly because the people are already burdened with a lot of economic loads, and things are skyrocketing every moment. So, they may not be so happy to welcome additional huge economic burdens" (Appendix F: page 4). Participant 6 said: "They are easy going people. They are good followers of the government policies and projects… most of them will like it". He explained that "people will like it because they are not always there at home, so they cannot pay for what they did not use". Recall that it was earlier established (section 5.2.1.4) that the Water Institution also uses estimation for water billing (Appendix F: page 18). Participant 8 said: "And I believe people will also be willing. Nobody wants to be left behind in the move of technology. Nobody wants to remain in analogue age in old system like I told you we are using analogue. Yeah, nobody would like to" (Appendix F: page 31). Participant 10 indicated: "We have people who are ready to use technology" (Appendix F: page 40). Participant 11 said: "I believe every household will buy into it" (Appendix F: page 48).

Only one of the eleven participants (9%) said that 50% of the populace may not appreciate the real value of a SWMS. This is shown in Participant 9's response:

> *"For instance, if the whole of this metropolis are installed with smart water meter there are senior citizens who will not be able to operate/understand the system. My mother has a phone, the much she knows is hello. Who is this? She does not read mail or message. So, my perception is that 50% of the populace may not appreciate the real value". The Participant further said that what people want is how to benefit more. If the smart water technology will not benefit the people with what they want. They may not key into the idea* (Appendix F: pages 33 & 34).

Participant 9 further explained that people may come up with allegations for the smart water meter, "that maybe government want to defraud the populace, or an opposition political party may just go and say that, hey, this government it is no longer water that you are providing. That they want to kill the people, or make the people dry. And it will become a serious political issue. To a reasonable extent, we have not reached that stage of using the smart water meter" (Appendix F: page 36).

5.3.2 Experts and technicians

The **Experts and technicians** category describes staff members' expertise and the need for capacity building for staff in terms of using a SWMS.

There is an indication that it is 70% possible to use SWM as a water management approach. Two of the eleven participants 6 and 10 (18%) believe that their institution has good management and personnel, including manpower, plumbers and engineers capable of effectively managing a SWMS as a water management method (Appendix F: pages 18 & 40). For example, Participants 10 said: "it's possible because we have good personnel that can manage it. And we have a good supporting government. We also have a good environment that would supports such venture". When asked to explain what he meant by good environment, the participant said: "Good environment in that; we have good personnel, we have good management" (Appendix F: page 40).

However, seven of the eleven participants (64%) believe that there is a need for capacity building for staff members before the adoption of a SWMS as it is a new technology. Capacity building for staff is a systematic approach to improving employees' knowledge, skills and capabilities so that they can effectively use and maintain the new technology (SWMS). This statement is emphasised by the responses of Participants 2, 3, 4, 6, 7, 8 and 10.

Participant 2 said: “When such new technology arrives, it requires training” (Appendix F: page 5). Participant 3 noted: “Capacity building of utility staff in handling of the new technology” (Appendix F: page 10). Participant 4 said: “The possibility of this internet enabled water management is by training people on the new technology” (Appendix F: page 12). Participant 6 noted: “Start training on the smart water meter from scratch. We have people who are IT-oriented, so the only thing to do is just to take them through the programmes of smart water metering. And they will take off from there” (Appendix F: page 18). Participant 7indicated: “staff members need to be trained on how to use the system before it can be adopted” (Appendix F: page 23). Additionally, Participant 8 emphasised that:

> *“Before we can start to use smart water meters or Internet enabled meters, there should be capacity building for the staff members. It will be a serious matter that will be looked at. People that will go to the field, people that will use it. The operational system of that meter must be known. People should have knowledge of how it operates, and they should be guided. That is capacity building, before you bring such a system or meter, people should go for training. If people are not trained, they may not be properly guided, and it will become an issue. Whether it is how to read it, how to manipulate it, or how to use it, it will become an issue if people are not trained”* (Appendix F: page 28).

The participant concluded by saying that their staff members are fast at learning and would be willing to be trained on how to use a SWMS. Additionally, Participant 10 said: “There should be Maintenance personnel” (Appendix F: page 40).

5.3.3 Logistics/adoption framework

Logistics is a key factor that the Water Institution need to have, as noted by one of the participants (9%). There is an indication that the Water Institution needs logistics to help with the smooth running of SWMS adoption. Participant 10 explained: “Moving meters requires vehicles to where you are going to install it. Smart water meters are well packaged, so you need good logistics to manage it. So, these are the things that can make it work effectively” (Appendix F: page 40).

It has been found that a framework is needed to help with the adoption of a SWMS. In support of this statement, Participant 4 stated: “We need some consultant firm to do some framework for the institution” (Appendix F: page 12).

5.3.4 Unaccounted-for water

The **Unaccounted-for water** category describes the amount of water that is being wasted, drawing attention to possible losses, theft or inefficiencies in the system, comprising both metered and unmetered consumption. Findings show that the percentage (above 60%) of unaccounted-for water in the researched Water Institution is very high. Participants 7 and 9 mentioned that people use water any how they like, and most people are not paying for water

(Appendix F: pages 21 & 35). Participant 11 indicated: "Right now as we are talking our unaccounted-for water, the percentage is very high" (Appendix F: page 45). Participant 8 believe the smart meter water will be very much useful: "The percentage of unaccounted-for water in this corporation is about 60%" (Appendix F: page 31). In support, Participant 6 explained: "I can say more than 90% of water produced are not being paid for. It is always difficult to get them to pay. It is either you go and cut off their line, which sometimes when you do, if you move out of the site they will go and, reconnect it and continue using water. So, at the end you see that you produce a large quantity of water, very minor quantity will be paid for. And that's depriving the institution of the finance, the operational fund they are supposed to use in maintaining the equipment". The participant further said the study area is a metropolitan city with no source of water supply except through them (the Water Institution) and the water vendors.

> *"So, many people need the water, and we can't deprive them water because it can cause an outbreak of disease and other challenges if we say we will not supply them because they are not paying. But at the end, it is telling on the institution because we cannot have enough funds to provide the facilities we need even to maintain the ones we have"* (Appendix F: page 16 & 17).

5.3.5 Summary of findings for the Organisational factors theme

The **Organisational factors** theme towards SWMS adoption summarises the derived categories as follows: *Acceptance; Expert and technicians; Logistics/adoption framework; and Unaccounted-for water.*

- All the participants (11 in total) (100%) from the researched Water Institution are interested in a SWMS because of its many attractive benefits, such as improving the services and the operations of the institution (see section 5.2.5 for identified benefits). Five of the eleven participants (45%) believe that majority of water users would be happy to use the SWMS, but it should not be costly because the people are already burdened with many economic loads, and things are skyrocketing every moment. Only one of the eleven participants (9%) said that 50% of the populace may not appreciate the real value of SWM.
- Findings show that SWM should be added as one of the water management technologies in the researched institution.
- Participants noted that there is a 70% possibility of using a SWMS because their institution have good management and personnel, including manpower, plumbers and engineers capable of effectively managing a SWMS as a water management method. However, some participants (64%) believe that there is a need for capacity building for staff members before the adoption of a SWMS as it is a new technology and for them to maintain.

- Findings show logistics is a key factor; the Water Institution needs to help with the smooth running of SWMS adoption.
- It has been found that a framework is needed to help with the adoption of a SWMS.
- The percentage (about 90%) of unaccounted-for water in the researched Water Institution is very high because people use water any how they like, and most people are not paying for water. Findings show that sometimes when their line is cut off, when the staff move off site, they will reconnect it and continue using water. The Water Institution cannot deprive them of water because it can cause an outbreak of disease and other challenges if they do.

5.4 Environmental factors

The **Environmental factors** theme describes the landscape in which an organisation does business. This includes external factors that present possibilities and limitations for technological innovations within an organisation. The theme has four categories:

i) *Service provider support* describes concerns around maintenance and knowledge transfer for sustainable adoption of a SWMS.

ii) *Environmental concerns* describe concerns around the water production, electricity, and the built environment for sustainable adoption of a SWMS.

iii) *Government support* describes whether the government supports the researched Water Institution in the adoption of ICT for water management.

iv) *Government policy* describes whether the government policies encourage the adoption of new technology (smart water meter systems) for water management.

5.4.1 Service provider support

This sub-section describes some challenges around maintenance and knowledge transfer that might affect the adoption of a SWMS.

It became evident that one of the challenges of SWMS adoption would be poor maintenance of the meter. Six of the eleven participants (55%) noted that spare parts are not available; frequent battery failures, poor maintenance of the meter and lack of manpower would be a challenge to the sustainability of the new technology usage. These participants stated that it would require high-profile personnel to manage the smart water meter for the institution. The responses of participants 3, 4, 5, 7, 10, and 11 all support this statement.

Participants 5, 7 and 11 are concerned about the sustainability of the SWMS if a problem arises (Appendix F: pages 13, 22 & 45). Participant 3 said: “The challenges would be… frequent battery failures” (Appendix F: page 9). Participant 4 indicated: “The challenges are so many: poor maintenance of the meter, lack of manpower” (Appendix F: page 11). Participant 10 said: “It would require high-profile personnel to manage the smart water meter for our institution”

(Appendix F: page 38). Additionally, Participant 11 explained that SWM will not help the researched Water Institution if there is no plan for sustainability:

> *"in the recent past we had the World Bank assisted Water Project. We were on board, they helped install new facilities, new pumps, and they largely rehabilitated our system. But do you know that as we are talking the whole system has collapsed. They are all grounded because we lack sustainability. The spare parts are not available, the knowledge is not there. So, these are some of the major challenges I need to address, even if the smart water meter is adopted, it needs to function very well and give us the desired results".*

Knowledge transfer is also an obstacle as management believes it is not always available. Participant 7 explained that government work requires constant training for staff members to ensure proper maintenance and care if a SWMS should be adopted. Without this training, replacing retiring staff who have the knowledge can be challenging. By implementing batch training, it is possible to ensure that other staff members are equipped to handle the SWMS effectively even when older staff retires, ensuring smooth operations and efficient use of the resources is necessary (Appendix F: page 22).

Furthermore, Participant 11 noted:

> *"Going by experience, the existing challenge I have come to notice is Knowledge transfer. Is not always available. There was a man who was hired to install a computerise system. After having done the computerisation, when the system develops technical fault, if the man is not around, it will tend to frustrate those using the system. So sometimes we will look for him for days before he can come around and rectify the situation. So, knowledge transfer is not always available. I do not know whether the owner of the technology is hiding the information so our staff that are supposed to take over from them are not normally properly informed. Staff must take a proper grip of the technology when it is installed"* (Appendix F: page 45).

5.4.2 Environmental concerns

Findings show that electricity supply would be a hindrance to the adoption of a SWMS, especially in Nigeria. According to Participant 9: "You will need to have steady electricity. In Nigeria power supply is a hindrance to this technology you are talking about now" (Appendix F: page 32).

There is a perception that a SWMS cannot be installed in some buildings because of the structure of the building and the environment. Participant 10 argued: "the structure of the building will determine the effectiveness of the sensor… based on the environment, some buildings may not have good environment where the system will be installed" (Appendix F: page 38).

Findings show that the pipeline water reticulation are limited to some places, even in townships, as such some people will not have smart water meters. Participant 9 explained this point by saying: “I think the smart water metering system is not in use in Africa because of obvious challenges. One is that the pipeline water reticulation is limited to some places even in townships. And so long as it is not commonplace some people will not have smart water meters” (Appendix F: page 32). However, Participant 6 argued: “we have our pipe network clearly specified. So, we have the drawings and everything in our archives” (Appendix F: page 18). Pipeline water reticulation denotes the water distribution network that gathers, treats and distributes water to customers.

It has been indicated that before smart water metering is adopted, water production needs to increase (be scaled-up). It is believed that when there is a sustained increase in water production volume, there is also the need to accurately determine the volume of consumption. This view is seen in the response of Participant 1, who stated:

> *“We need to scale up our water production. And when we scale up our water production, we have to sustain the scaled-up production, and when we do that, then the need for the smart water meter arises. If we can’t produce enough water to supply to satisfy the customers, that means the demand for the smart water meter would be somehow at a minimal level. If we have the product. Then the need for the smart water meter to do its work now comes in”.*

When asked if there is not enough water production currently, Participant 1 said:

> *“There’s a need for increased water production. And when we have that volume that sustained volume. Then there is need to accurately determine the volume of consumption. So, if there’s nothing to consume. Then, there’s nothing for the smart water meter to read”.*

The participant further explained that “it is better that water production is scaled up so that customers will be happy using the system and they will be the ones demanding for it. But at this minimal production level, people may not be out for it, because customers want the products “water” first before the smart water meter” (Appendix F: page 3). In support, Participant 9 said: “my thinking is that if over time, we have water production challenges. It may affect the efficacy of the smart water meter” (Appendix F: page 33). Contrary to the above views, Participant 11 argued:

> *“I know the water production is not completely achieving 100% yet. But then even the much we are achieving all of them are not being translated into revenue because of losses here and there, and even commercial losses. So, water needs to be monitored, otherwise instead of improving, you see yourself retrogressing”* (Appendix F: page 45).

5.4.3 Government support

All the participants (11 in total) (100%) noted that the government actively supports the researched Water Institution towards new technology adoption for water management. This is illustrated in the following responses:

Participant 1 acknowledged that the government has been very supportive on many issues, including funding (Appendix F: page 3). In support, Participant 5 added that their "institution is accountable to the government which plays supportive and supervisory roles" (Appendix F: page 14). Participant 6 noted that the prepaid meter "was installed by the government. So, they are actively involved" (Appendix F: page 19). Participant 10 said: "Yes, the government is actively involved. The state government has a good interest in the provision of potable water to the citizens. They have been funding water and anything that involves water, they're always ready to fund it and ensure that the citizens get water" (Appendix F: page 41). Participant 11 concluded by saying that:

> *"Of course, yes, our institution is, wholly accountable to the government. It does not operate in isolation. Government makes decisions and policies that guide the operations of the corporation. So, if it must work out, the government must be carried along"* (Appendix F: page 47).

However, Participants 3 and 4 (18%) indicated that the government partly supports the institution with grants from international organisations such as International Development Association (IDA), the French Development Agency (AFD), and World Bank (Appendix F: pages 10 & 12). Participant 7 said: "But we want them to improve more so we can have the smart water meter. Though, the government gives little subvention for water management in this area". Subvention is the little money the government give to support what the institution generates to subsidise their expenses. "They give subvention monthly" (Appendix F: page 24). Participant 6 emphasised that the government does not have funds either:

> *"Even the government is kind of funded. We all know they do not have enough funds. But within their own limited resources, they still extend their hands to assist the institution. So, government is part and parcel of our corporation and the adoption of whatever we are doing"* (Appendix F: page 19).

There is an indication that the government should provide an enabling environment for genuine investors by providing new ICTs to support SWMS adoption. Participant 1 illustrated this as follows:

> *"Government comes into play by allowing people that are more capable and providing an enabling environment for investors, genuine investors. They may not necessarily be from Nigeria or from Africa. Once they have the capacity to render Optimum services. They should be allowed to do that. So, if you bring in the right people, provide them with*

the right environment. And with the right attitude, everything will be in place" (Appendix F: page 4).

Participant 8 supported by saying that "government can do that by provision of enabling environment, like a computer room, furnished and equipped office where people will be able to sit down comfortably do their work" (Appendix F: page 30).

There is an indication that the government should concentrate its effort on ensuring that the analogue and prepaid water meters work very well. Participant 9 argued: "I think what government should do is to concentrate its effort in ensuring that the meters we have here work very well". The participant explained that a smart water meter would require the collaboration of internet service providers. It also needs a database in the office. Many ICT databases that can power the system, inverter or solar for steady power supply. "You know, and all those things come with cost… I think for now that is what is most appropriate for this our tropical area. And the people will easily understand you" (Appendix F: page 36).

5.4.4 Government policy

External influences such as government policy may drive or encourage the adoption of a SWMS. This is illustrated in the responses of Participants 1, 2, 3, 5, 6, 7, 8, 9, 10 & 11 (91%).

Participants 1, 3, 7, 8, and 9 believe that government policies are technology friendly as it encourages new technology adoption (Appendix F: pages 3, 10, 24 & 35). Participant 2 stated: "The government will be very interested. Subsequent policy, they are working towards digitalisation of most of our activities here. So, they will adapt to such new technology" (Appendix F: page 7). Participant 5 stated: "Government also makes policies and decisions that inform/guide the operations of the corporation" (Appendix F: page 14). Participant 6 explained: "Their policies are friendly in terms of using this smart water meter. For example, they assigned the contract to the contractor that installed those prepaid meter I told you. In the sense that they passed the law, deliberated on it, gave a go ahead on that. So, it was purely the government policy, and the project was done. It was not done by the corporation own will or activity. So, it was funded and handled by the government. So, I think their policies are friendly to that" (Appendix F: page 19). Participant 10 emphasised: "Government has a policy that is, you pay for what you consume. Government wants citizen to pay for only what they consume… And that was what led to the procurement of the prepayment smart meters, so that the customer will only pay for what they consume" (Appendix F: page 42). Only one participant noted that government policies do not really have an impact on SWMS adoption. Participant 4 said: "No really impact on this area from government because most of the government agencies are not paying the water bills" (Appendix F: page 12).

From the responses of participants, it became evident that the government needs to be involved for a SWMS to be adopted. Seven of the eleven participants (64%) stated that if the government is involved, SWM will be well-promoted, masses will accept it, people will be served faster and better. Participants 1, 2, 3, 5, 7, 8 and 11 agreed with this statement (Appendix F: pages 4, 8, 10, 15, 24, 31 & 47).

Participant 2 said: “There is a need mostly in this part of the country. Government is very, very active in the water industry as far as Nigeria is concerned, they are very, very active. They contribute, majorly about the working of water system in Nigeria and in state reporting” (Appendix F: page 8). Participant 3 indicated: “Yes. This will help to make the technology popular and make the people to be served faster and better by reducing non-revenue water” (Appendix F: page 10). Participant 5 mentioned: “Yes, there is much need as that will make them to buy and promote the ingenious idea quickly and convincingly” (Appendix F: page 15). Participant 7 emphasised: “the government must be involved before any technology adoption will take place… if the government supports the adoption of [a] SWMS the masses will accept it” (Appendix F: page 24). Participant 8 explained that “there is need very much need. Because the world is technologically advancing, we should not be left behind, so we should be in the same level with other countries that are succeeding in this kind of system” (Appendix F: page 31). Participant 11 emphasised by saying:

> *“Government policies and their decisions largely drives the operations of the corporation. Government must come into it and be informed properly about it so that they can see how it can facilitate or aid the provision of services. Government policy overrides any new idea or technology which comes into play. So, the government must approve of it and incorporate it into their policy plans”* (Appendix F: page 47).

In support, Participant 8 said: “I believe that with government conviction. Government will be willing because they have been helping in other areas to assist in water production, in water treatment, in maintenance. So, I do not see any reason why government should not be involved in smart water meter” (Appendix F: page 30). Participant 1 said the government would be interested depending on how effective the smart water meters are (Appendix F: page 4).

Interestingly, participants pointed out that the Water Institution and government would need to have the zeal and agree to use a SWMS for it to be adopted. This point is consolidated in the responses of Participants 6, 7 and 8. Participants 6 said: “we will adopt it if it is made available to us” (Appendix F: page 17). Participant 7 said: “what can drive the adoption of the smart water meter is that the institution and government would agree to use the system” (Appendix F: pages 23 & 24). Finally, Participant 8 said: “the factors that can make it happen is the government buying the idea”. The participant explained that if the fund is available and government is convinced that SWM will be a better way of handling the water management, it will be adopted (Appendix F: page 30).

Findings also show that one of the factors that would drive SWMS adoption is if the government is the vision bearer and supervises the process. The government is a regulating body, and anything supervised by governments has always been done well. The government protects the citizens. In support of this point, Participant 5 stated: "The government to be the vision bearer to envision the corporation and to also drive and supervise the process" (Appendix F: page 14). Participant 10 explained: "Because the government is a regulating body. And anything supervised by governments has always been done well. The government protects the citizens. That's why it's necessary they should be involved" (Appendix F: page 42).

For sustainability of the SWMS, it was noted that the government needs to enact a law that would prevent people from tampering with any installed meter and then stipulate punishment for offenders. This statement is represented by Participant 9 who said that "by enacting a law that would prevent people from tampering with any installed meter and then stipulating punishment for offenders" (Appendix F: page 35). In support, Participant 6 said: "just passing it into the law in the House of Assembly or in any other chamber. Make it part of either state's law or order". He explained that the SWMS should be acquired and made available for people to use first before making it a law as disconnecting those not using the meter can cause trouble. Which means invariably government just want to deny them access to water (Appendix F: page 19).

5.4.5 Summary of findings for the environmental factors theme

The **environmental factors** for SWMS adoption include *Service provider support*, *Environmental concerns*, *Government support* and *Government policy*.

- Some of the participants (55%) identified poor maintenance as a significant challenge to SWMS adoption. They noted that the lack of spare parts, frequent battery failures, and a lack of manpower would hinder the sustainability of the new technology. High-profile personnel are required to manage the SWMS effectively.
- Knowledge transfer is also an obstacle as management believes it is not always available. Government work requires constant training for staff members to ensure proper maintenance if SWM is adopted. Without this training, replacing retiring staff who have the knowledge can be challenging. By implementing batch training, it is possible to ensure that other staff members are equipped to handle the SWMS effectively even when older staff retires, ensuring smooth operations and efficient use of the resources.

- Findings show that electricity supply would be a hindrance to the adoption of SWM, especially in Nigeria.
- A SWMS cannot be installed in some buildings because of the structure of the building and the environment.
- Findings show that the pipeline water reticulation are limited to some places even in townships as such some people will not have the smart water meters installed in their residences.
- The researched Water Institution has their pipe network clearly specified thereby encouraging SWMS adoption.
- It has been indicated that before smart water meter is adopted, Water production needs to increase (be scaled-up). It is believed that when there is a sustained increased water production volume, comes the need to accurately determine the volume of consumption. However, findings also show that water needs to be monitored because the water currently being produced are not being translated into revenue because of losses here and there, and even commercial losses.
- All Participants (100%) noted that the Government actively supports the researched Water Institution towards new technology adoption for water management. However, some participants (18%) indicated that the government partly supports the institution with grants from international organisations such as International Development Association (IDA), the French Development Agency (AFD), and World Bank.
- The researched Water Institution is wholly accountable to the government which plays supportive and supervisory roles. The government makes decisions and policies that guide the operations of the corporation. So, if SWM must be adopted, the government must be carried along.
- It was indicated that the government needs to improve more in supporting the institution so that smart water meter can be adopted. The government should provide an enabling environment for genuine investors, such as a computer room, furnished and equipped office where people will be able to sit down comfortably and do their work.
- There is a believe that the government should concentrate its effort in ensuring that the analogue and prepaid water meters work very well because adopting a SWMS comes with cost.
- According to participants (91%) external influences such as the government policy and support may drive or encourage the adoption of a SWMS.
- The government has a policy in which you pay for what you consume. The government wants citizens to pay for only what they consume. That was what led to the procurement of the prepayment (prepaid) meters.

- Only one Participant (9%) noted that government policies does not really have impact on SWMS adoption.
- Government must be informed properly about SWMSs so that they can see how it can facilitate or aid the provision of services. Government policy overrides any new idea or technology which comes into play. So, the government must approve of it and incorporate it into their policy plans.
- Furthermore, Some Participants (64%) believe that with government involvement, SWMSs will be well-promoted, masses will accept it, people will be served faster and better.
- Interestingly, the researched Water Institution and government would need to have the zeal and agree to using SWMSs for it to be adopted.
- Another factor that would drive SWMS adoption is if the government be the vision bearer and supervise the process. The government is a regulating body, and anything supervised by governments has always been done well. The government protects the citizens.
- For sustainability of the SWMS, it was noted that the government need to enact a law that would prevent people from tampering with any installed meter and then stipulate punishment for offenders.

5.5 Economic factors

Economic factors refer to factors that present limitations and possibilities for the adoption of a SWMS. The theme has two categories:

i) *Cost and funding* denotes concern regarding the cost of implementing a SWMS and the lack of funds within the researched Water Institution.

ii) *Return on investment:* Understanding ROI is vital for businesses when assessing the effectiveness of their financial decisions (*see section 5.2.5* on benefits relating to ROI).

5.5.1 Cost and funding

The responses of participants demonstrated that businesses are fundamentally cost-driven. Three of the eleven Participants (27%) emphasised that a SWMS would be costly to adopt because of the financial outlay will be so much mind boggling in this present economic downturn. They stated that a low-cost SWMS with immense benefits would attract customers as people are already complaining of a lot of their costs. This statement is supported by the illustrations of Participants 1, 2 and 9.

Participant 1 said: “The challenge is high cost because people are already complaining of a lot of our costs. So, if the technology will come at minimum cost and immense benefits. I think people will be out for it. They may go for it, but if it comes with increased tariff system in this economic burden. They may shy away from it. So precisely, cost" (Appendix F: page 2). Participant 2 also identified cost as a challenge to SWMS adoption. He said: "I think it will be too costly to acquire. It's one of the problems because this kind of technology, I don't think it is cheap. In this our environment, is one of the major issues, and it's a kind of fear. Yes, because approaching such a new technology, it will cost much because everything will be new, so it will be very costly… the cost may be high for the consumers to acquire it" (Appendix F: pages 5 & 6). In support that a SWMS would be costly to acquire, Participant 9 concluded by saying "The financial outlay will be so much mind boggling in this present economic downturn. All these things come with cost. Much as the whole idea of this invention is to save water and help generate revenue" (Appendix F: page 36).

There is an indication that for SWM to work, customers should be allowed to pay for the meter on instalment basis rather than them making full payment outrightly. Participant 11 argued: "I do not know whether most of the households are well to do in terms of funding. I do not know whether the installation of the smart water meter can be made, then the users will pay by instalments. That will make it also work out because if you have them to pay out right for the technology, many of them may not be able to afford it" (Appendix F: page 48).

A SWMS is difficult to adopt because of the lack of funds within the institution. Many participants indicated that their institution does not have the funds; that even maintaining their workforce and facilities is a major challenge for them. This point is supported by the responses of Participants 3, 4, 6, 7, 8 and 11.

Participant 3 said: "The challenges would be funding" (Appendix F: page 9). Participants 4 said: "The factors that can help in smart water meter adoption are; full government support in the institution by funding Human resource management is very important for the smart water meter to function very well" (Appendix F: page 12). Participant 6 emphasised: "the major problem we have here now is how do we fund the smart water meter technology. The institution, the corporation, we do not have that fund. Even maintaining our workforce and their facilities is a very big challenge to us" (Appendix F: page 17). In support Participant 7 said: "The possibility of having [a] smart water meter system is funding. The institution may not even have money to order for the meter unless the government help the institution to order for the meter. If the government helps to order for the meter, is a benefit for the institution and even for the government. The institution cannot get it because of lack of funds" (Appendix F: page 23). Participant 11 explains by saying:

> *"You cannot remove the issue of funding. Funding has been a challenge and it's difficult sourcing it. I want to tell you that in the year 2021. The state had a very wonderful budget estimates approved for the corporation at the end of the year only 12% of the estimates were released. That shows you that operating the system was almost incapacitated due*

to lack of sufficient fund. So, I know that the smart water meter is something that is capital intensive because in terms of maintaining it, even installing it, it calls for finance. If the supporting facilities are not provided in good time, then the technology will not bring the desired results" (Appendix F: page 46).

Participant 3 and 8 also noted that funding is a big challenge, and as a government agency, the government would bring in the fund (Appendix F: pages 9 & 28).

5.5.2 Summary of findings for the economic factors theme

The summary for the **economic factors** theme is presented below, organised by the determining category *cost and funding.*

- Some participants (27%) consider a SWMS costly to be adopted because the financial outlay will be massive in this present economic downturn.
- A low-cost SWMS with immense benefits would attract customers as people are already complaining of huge economic burden from the researched Water Institution.
- It is believed that for SWM to work, customers should be allowed to pay for the meter on an instalment basis rather than them making full payment outrightly as they may not be able to afford it.
- A SWMS is difficult to adopt because of the lack of funds within the institution; it was noted that they face major challenges in maintaining their workforce and facilities.
- The possibility of having a smart water meter system is full government support by funding Human resource management. The government also needs external support from international organisations to fund the adoption of a SWMS for sustainable water management.

5.6 Knowledge

The **knowledge** theme describes the importance to expose the existence of a SWMS to the social system. It is when the people gain knowledge about an innovation. The theme has two categories:

i) *Technology awareness* denotes the need to create awareness for both the government and water users on the innovative idea (SWMS).

ii) *Users' education to accept change* denotes the need to properly educate users to avoid challenges towards using a SWMS.

5.6.1 Technology awareness

In business, it is important to create an awareness when there is a plan towards adopting an innovation to benefit from the programme. Six of the Participants (55%) believe that proper awareness needs to be created on how a SWMS work, including their usage and maintenance. This statement is supported by Participants 1, 2, 8, 9, 10 and 11.

In supporting the above statement, Participant 2 said: “get the consumers informed about the new technology” (Appendix F: page 5). Participant 8 said: “what I believe is that before we can introduce this kind of Internet enabled meter, people should be aware. For instance, this is what is coming on board. This is how to go about it. This is how the technology works” (Appendix F: page 28). Participant 11 said: “it calls for proper awareness. They need to be made to know and understand the potential benefits that they will enjoy” (Appendix F: page 48).

Participant 1 generally noted that people need to be enlightened including the technical staff, all staff concerned and then the public on the care, maintenance, and proper management of the smart water meter system. He said, if proper enlightenment on the smart water meter is done; it means that it will solve a lot of problems, as the demand for it and proper governmental strength action would increase. Participant 1 further emphasised that everybody to an extent, has limited knowledge on certain things that if proper enlightenment is made available to government key officials, they would go for it because it will make governance easier. He concluded that:

> *“the people in power, the government, the governor, the Commissioners, are the people responsible for water at the highest levels echelon. So, I think that’s the best way to start because they are the policymakers. And they’re the one that back up their action with measurable financial votes”* (Appendix F: pages 1, 3 & 4).

In support of the above claim, Participant 10 said: “The government works with information. Once the information you give to the government is valuable, they will adopt it. Once the information brings succour to the citizen, the government will act on it without delay”. He explained that the organisation which deals on the SWMS would be the body to approach the government (Appendix F: page 41). Additionally, Participant 11 said: “Make the government catch into the vision. So, when they see the importance of it, when they are convinced about the need to have the system, they will drive and supervise the project. Because without government being persuaded about it, and being convinced about it, the system will not succeed” (Appendix F: page 47).

According to Participant 9, sufficient and adequate down to earth sensitisation is needed for a SWMS to be adopted. It would require people to organise a lot of town hall meeting with maybe zones, outlets in different location and asking for their opinion. He continued by saying:

> *“For instance, independence layout is a very large area. So, if you ask all the residents of independence layout, they will all accept the smart water meter system because it is an elitist (highbrow) zone. I am telling you those areas that are considered elitist, residents in those area are sufficiently literate enough to understand the basic advantages. And the gains of this kind of technology in enabling the water distribution*

and conservation. Then if you go to the urban proper, even in South Africa, there are also slums. Those people may not understand the technology well. They will argue about their cost of living. And so many things. You may even get all sorts of gangs. Some people pride themselves in forestalling government well-intentioned project. So, it will need a lot of time on meeting, and a lot of sensitisations, and getting peoples opinion, and their feedback" (Appendix F: page 34).

Another key factor that would drive the adoption of a SWMS is to make it a little enticing by mentioning that it comes with reduced cost for any neighbourhood that accept the implementation. Participant 9 explained:

> *"Make it a little enticing. For instance, maybe a cubic meter of water normal cost is N100. You may reduce it to N80 to any pilot area or housing estate or zone or neighbourhood that accept the implementation. It needs to look very enticing for acceptance by mentioning that it comes with reduced cost"* (Appendix F: page 34).

5.6.2 Users' education to accept change

Finding also show that one of the challenges to SWMS adoption would be getting consumers to understand the new technology. So, it will not be a challenge to the institution. There is need to properly educate users to avoid challenges towards using a SWMS. This point is best illustrated by the responses of Participants 1, 2, 3 and 9 (36%).

Participant 1 said it is important for people to know how to operate and monitor a SWMS, "so, it will not be a challenge to the institution" (Appendix F: page 1). Participant 2 indicated that the "challenges could be to get consumers to understand the new technology" (Appendix F: page 6). Participant 3 said: "The challenges would be … consumer education" (Appendix F: page 9). Participant 9 emphasised that:

> *"if people do not have sufficient orientation on the use of a particular thing, they may not use that well. They may have difficulty managing whatever technology you are making available to them. And it would create some challenges such as constant error messages as system feedback"* (Appendix F: page 33).

5.6.3 Summary of findings for the knowledge theme

The summary for the **knowledge** theme is presented below, organised by the determining category *Technology awareness, and users' education to accept change.*

- Participants (55%) noted that before introducing SWM to the social system, sufficient and adequate down-to-earth proper awareness should be created for the people to introduce the system on how it works including its usage and maintenance.
- It is believed that with proper awareness of SWM, the demand for it would increase.

- It has been found that the people responsible for sustainable water management are the government (such as the governor, and the Commissioners), and it is important to start the awareness campaign with them as they are the policymakers.
- Findings show that the organisation which deals with the SWMS would be the body to approach the government.
- Findings show that the zones considered elitist, residents in those areas are sufficiently literate enough to understand the basic advantages of this kind of technology in enabling sustainable water management. Whereas people who live in the slums may not understand the technology well.
- A SWMS will need a lot of time on meetings, a lot of sensitisations, and obtaining people's opinions and feedback before it can be adopted.
- Another key factor that would drive SWMS adoption is to make it a little enticing by mentioning that it comes with reduced cost for any neighbourhood that accepts the implementation.
- One of the challenges to SWMS adoption would be getting consumers to understand the new technology. So, it will not be a challenge to the institution. There is a need to properly educate users to avoid challenges towards using a SWMS.

5.7 Trialability

The **trialability** theme describes the need to conduct a small-scale pilot study to test an innovative idea before adopting it on a large scale. It acts as a feasibility study to help organisations understand how the proposed innovation would function in practice. This theme has no determining category.

One of the key factors when deciding to adopt SWM as water management approach is to verify the workability from nations where it exists; or conduct a small-scale pilot study to test the workability of the system such as in revenue generation, water management, leak detection, water wastage monitoring and more. The responses from Participants 2, 8, 9, and 11 best demonstrate this (36%).

Participant 2 said: "Most of the time the government cannot do without verifying the workability of the new technology. Possibly they will have to travel to such nations where the system exists and verify. And the company will give them evidence of it working down here before they abide by it" (Appendix F: page 8). Participant 8 said that some areas should be used as a pilot study "to see the workability in terms of revenue, in terms of water management, controlling of waste of water. So, when we look at it, then that will bring us into knowing whether we will generally adopt it as a system for the entire area as we supply water" (Appendix F: page 29). Participant 9 explains:

"The possibility of having an Internet enabled water management system is that it needs to be a long-term project… It can work out. If it is a long-term project. And you first start with a trial. Map out an area and try the technology over some time such as one to six months. And find out how best it is working out there. Before you can deploy the whole smart water metering system to a very large metropolis like ours. All you just need to do is to get good feedback". He said if it works, it can be implemented in that area, or it could become a subject of option such as: Do you want it? Yes or No. And if it does not work, they return to continue with the analogue meter (Appendix F: page 34).

Participants 7 and 11 are also in support of conducting a pilot study. Participant 11 concluded by saying "You can best promote and encourage what you are used to. When government see the system working, they will be at the forefront in promoting it and then helping to facilitate the use of it" (Appendix F: pages 23 & 48).

5.7.1 Summary of findings for the trialability theme

Participants believe that one of the key factors when deciding to adopt SWM as a water management approach is to verify the workability from nations where it exists; or conduct a small-scale pilot study to test the workability of the system such as in revenue generation, water management, leak detection, water wastage monitoring and more.

Findings show that SWM should be a long-term project, and that an area should be mapped out for the SWMS trial for about six months. If it works, it can be implemented in that area, or it could become a subject of option such as: Do you want it? Yes or No. And if it does not work, they return to continue with the analogue meter.

5.8 Conclusion to Chapter Five

In Chapter Five, the findings on SWMS adoption in the Nigerian context were presented in alignment with the study's aim, namely, to explore the reasons behind the failure of institutions to adopt an IoT-based smart water meter system to improve the efficiency of water management for a sustainable future. The findings were presented in themes and linked to categories.

Table 5.1 summarises the study's findings based on the themes identified.

Table 5.1: Summary of findings

Technological factors **(section 5.2)**	**The following are the main findings for the *practice* category:** • All participants (100%) from the researched Water Institution acknowledged that smart water meter systems are not adopted or in use. Interestingly, some participants were unaware of a SWMS before the fieldwork data collection. • Various water management practices exist in the researched Water Institution, such as using traditional analogue water metering, prepaid water metering, and estimation. **Below are findings on the *Traditional analogue water metering:***

	• Analogue water metering is the dominant meter in homes and does not come with cost for installation. Customers only pay for the water consumed within a billing period. • Findings show that staff members go to the field (residences, hotels, institutions etc.) with their notebook/logbook to read and record meter readings. This is done together with the customers to ensure that calculated bill is correct. • The analogue water meter is calculated as; the present reading of the meter minus the previous meter reading, gives the quantity of cubic meters a customer consumed within a time frame. The difference between the two readings provides the consumption of water over time, which is then multiplied by the tariff rate for that period. • Findings show that there are challenges associated with using analogue water meter. One of the participants (Participant 7) noted that the meter increases manpower and, also introduces delays in preparing water bills for customers. • Findings show that the analogue water meter is at risk in the location where it is installed as the Water Institution does not have direct daily control or monitoring of the meter in the field. Further, if the analogue water meter is located where there is flood, the meter quickly spoils, and it becomes difficult to take readings as a flood can destroy some elements of the meter; or it becomes difficult to visit the flooded area to take record of the meter reading. • The findings show that debris can destroy the fan of the analogue water meter during repairs of pipes. This debris (plastic, little stones) can cause the meter to stop moving, and when the meter stops moving, the water passing through is no longer calculated. **Below are findings for the *estimation* category:** • The researched Water Institution uses estimation for water billing; estimation in the sense that if a customer stays in a three-bedroom flat, he pays a fixed amount of money. If a customer stays in a room apartment, he pays a fixed amount of money, etc. It is fixed, irrespective of how much water the customer uses within a month or the period of billing. **Below are findings for the *prepaid water meter* category:** • Eighty-one percent (81%) of the participants acknowledged that their institution uses prepaid water meters, although only few customers have it installed in their homes. Findings also show that the prepaid water meter is being used as a pilot case study in mapped-out areas such as (GRA or New Heaven). • About 500 plus prepaid meters were supplied and installed by a contractor after a contract agreement was reached. • On billing and functionality of the prepaid water meter, six participants (55%) mentioned that the prepaid water meter works similar to recharging for electricity (prepaid) or the smartphone (pay-as-you-go system). • Findings show that the prepaid water meter simplifies bill payments as it automatically stops water flowing into premises when money recharging finishes, thus eliminating challenges in billing. It was also found that it helps customers save costs. • The prepaid water meter component is installed on customers' premises, while the card reader is installed in the kitchen. • Technically, it was found that the prepaid water meter lacks the functionality of a SWMS, such as providing information on water leakages or wastages to smartphone or internet devices. However, it sends signal to the server room of the water provider, and they will send a maintenance team to repair the leak. • Findings show that there are challenges with using prepaid water meter such as maintenance of the meter. The maintenance culture is not effective as the Water Institution depends on the contractors for maintenance and parts replacement of the prepaid water meter, and they are usually not available when contacted.

	• The batteries of the prepaid water meter only last for approximately six months, thereby affecting water supply to customers. If the battery goes down, the possibility of getting new batteries to replace them becomes difficult. During the COVID-19 pandemic period, replacing batteries was difficult for the institution because of the batteries being overseas. The researched Water Institution would normally get fake batteries to change it, which leads to the uninstallation of some of the prepaid water meter from the field. • The negative effect of dust on the prepaid meter sensor, influenced by the environment, is a significant concern. Dust can disrupt communication between the meter and the card reader, posing a challenge to the device's functionality. External factors like children, users and floods also have an impact on the prepaid meter's performance. • Other challenges faced by the institution in terms of using the prepaid include cost implications such as funding the project and human resources management in the institution. **Below is summary of findings for the *IT device availability* and *connectivity* categories**: • Computers and Internet connection are the ICT technologies available in the researched Water Institution, which can support the use/adoption of a SWMS. • Computer technologies are installed in designated offices for data processing and information storage. • Internet is used for sourcing and/or transferring of information locally and globally. • It is possible for the researched Water Institution to use SWMS as a water management approach because of their digital operations, which is an integral part of the global world. • Water users can use a SWMS as 80% of the people use smartphones. However, internet access is presently limited among water consuming public. • The findings reveal that there are many limitations or challenges in information technology, such as internet network failures in Nigeria. As a result, it is believed that the internet connection needs to be available, reliable, and with sufficient network coverage for a SWMS to be adopted. • To adopt this smart water metering, you will possibly need to partner with a telecommunication company such as MTN for internet connections to help power the SWMS, otherwise it will be unsuccessful. • Finally, two of the Participants (18%) believe that Nigeria does not have the same network capacity as advanced countries for SWMS adoption. As a result, it was pointed out that analogue water metering and the prepaid water metering will work in Africa. **Below is summary of findings for the *water bypass and illegal connection* category:** • It was found that some water customers engage in fraudulent activities such as water bypass, and illegal water meter connections. As a result, they might want to default the system so that it does not keep sending them updates, so they will have opportunity of manipulating or manoeuvring bills. • Findings also show that water cost is a 'big thing' especially in Africa as customers want everything manipulated. **Below is summary of findings for the *perceived benefits of smart water meter systems:*** • Some Participants (27%) believe that a SWMS will help curb the menace of unpaid water bills and increase revenue for the Water Institution, allowing them to better maintain their equipment and increase water production, thereby leading to water supply to more zones in the state.

	• Some Participants (27%) perceive that a SWMS will make things easier by saving cost for water consumers and the Water Institution; they also believe that a SWMS will help their institution manage time even in billing. • SWMS is perceived as an innovative tool that will enhance accountability within the researched Water Institution in terms of providing information on where water produced goes, and who uses the water. • It has been found that SWMS robustness, dual ability, and adaptability are the factors that will drive its adoption. Robustness in terms of capturing a wide array of vital customer water information in real time; dual ability in terms of transmitting such information both to customers, and the service providers in real time, and adaptability of the smart water meter to the Water Institution services. • SWM is considered as a technology that will reduce manual labour and manpower as a meter that detects leakage does not need manpower for leakage detection. • Some Participants (55%) recognise that a SWMS will help to detect and reduce water leakages, water wastages, and help households save water. They believe that smart water metering will prove to be more efficient than the analogue methods. • It was found that water supply is less than the demand in the city currently. As such, findings reveal that a SWMS will save water and when water is saved, it will be available to more people than it is currently leading to revenue increase for the Water Institution. • Findings consistently revealed that when water is saved by people that have water supply in lower areas, water pressure will build up to travel to high areas so they too can have water supply. • It is believed that as people do not pay for water as it should be, they waste it, as such, using a SWMS can help people understand the value of water and motivate them to save it in their homes.
Organisational factors **(section 5.3)**	• All the Participants (11 in total) (100%) from the researched Water Institution are interested in SWMS because of its many attractive benefits, such as improving the services and the operations of the institution (see section 5.2.5 for identified benefits). Five of the eleven Participants (45%) believe that majority of water users would be happy to use the SWMS, but it should not be costly because the people are already burdened with many economic loads, and things are skyrocketing every moment. Only one of the eleven Participants (9%) said that 50% of the populace may not appreciate the real value of a SWMS. • Findings show that SWM should be added as one of the water management technologies in the researched institution. • Participants noted that there is 70% possibility of using a SWMS because their institution have good management and personnel, including manpower, plumbers and engineers capable of effectively managing a SWMS as a water management method. However, some Participants (64%) believe that there is a need for capacity building for staff members before the adoption of a SWMS as it is a new technology and for them to maintain. • Findings show that logistics is a key factor; the Water Institution needs to help with smooth running of SWMS adoption. • It has been found that a framework is needed to help with the adoption of a SWMS. • The percentage (about 90%) of unaccounted-for water in the researched Water Institution is very high because people use water any how they like, and most people are not paying for water. Findings show that sometimes when their line is cut off, when the staff move off site, they will reconnect it and continue using water. The Water Institution cannot deprive them of water because it can cause an outbreak of disease and other challenges if they do.
Environmental factors	• Some of the Participants (55%) identified poor maintenance as a significant challenge to SWMS adoption. They noted that the lack of spare parts, frequent battery failures, and a lack of manpower would hinder the sustainability of the

(section 5.4)	new technology. High-profile personnel are required to manage the SWMS effectively. • Knowledge transfer is also an obstacle as management believes it is not always available. Government work requires constant training for staff members to ensure proper maintenance if SWM is adopted. Without this training, replacing retiring staff who have the knowledge can be challenging. By implementing batch training, it is possible to ensure that other staff members are equipped to handle the SWMS effectively even when older staff retires, ensuring smooth operations and efficient use of the resources. • Findings show that electricity supply would be a hindrance to the adoption of SWM, especially in Nigeria. • A SWMS cannot be installed in some buildings because of the structure of the building and the environment. • Findings show that the pipeline water reticulation are limited to some places even in townships as such some people will not have the smart water meters installed in their residences. • The researched Water Institution has their pipe network clearly specified thereby encouraging SWMS adoption. • It has been indicated that before smart water meter is adopted, Water production needs to increase (be scaled-up). It is believed that when there is a sustained increased water production volume, comes the need to accurately determine the volume of consumption. However, findings also show that water needs to be monitored because the water currently being produced are not being translated into revenue because of losses here and there, and even commercial losses. • All Participants (100%) noted that the Government actively supports the researched Water Institution towards new technology adoption for water management. However, some participants (18%) indicated that the government partly supports the institution with grants from international organisations such as International Development Association (IDA), the French Development Agency (AFD), and World Bank. • The researched Water Institution is wholly accountable to the government which plays supportive and supervisory roles. The government makes decisions and policies that guide the operations of the corporation. So, if a SWM must be adopted, the government must be carried along. • It was indicated that the government needs to improve more in supporting the institution so that smart water meter can be adopted. The government should provide an enabling environment for genuine investors, such as a computer room, furnished and equipped office where people will be able to sit down comfortably and do their work. • There is a believe that the government should concentrate its effort in ensuring that the analogue and prepaid water meters work very well because adopting a SWMS comes with cost. • According to participants (91%) external influences such as the government policy and support may drive or encourage the adoption of a SWMS. • The government has a policy in which you pay for what you consume. The government wants citizens to pay for only what they consume. That was what led to the procurement of the prepayment (prepaid) water meters. • Only one Participant (9%) noted that government policies does not really have impact on SWMS adoption. • Government must be informed properly about SWMSs so that they can see how it can facilitate or aid the provision of services. Government policy overrides any new idea or technology which comes into play. So, the government must approve of it and incorporate it into their policy plans. • Furthermore, Some Participants (64%) believe that with government involvement, SWMSs will be well-promoted, masses will accept it, people will be served faster and better.

	• Interestingly, the researched Water Institution and government would need to have the zeal and agree to use a SWMSs for it to be adopted. • Another factor that would drive SWMS adoption is if the government be the vision bearer and supervise the process. The government is a regulating body, and anything supervised by governments has always been done well. The government protects the citizens. • For sustainability of the SWMS, it was noted that the government need to enact a law that would prevent people from tampering with any installed meter and then stipulate punishment for offenders.
Economic factors **(section 5.5)**	• Some participants (27%) consider a SWMS costly to be adopted because the financial outlay will be massive in this present economic downturn. • A low-cost SWMS with immense benefits would attract customers as people are already complaining of huge economic burden from the researched Water Institution. • It is believed that for SWM to work, customers should be allowed to pay for the meter on an instalment basis rather than them making full payment outrightly as they may not be able to afford it. • A SWMS is difficult to adopt because of the lack of funds within the institution; it was noted that they face major challenges in maintaining their workforce and facilities. • The possibility of having a smart water meter system is full government support by funding Human resource management. The government also needs external support from international organisations to fund the adoption of a SWMS for sustainable water management.
Knowledge **(section 5.6)**	• Participants (55%) noted that before introducing SWM to the social system, sufficient and adequate down-to-earth proper awareness should be created for the people to introduce the system on how it works including its usage and maintenance. • It is believed that with proper awareness of SWM, the demand for it would increase. • It has been found that the people responsible for sustainable water management are the government (such as the governor, and the Commissioners), and it is important to start the awareness campaign with them as they are the policymakers. • Findings show that the organisation which deals with the SWMS would be the body to approach the government. • Findings show that the zones considered elitist, residents in those areas are sufficiently literate enough to understand the basic advantages of this kind of technology in enabling sustainable water management. Whereas people who live in the slums may not understand the technology well. • A SWMS will need a lot of time on meetings, a lot of sensitisations, and obtaining people's opinions and feedback before it can be adopted. • Another key factor that would drive SWMS adoption is to make it a little enticing by mentioning that it comes with reduced cost for any neighbourhood that accepts the implementation. • One of the challenges to SWMS adoption would be getting consumers to understand the new technology. So, it will not be a challenge to the institution. There is a need to properly educate users to avoid challenges towards using a SWMS.
Trialability **(section 5.7)**	• Participants believe that one of the key factors when deciding to adopt SWM as water management approach is to verify the workability from nations where it exists; or conduct a small-scale pilot study to test the workability of the system such as in revenue generation, water management, leak detection, water wastage monitoring and more.

	• Findings show that SWM should be a long-term project, and that an area should be mapped out for the SWMS trial for about six months. If it works, it can be implemented in that area, or it could become a subject of option such as: Do you want it? Yes or No. And if it does not work, they return to continue with the analogue meter.

In the next chapter (Chapter Six), the researcher discusses the research findings considering existing literature to define this study's contribution to the body of knowledge.

CHAPTER SIX: DISCUSSION OF RESEARCH FINDINGS

6.1 Introduction

This research followed subjectivist ontological and interpretivist epistemological assumptions. The inductive approach was followed, which emphasises collecting empirical evidence and developing a theory based on the findings. Qualitative data were collected, and thematic analysis was used to derive empirical evidence about the phenomenon investigated. The findings aimed at attaining a better understanding of the barriers and factors that influence the adoption of an IoT-based smart water meter system (SWMS) at a water utility provider in Nigeria.

The findings were presented using themes that emerged from the data collected from the researched Water Institution, which was the case study in this study. The discussion in this chapter is structured around these themes. Chapter Six examines and validates the findings by comparing them to similar findings from previous studies. The use of literature to interpret findings helps to clarify the subject matter. Then, an information systems (IS) conceptual framework is proposed to stimulate widespread adoption of an IoT-based SWMS.

Chapter six is organised as follows:

- Section 6.2. Discussion of technological factors
- Section 6.3. Discussion of organisational factors
- Section 6.4. Discussion of environmental factors
- Section 6.5. Discussion of economic factors
- Section 6.6. Discussion of knowledge
- Section 6.7. Discussion of trialability
- Section 6.8. Conceptualisation of the Smart Water Meter System Framework
- Section 6.9. Conclusion to chapter six

6.2 Discussion of technological factors

The **Technology factors** theme is adapted from the TOE framework described in section 2.9.3. The theme consists of internal and external variables that affect an organisation's willingness to accept innovation (Tornatzky et al., 1990; Leung et al., 2015). Internal technologies are practices and technologies in the organisation, while external technologies refer to those available on the market but not yet in use by the organisation (Leung et al., 2015). This indicates that the focus of the technological context is on how the characteristics of the technology itself can affect the adoption process.

The following sub-sections discuss the **Technological factors** theme, which is subdivided into: (i) Water management practices; (ii) ICT availability; (iii) Water bypass, illegal connection, and SWMS; and (iv) Benefits of a SWMS in a Nigerian context.

6.2.1 Water management practices

Practice describes the actual water management practices used by the researched Water Institution.

Findings show that all the participants (11 in total) (100%) from the researched Water Institution in Nigeria stated that a SWMS is not used or installed in customers' residences (section 5.2.1.1). However, various water management practices exist in the researched Water Institution, such as using traditional analogue water metering, prepaid water meters, and estimation. Six of these participants (55%) stated that the researched Water Institution uses the traditional analogue water meter. The dominant meter in homes is the traditional analogue water meter (section 5.2.1.2). Interestingly, several nations (such as South Africa and Indonesia) depend heavily on analogue water metering and manual formats for the management of water supply and use (Mudumbe & Abu-Mahfouz, 2015; Hudiono et al., 2021; Sani, 2021). This suggests that people may not be aware of SWMS. IoT-based SWMS implementation in developing countries is limited, while developed countries leverage and implement IoT innovations (Whitmore et al., 2015; Amadin et al., 2017).

On how the traditional analogue water meter works, staff go to the field (e.g., residences, hotels, institutions, etc.) with their notebook (logbook) to read and record meter readings at the end of the month. This also aligns with authors who noted that traditional water meter readings take place monthly, quarterly, or yearly (Sønderlund et al., 2014; Cahn et al., 2020; Adams & Jokonya, 2022). Furthermore, the staff members record the meter reading together with the people in the field. So, both parties confirm that what is written, is the correct record of the meter reading and meter rate for clarity purposes. The present reading of the meter minus the previous meter reading determines how many cubic meters a customer consumed within a time frame, which is then multiplied by the calculation per cubic meter reading. These readings can be labour-intensive and frequently inaccurate because of time lag, projections based on historical data, or deliberate manipulation. Rizzo (2006) argues that smart meter reading is a solution to errors of manual meter reading. Rizzo also notes that meter readers tend to "under-read" meters as it causes less problems with the consumer, and there could be an agreement reached with the consumer. Ravindra (2019) asserts that the traditional method of manually reading meters is problematic and time-consuming, and it wastes resources. Ravindra states that the method is also incapable of effectively achieving sustainable water resources as it needs efficient, accurate and reliable techniques that allow the utility sector and water consumers to know in real time the actual level of water consumption.

Furthermore, water leakages/wastages cannot be accurately determined with the use of the traditional analogue water meter. Increased water leakages may occur for people who cannot take accurate meter readings or calculate the difference between meter readings to ascertain leaks. Britton et al. (2013) assert that leaks will gradually escalate significantly if they are neglected. Britton et al. further note that most water utility customers with traditional water meters only take water leaks seriously when they receive their quarterly or six-month water bill, which can shock them into acting because of potential financial impacts.

Some of the challenges associated with the traditional analogue water meter include: (i) increase in manpower (e.g., staff must go into the field and take readings, then go back to the office to prepare bills for the customer); (ii) delay to push bills in time; (iii) the analogue water meter is at risk on the premises where it is installed because the water utility institution does not have control over the meter; (iv) the analogue water meter quickly deteriorates and becomes challenging to read if it is placed in an area that is susceptible to flooding because the water can destroy some of the meter's elements; or visiting the flooded area to record the meter reading becomes challenging; (v) during repairs (maintenance) of pipes, at times, some debris destroys some elements of the meter such as the fan. It may cause the meter to stop moving, and when the meter stops moving, water passing through is no longer calculated.

Only one of the participants (9%) stated that the institution uses estimation for water billing. Estimation means that if a customer stays in a three-bedroom flat, he pays a fixed amount of money. If a customer stays in a one-room apartment, he pays a fixed amount of money. If a customer resides in a Bungalow, a certain amount is paid. It is fixed, irrespective of how much water the customer uses within a month or a billing period, even if a customer locks up his/her apartment and travels elsewhere. The customer will still pay the same amount of money allocated to the apartment. Even if a customer wastes water, the same amount of money is paid. Sani (2021) explains that when customers' premises are not easily accessible to take meter readings, consumption estimations will be used to calculate the water bill.

6.2.2 ICT availability and readiness

ICT can be described as the use of smartphones, telecommunication and computers to edit, send and receive information. ICT availability in this section thus denotes the ICT technologies that are available, in use and accessible, as well as resources required to improve the sustainability of smart water metering (SWM) in the researched Water Institution. Further, in today's world, technological readiness refers to the ease with which an organisation or economy uses existing technologies to boost productivity. It focuses on an organisation's ability to integrate ICTs into daily operations and production processes for increased efficiency and to foster innovation for competitive advantage. ICTs have evolved into "general purpose technology" in that they are essential to the infrastructure that supports industry (Schwab & Sala-i-Martín, 2014:7).

Computers and an internet connection are the ICT resources available in the researched Water Institution that can support the use/adoption of a SWMS. Findings show that computer technologies are installed in designated offices for data processing and information storage. The computers help the researched Water Institution in processing data, and they have staff members who are good at that. They gather data, process it, come up with information that enhances decision making as the need arises. The internet is used for sourcing and/or transferring of information locally and globally. The researched Water Institution is benefitting from the technological improvement of internet connectivity. Participant 2 explained that the possibilities of having a SWMS are there because they are using the internet. So, a SWMS will be as good as adding to what they have been using. Participant 2 said that water users can use a SWMS as 80% of the people use smartphones (section 5.2.2). This finding is essential because the researched Water Institution can use SWM as water management approach because of their digital operations, which is an integral part of the global world. But they have not adopted a SWMS to date.

Furthermore, the findings reveal that there are many limitations or challenges in information technology in Nigeria, such as internet network failures. Thus, 36% of the participants believe that the internet connectivity needs to be available, reliable and have sufficient network coverage for a SWMS to be adopted because internet access is presently limited among the water consuming public. However, two of the participants (18%) believe that Nigeria does not have the same network capacity that advanced countries for SWMS adoption. As a result, it was pointed out that the traditional analogue water meter and the prepaid water meter will work in Africa (section 5.2.3). This finding is important because it shows that to successfully adopt a SWMS, it may be necessary to partner with a telecommunication company with global infrastructures like MTN for sufficient reliable internet connection coverage.

The reliability of an internet connection is determined by the type of connection used. Wi-Fi is frequently used in public hot spots to provide mobile devices with broadband internet connection with high data rates (Ding et al., 2020). Wi-Fi is used to monitor water consumption in buildings (Horsburgh et al., 2017; Gautam et al., 2020). For long-range communication, cellular communication networks are widely used. The 5G network is made to meet IoT requirements for the development of future smart cities by offering high data rates, lower latency for real-time applications, and many connected devices (Arshad et al., 2019). For example, MTN's 5G network coverage allows for better connectivity at lightning-fast speeds.

6.2.3 Water bypass, illegal connection and smart water meter systems

Findings show that water cost is 'big thing', especially in Africa as customers want everything manipulated. Participant 9 asserted that some water customers engage in fraudulent activities such as water bypass and illegal water meter connections. Accordingly, they might want to default the SWMS so that it does not keep sending them updates, thus opening up the opportunity for them to manipulate or manoeuvre bills (section 5.2.4). Given the rise in the use of data-driven systems, enhanced control and security is a crucial component of technology integration. Data segmentation and segregation is a crucial safety measure to take into consideration (Ferrier, 2019; Sobczak, 2019). Segmentation is a process that divides a network into smaller networks to enhance security and control. Segregation ensures higher security and compliance by isolating essential assets completely. The uncertainty that comes with investing in technology is already present, and increasing cybersecurity concerns make it worse (2.7.2). Therefore, it is crucial to take cybersecurity issues into account as a potential challenge to any technology adoption.

6.2.4 Benefits of smart water meter systems in a Nigerian context

The TOE framework indicates that factors like perceived benefits, perceived risk, and perceived cost of innovations will influence how widely technology is adopted (Adams & Jokonya, 2022). The findings support the widely acknowledged benefits of SWM, as listed and discussed below.

i) Decrease in unpaid water bills and increase in revenue for water utility

Participants (27%) believe a SWMS could help curb the menace of unpaid water bills and increase revenue for the Water Institution. It was noted that customers may claim they did not see their bill when it was delivered at their property, causing payment of water bills to last for six months to a year. Further, findings show that a SWMS will help with making more revenue for the institution to expand its coverage of water supply to more zones in the state.

This view aligns with previous studies (Beal & Flynn, 2015; Yi et al., 2018). Beal and Flynn (2015) point out in their study that a SWMS increased revenues because of more accurate meter readings, increased water distribution infrastructure, and a decrease in non-revenue water losses. Yi et al. (2018) point out how the SWM project has led to 20% improvement in the revenue water ratio and a 190,000 m^3 reduction in leakage per year. This view is important because it shows the economic benefits of SWM. An increase in revenue for the Water Institution will help the institution maintain their equipment and water production will increase. This increase in production will amount to an increase in the supply of the service (water).

ii) Cost savings for both customers and Water Institution

Three participants (27%) believe that adopting a SWMS could make things easier by saving costs for water consumers and the Water Institution. These savings include that water leakage in customers house can be easily addressed without much wastage, as reducing wastage leads to reduced costs, and customers only pay for the water they consumed (section 5.2.5). Beal and Flynn (2015) also mention reduction in operating costs as one of the benefits of a SWMS for water utilities. Johnston (2021) explains that Aigües de Barcelona achieved operational cost efficiencies that eliminated the cost of nine million annual manual reading operations and the risk of meter fraud. Customers behaviours improved towards supporting water saving because of access to appropriate water information. It further reduced overconsumption alerts from 9% to 3%.

Participants 4 and 6 generally believe that a SWMS will assist the institution with time management during billing periods (section 5.2.5). Technology is a welcome development around the world. It saves time and resources. Therefore, it will save significant costs and time on billing and leak detection.

iii) Robustness, dual ability, and adaptability of smart water meter systems

It has been found that SWMS robustness, dual ability and adaptability are the factors that drive its adoption – robustness in terms of capturing a wide array of vital customer water information in real time; dual ability in terms of transmitting such information to the customers and the service providers in real time, and adaptability of the smart water meter to the Water Institution's services. It was noted that a SWMS can be adapted into what they are already doing, such as operational information. Cooper and Zmud (1990) assert that most technology adoption failures happen because of the new technology's inability to adapt to the unique contexts of organisational processes and existing technologies. Pfeffer and Veiga (1999) argue that innovation, speed and adaptability become increasingly important for success in today's competitive markets. Thus, the more flexible an innovation or new technology capability, the better the integration and adaptability to the business process.

iv) A smart water meter system is perceived as an innovative tool that can enhance accountability in water management

SWM provides real-time data on water consumption, making it possible to accurately measure and monitor water usage. Transparency promotes accountability with water consumers and water utilities making it simpler to track water usage patterns. For instance, the consumer can track where their water goes. That is, where does the water you produce go? Who uses the water?

v) Potential to decrease manpower and manual labour

SWM is considered a technology that will reduce manual labour and manpower because a meter that detects leakage does not need manpower for leakage detection. This is one of the major benefits of a SWMS that can drive its adoption. The potential of a SWMS to reduce manpower and manual labour in water management is acknowledged. SWM automates data collection, which reduces the need for manual meter reading and the associated labour costs (Monks et al., 2019; Randall & Koech, 2019). With digital technologies, SWM improves efficiency and streamline processes, which reduces the number of human resources needed for regular water metering and management tasks.

vi) Leak detection, reduction, and water conservation

Some participants (55%) recognise that a SWMS can help detect and reduce water leakages and water wastages, and help households save water. They believe that smart water metering will prove to be more efficient than the analogue methods. Leak detection and reduction is prominent in SWMS literature (Britton et al., 2013; Berger et al., 2016; Muhammetoglu et al., 2020). The City of Sacramento implemented smart water meters in 2009, resulting in 17,600 meters being installed in 2010 and 2011. Their data analysis revealed 1,076 leaks, with 75% confirmed to be in the field. Repairing these leaks saved the city 236 million gallons of water over two years, saving 12.6 gallons for each person per day (Berger et al., 2016). Prompt leak detection is one of the main benefits of a SWMS. By constantly monitoring water flow and detecting anomalies that indicate leaks, these systems assist utilities with reducing water losses and demonstrating accountability in terms of infrastructure maintenance. Furthermore, it can help every household conserve water. Schultz et al.'s (2018) study shows that households that logged into the online SWMS portal repaired leaks more quickly than households who did not.

Finally, the data revealed the following findings, which are not widely reported in the literature: A SWMS will save water and when water is saved, it becomes available to more people than is currently the situation. It was also found that water supply is less than the demand currently in the City. Participants believe that with SWM, instead of people with water supply in lower areas frequently wasting it, they will turn off their taps; then the pressure will build so that water travels to higher areas, and people living in these higher areas will also have access to water supply. As a result, water that would have been wasted in one place can now be used in another.

Thus, a SWMS can increase water accessibility to a wider audience, consequently boosting revenue for the Water Institution. Furthermore, a SWMS can help individuals understand the value of water and motivate them to save it in their homes, as people often do not pay for water as it should be.

6.3 Discussion of organisational factors

The **Organisational factors** theme denotes the characteristics (such as its size, business focus, and management structure) and resources (both human and slack) an organisation has for the effective adoption and operationalisation of new technology. This construct is adapted from the TOE framework (section 2.9.3). The organisational context in this section describes the characteristics and resources needed for successful and sustainable adoption of a SWMS.

Davis (1989) emphasises the significance of developing important theoretical constructs of user acceptance in the IS field to understand user acceptance so as to adopt technology for a purpose. Four concepts were examined: i) acceptance to use a SWMS; ii) staff expertise; iii) logistics to enhance sustainable adoption; and iv) the high percentage of unaccounted-for water.

6.3.1 Acceptance to use smart water meter systems

All the participants (100%) from the researched Water Institution are interested in using a SWMS. The majority identified many attractive benefits that would accrue to people if they used a SWMS, such as not having to pay for water they do not use, assisting in the detection of leaks, and water conservation (section 5.3.1). This perspective is consistent with the assertion of Davis (1989) that a construct needs to be developed on user acceptance of ICT use for a purpose (e.g., SWMS). Further, previous studies identified perceived benefits as examples of technological characteristics that have a significant impact on the adoption of IT (Kim et al., 2015). The acceptance to use a SWMS could also be tied to participants' willingness to negotiate for fast and reliable ICT facilities (e.g., 5G network) to enable them to use a SWMS effectively. Hence, acceptance to use a SWMS shows that SWM can be an added technology to the existing water management practices. It also shows that the researched water utility professionals are motivated to save water resources.

Additionally, participants (45%) believe that most water users would be happy and willing to use/adopt a SWMS, but it should not be costly because the people are already burdened with many economic loads, and things are skyrocketing every moment. This indicates that some of the populace would have a positive attitude toward adopting SWM. Affordability is critical to the widespread acceptance of SWM. For instance, for increased adoption, customers could be allowed to pay for the meter on an instalment basis rather than making full payment outright as they may not be able to afford it. However, Goulas et al. (2022) note that more people will likely accept a SWMS if it is installed for free. Goulas et al. further state that many citizens are already overwhelmed by the stress of daily life, so high-resolution data might not interest them. Still, the ability to quickly locate and fix water leaks is a useful and appealing feature.

Finally, only 9% of the participants said that 50% of the populace may not appreciate the real value of SWM. This emphasises the need to launch education and awareness campaigns to provide information about the benefits of SWM.

6.3.2 Experts and technicians in the Water Institution

Participants noted that there is a 70% possibility of adopting a SWMS because their institution has good management and personnel, including manpower, plumbers and engineers capable of effectively managing SWM as water management method (section 5.3.2). This shows that the institution is confident in its capacity to manage SWM as water management technique. The institution's strong management structure and its pool of highly qualified personnel add to the perceived possibility of SWMS adoption. These factors are critical for the successful implementation and maintenance of a SWMS.

For a sustainable implementation and maintenance of a SWMS, some participants (64%) believe that there is a need for capacity building among staff members before SWM can be adopted, since it is a new technology. Capacity building for staff is a systematic approach towards improving employees' knowledge, skills and capabilities so that they can effectively use and maintain the new technology (SWM). The perception that a staff member needs training to use a SWMS is not prominent in literature on smart water meters. This finding could mean that the staff members going into the field as well as those in the office need training in SWM, including knowledge and guidance on the operational system of the SWMS and how the SWMS operates, otherwise it will become an issue if people are not trained. This implies that the Water Institution should have maintenance personnel in charge of maintaining the devices before it is adopted.

6.3.3 Logistics and adoption framework

One participant (9%) identified logistics as an important factor needed in the adoption of a SWMS within the research Water Institution. For example, smart water meters require efficient logistics to be managed effectively, as they are well-packaged and require transportation to their installation location (section 5.3.3). Logistics is important in many aspects of the adoption process, such as the procurement, installation, training and maintenance of a SWMS. This acknowledgement highlights how important it is to handle logistical concerns well to guarantee the seamless and effective implementation of a SWMS. Addressing logistical issues can make it easier for the system to be installed and operated effectively, which will ultimately lead to better water management techniques.

It was noted that a framework is needed to help with the adoption of a SWMS within the researched Water Institution. An organisation endeavouring to successfully implement smart water metering technology will benefit from having a framework that provides guidance. The adopted framework for this study is TOE. Three constructs—technology, organisation and environment—found in the TOE framework were deemed appropriate for this study (Tornatzky et al., 1990). The framework shows how exogenous variables—technological, organisational, and environmental—affect an organisation's willingness to embrace innovative technology, with each variable having an impact on the organisation's intention to adopt the technology (Kim et al., 2015).

6.3.4 Unaccounted-for water

The research findings highlight a significant issue with unaccounted-for water, indicating that the researched Water Institution loses a high percentage of water, approximately 90%. This loss is mainly attributed to people using water anyhow (any way the want), and to non-payment of water services. Findings show that when water utility staff cut off a customer's water line and leave the site, the customer will often reconnect it and continue to use the water (section 5.3.4). This can be referred to as non-revenue water (NRW). Berger et al. (2016) note that NRW such as commercial losses are caused by water theft, inaccurate or faulty meters, and errors in data handling or leaks. The findings aligns with the work of Chawira et al. (2022) who argue that real water loss to NRW in developing countries is approximately 70–80%. The authors assert that a high level of NRW typically denotes a water utility that lacks the technical, managerial and governance abilities required to deliver a reliable service.

Addressing this issue presents a challenge for the Water Institution, as the study area is a metropolitan city with no source of water supply except through the researched Water Institution and water vendors. So, many people need water, and depriving them of it could lead to disease outbreaks and other challenges. However, the constant loss of water resources because of unauthorised use and nonpayment highlights the need for effective water management techniques such as the SWMS to reduce unaccounted-for water and help promote responsible water practices. Several studies have shown the economic benefits associated with SWM, such as a decrease in non-revenue water losses, savings in operating costs, and increased revenues for water utilities from more accurate meter readings (Beal & Flynn, 2015; Yi et al., 2018; Monks et al., 2019).

6.4 Discussion of the environmental factors

The **Environmental factors** theme describes the landscape where an organisation does business. This includes external factors that present possibilities and limitations for technological innovations within an organisation (Tornatzky et al., 1990; Leung et al., 2015). Institutions both near and far can affect the adoption decision (Azadegan & Teich, 2010). The environmental context of smart water meter adoption in this section includes service provider support, environmental concerns, government support, and government policy.

6.4.1 Support from service providers

It became evident that there are many adoption challenges to a SWMS. Some of the participants (55%) noted that the lack of spare parts, frequent battery failures, and the lack of experts to maintain the system for their institution could hinder the sustainability of the new technology. The participants' experience with the prepaid water meter may have contributed to them identifying these barriers as a challenge to SWMS adoption. The lack of spare parts for a SWMS could cause extended downtime and reduce operational effectiveness. For example, findings show that the prepaid water meter's batteries only last roughly six months, which has an impact on customers' access to water. Typically, the researched Water Institution will replace it with fake batteries as there are no access to quality batteries (section 5.2.1.4).

Battery failures can be a challenge to the adoption of smart water meters. This problem can affect the meters' reliability and functionality, thereby reducing their effectiveness. The lifespan of batteries has an impact on smart water meters' reliability, and shorter lifespans require more frequent replacement. According to Laison (2023), battery lifespan is influenced by the capacity of the battery, which is expressed in milliampere-hours (mAh) (e.g., the ER26500 is 8500mAh); the power consumption of smart water meters under various conditions (e.g., communication technology); and how the firmware is designed to manage power consumption, such as sleeping mode. Power consumption is furthermore affected by the working environment, the IP rating of the meters, and the components. Thus, low-quality batteries are more likely to fail.

Addressing battery failures in smart water meter systems necessitates that SWMS designers invest in high-quality batteries and low-power wide area networks (LPWAN). For example, LoRaWAN provides low power consumption (battery life can last up to ten years), allowing the devices to operate for as long as possible. The LoRaWAN protocol offers long communication ranges (1-5 km in urban areas and up to 15 km in rural areas) and excellent penetration for underground communications. Consequently, LoRaWAN offers enormous opportunities. LoRaWAN networks can be used for various smart water applications, including smart water metering, smart water quality monitoring, and leak detection (Lalle et al., 2021). Furthermore, the Narrow-Band IoT (NB-IoT) is an LPWAN technology that coexists with cellular networks, specifically LTE and GSM. NB-IoT has several benefits for smart water applications, mainly its long battery life (up to 10 years), long communication range, high penetration, and low data rates. Finally, NB-IoT is preferred for smart water applications because of its low power consumption (Mekki et al., 2018). See Table 2.1 for a summary of the technical parameters of LPWAN (section 2.3.2.2).

Similarly, incorporating photovoltaic solar energy into IoT-based smart water technology is revolutionary, especially in tropical nations such as Nigeria. It increases system sustainability while reducing reliance on traditional energy sources. A photovoltaic system is a robust and proven technology, with solar modules readily available from a variety of suppliers. Module lifespan is typically guaranteed for at least 20 years (Decker, 2014), whereas the lifespan of lead-acid batteries is 4-6 years (Wong et al., 2021).

Management considers that knowledge transfer could be a barrier to SWMS adoption as it is not always available. Current literature on smart water technology literature does not provide sufficient clarity or information on this. Going by the findings, knowledge transfer is a crucial aspect in any organisation, but it is not always available. For instance, a faulty computerised system can be frustrating when the supplier of the system is unavailable to fix it, leading to frustration for users. This issue is not only attributed to the lack of knowledge transfer; the information on how to maintain the system is often hidden by the owner (suppliers), causing staff to be uninformed and unable to manage and maintain the system (section 5.4.1). Successful SWMS adoption suggests that staff members require constant training to ensure proper maintenance of the SWMS, as previously noted. Without this training, replacing retiring staff who have the knowledge can be challenging. By implementing batch training, it is possible to ensure that other staff members are equipped to handle the SWMS effectively even when older staff retires, thereby ensuring smooth operations and efficient use of the resources.

6.4.2 Environmental concerns in a Nigerian context

It was found that *electricity supply* issues pose a major challenge to the adoption of a SWMS, especially in Nigeria (section 5.4.2). Onimisi (2023) explains that majority of Nigerians rely on privately supplied energy sources to generate electricity for both business and domestic purposes. Without these different arrangements, the operations of hoteliers, artisans, restaurant businesses, bakeries, hospitals and the entire productive sector of the Nigerian economy would have virtually stopped because of poor electricity supply from the national grid. In the last ten years, the power supply has failed to provide electricity to 40% of Nigerians, and more than 80 million people lack access to electricity. Adoghe et al. (2023) emphasise that Nigeria's generating system capacity remains unreliable and unable to meet the rising load demand. Although the power sector has undergone significant restructuring, it does not appear that these efforts are having an impact on the availability of power supply to consumers. According to Somoye (2023), many developed countries such as China, the USA and Japan have stabilised their electricity supply by investing in solar energy. Developing countries such as Nigeria can potentially reduce or even eliminate energy poverty and promote environmental sustainability by implementing solar energy harvesting technologies.

Williams (2021) identified challenges for hard-to-meter properties in London, such as converted buildings and blocks of flats where the water supply is entirely or partially shared, insufficient space for meter installation, and separating pipeline configurations from nearby properties. From the gathered information, certain buildings may not be suitable for the installation of a SWMS because of structural constraints and environmental factors. For factors such as inaccessible locations, the structure of a building will determine the effectiveness of the meter sensor as some buildings may not have a solid environment where the system will be installed. This is a significant challenge that could affect the widespread adoption of a SWMS for water management (section 5.4.2). However, addressing these challenges requires alternative water management practices such as the use of prepaid water meters, and traditional water meters in areas where a SWMS cannot be installed to overcome the structural and environmental constraints.

Mixed views exist concerning pipeline water reticulation being a factor that could mar the adoption of SWMS in some areas. It is believed that SWM is not in use in Africa because pipeline water reticulation is limited to some places, even in townships. In this case, findings show that the researched Water Institution has detailed drawings and pipe networks clearly specified and preserved in the archives, providing grounds for possible SWMS adoption. Pipeline water reticulation denotes the water distribution network that gathers, treats and distributes water to customers. The availability or absence of this infrastructure has a significant impact on the possibility and success of SWMS adoption in various areas.

It has been indicated that before smart water metering is adopted, water production needs to increase (be scaled-up). It is believed that when there is a sustained increase in the volume of water production, there is also the need to accurately determine the volume of consumption. This implies that if there is water scarcity or no water to consume, there is nothing for the smart water meter to read. Therefore, it is better to increase the amount of water produced so that customers will be happy to use the system and they will be the ones having a demand for it. But at minimal production level, people may not be open to a SWMS, because customers want the product (water) first before the smart water meter. However, findings also show that water needs to be monitored because the water currently supplied are not being translated into revenue because of household and commercial losses. This confirms participants' view that a SWMS could help curb the menace of unpaid water bills and increase revenue for the Water Institution so that they can better maintain their equipment for increased water production and water supply to more zones in the state (section 6.2.4). Further, studies have long shown the benefits of using a SWMS (section 2.7.1).

6.4.3 Government support and policy towards new technology adoption

All participants (100%) noted that the government actively supports the researched Water Institution in adopting ICT/new technology for water management, with some funding assistance from international organisations such as the International Development Association (IDA), the French Development Agency (AFD), and the World Bank. This collaboration emphasises how important government support is in advancing technological innovations for efficient water resource management. However, it is important to note that while the government provides support, some participants (18%) highlighted that the support is limited as the government gives little subvention monthly for water management, indicating the need for additional funding or more extensive support to fully take advantage of technological advancements in water management (such as the adoption of a SWMS). The government has been involved in smart water meter adoptions in developed countries. Take Seosan City, South Korea, for example, where the central government supported the water utilities in a USD 0.4 million project funded by the government's drought relief budget. The City saw improvements in customer satisfaction while decreasing water leakage and errors in the distributing reservoir's inflow and outflow (Yi et al., 2018).

Only one participant (9%) noted that government policies do not have an impact on SWMS adoption because most government agencies are not paying their water bills. Although government water policies may promote water management technologies, their impact on SWMS adoption may be limited because of a lack of specificity.

Participants (91%) noted that external influences such as government policy may drive or encourage the adoption of a SWMS. This finding aligns with the work of Liu et al. (2017), who note that in response to challenges such as water scarcity, demand management and population growth, governments everywhere are implementing strict water policies. For instance, water efficiency, drought relief plans, water use reduction targets and water supply taxes are indirect water policy interventions that inadvertently promote the adoption of smart water meters; on the other hand, direct water policy interventions specify the installation of smart water meters (Beal et al., 2011; Liu et al., 2017). Countries whose water policies inadvertently influenced the adoption of smart water meters include, but are not limited to, South Korea, Israel and the UK (section 2.8). For example, it was found from the researched Water Institution that the government has a policy in which customers are to pay for the water they consume. The government wants citizens to pay only for what they consume. That was what led to the procurement of the prepayment (prepaid) water meters (section 5.2.1.4). The adoption of a SWMS is significantly influenced by government support and policies. Government policies can also determine water efficiency programmes and regulations, which can influence water utilities and customers' decisions to adopt a SWMS (Adams & Jokonya, 2022). This not only improves water management practices, but also promotes sustainable resource use and conservation.

The researched Water Institution is wholly accountable to the government, which plays supportive and supervisory roles. The government makes decisions and policies that guide the operations of the corporation. Government policy overrides any new idea or technology that comes into play. Findings show that for a SWMS to be adopted, it is important to properly inform the government about the benefits of SWM. Interestingly, to ensure that the system is included in policy plans and to expedite the approval and provision of services, both the government and the research Water Institution have to agree and have the zeal to use the SWMS.

Another factor that would drive the adoption of a SWMS is for the government to be the visionary and supervise the process. It was found that since the government is a regulatory body, any project supervised by a government is always done well. For instance, some participants (64%) believe that with government involvement, SWM will be well-promoted, the masses will accept it, and people will be served faster and better. This submits that the government can ensure compliance with standards, best practices and regulations when they supervise SWMS adoption because water management is one of the utility services subject to government regulation. Government involvement and supervision would ensure that the adoption of a SWMS aligns with the citizens' safety and interests, since the government is tasked with protecting the people. Supervision protects the rights of customers, guarantees fair pricing, and aids in the prevention of malpractices. Therefore, government involvement is essential to the adoption of a SWMS because it guarantees compliance with regulations (such that would prevent people from tampering with any installed meter and then stipulating punishment for offenders), protects the rights of citizens, and builds public trust.

6.5 Discussion of economic factors

Qin et al. (2020) propose incorporating economic factors into the TOE adoption framework, arguing that businesses may be more willing to use IT if it is low-cost. A high initial investment will have a direct impact on organisational decisions because of the risk involved. As a result, this study incorporated the economic context as one of the factors for the SWMS adoption framework. The economic factors for SWMS adoption in this section are cost, funding, and return on investment.

Participants' responses demonstrated that businesses are essentially motivated by costs. Some participants (27%) considered a SWMS costly to adopt because the financial outlay will be so mind-boggling in this present economic downturn. A low-cost SWMS with immense benefits would attract customers as previously mentioned because people already complain about a huge economic burden (section 5.5.1). Adopting a SWMS can present financial challenges such as the cost of infrastructure, equipment and technology integration, especially during the initial investment. Operational expenses including maintenance, data management, cost of staff training and consulting fees for hiring SWMS experts add to the perceived cost burden (Qin et al., 2020). However, the long-term benefits of a SWMS like enhanced water conservation, leak detection, reduced water loss and improved efficiency often outweigh the initial costs (see sections 2.6 & 2.7.1). Monks et al. (2019) reveal 75 benefits associated with SWM. Their study attracted input from various water management experts for stakeholders considering SWMS implementation.

The possibility of having a SWMS depends on full government support through funding human resource management. The government also needs external support from international organisations to fund the adoption of a SWMS for sustainable water management. Governments and water utilities can work together to promote sustainable water management by looking into funding sources, grants and partnerships to mitigate financial challenges.

6.6 Discussion of knowledge

Knowledge refers to the stage at which a person is introduced to the existence of a new idea or innovation. It is the person's first communication with the technology. This is when the person learns about the technology, which can be accomplished through a variety of methods, including advertisements, exhibitions, networks and media. A person's primary concerns include what the technology is about, how it works, and why it works (Rogers, 1995). The knowledge needed to understand the functionality of the new technology could be obtained by asking the right questions and assessing the new technology's capability, applicability, adaptability and compatibility. The knowledge acquired can foster a synergy between business and technology, facilitating and meeting the impact and expectations required by the business (Palvalin et al., 2013). The knowledge factors for SWMS adoption in this section are technology awareness and users' education.

Participants (55%) noted that before introducing SWM to the social system, sufficient and adequate down-to-earth proper awareness should be created for people to introduce the system in terms of how it works, i.e., usage and maintenance (section 5.6.1). This viewpoint aligns with the above-explained claim made by Rogers (1995). Shah et al. (2020) assert that a high level of awareness indicates that 'now is the time' to implement environmental policies that incorporate better water conservation methods. It is believed that with proper awareness of a SWMS, the demand for it will increase. Therefore, the government (such as the governor and the commissioners) is responsible for sustainable water management as previously established (section 6.4.3). It is important to start the awareness campaign with them as they are the policymakers. For instance, the organisation dealing with the SWMS would have to approach the government and introduce the system.

From the gathered information, participants (36%) believe that one of the challenges to SWMS adoption would be getting customers to understand the new technology to avoid challenges towards using SWM (section 5.6.2). A lack of proper education can hinder the effective use and management of the technology, leading to challenges like constant error messages as system feedback. This viewpoint aligns with the study of Shah et al. (2020) who found that a common challenge to smart water metering is the degree of user awareness and their ability and willingness to pay for the service. Their study also emphasises the importance of communicating water efficiency awareness in a way that considers individual and household priorities and preferences. Therefore, for successful users' education to accept SWMS adoption: (i) make SWM a little enticing by mentioning that it comes with reduced cost for any neighbourhood accepting the implementation; (ii) focus on the elitist zones as residents in those areas are sufficiently literate to understand the basic advantages of this type of technology in enabling sustainable water management, whereas people who live in the slums may not understand the technology well.

Formal knowledge of SWM needs to be acquired by relevant stakeholders (government, water utility and customers) to motivate adoption. However, a SWMS could require a significant amount of time spent on education, meetings and gathering opinions and feedback before it can be adopted.

6.7 Discussion of trialability

Findings show that a small-scale pilot study is required to test the workability of a SWMS in terms of revenue generation, water management, leak detection and water wastage monitoring before widespread adoption. It could be a long-term project whereby an area is mapped out for the SWMS trial for about six months (section 5.7). Rogers (1995) explains that trials are frequently part of the persuasion and implementation stages of technology because they enable the Water Institution to create an accurate and positive impression of the innovation. For instance, from 2016 to 2020, Singapore conducted a pilot trial for smart water meters. In January 2022, they began installing smart water meters in Singapore residences and businesses (PUB, 2022).

A small-scale pilot study enables cost-effective trials of SWMS possibility and functionality, reducing financial risks associated with full-scale deployment. Additionally, pilot studies are useful in identifying potential implementation obstacles and challenges, such as logistical limitations, technical problems and user acceptance. A pilot study allows stakeholders to gain valuable insights, and gathering data that will guide decision-making processes and guarantee a more seamless adoption of a SWMS. For instance, it could become an option, e.g., "Do you want it?" Yes, or no. If it does not work, they return to using the traditional water meter. Future adopters can collaborate with water utilities in different countries that have adopted SWM to further understand and verify the workability of such a system (see sections 2.6 & 2.8 for cities that have adopted SWM).

6.8 Conceptualisation of the Smart Water Meter System Framework

The research followed an inductive approach, thus, findings from the research were extrapolated to existing theories and constructs found in the literature. Saldana (2009:11-12) note that “the development of an original theory is not always a necessary outcome for qualitative inquiry but acknowledge that pre-existing theories drive the entire research enterprise, whether you are aware of them or not”.

Therefore, the underpinning theoretical framework (i.e., the TOE framework) is used to validate findings. Related IT adoption theories such as the DOI theory were also adapted to account for the findings. Thus, emergent findings such as *economic factors*, *knowledge* and *trialability* have been added to the TOE framework of Tornatzky et al. (1990) to produce an extended framework for SWMS adoption (Figure 6.1). In Figure 6.1, green text shows the newly added constructs.

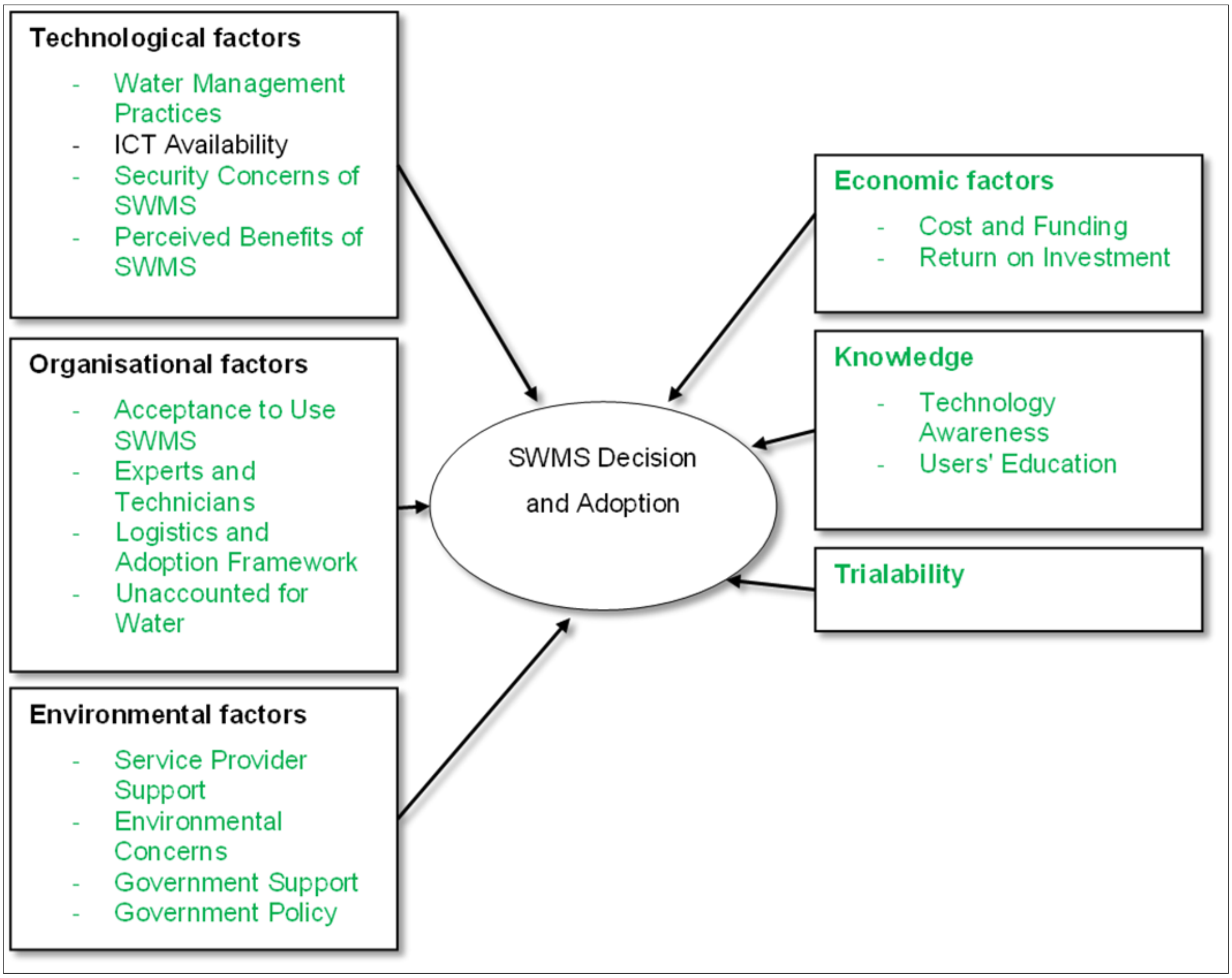


Figure 6.1: Research conceptual framework
(adapted from Tornatzky et al., 1990)

- The constructs **Technology, Organisation and Environment** were adapted from the TOE framework (section 2.9.3) together with insights from this study's interview analysis.
- Insights from interview analysis and viewpoints put forth by Qin et al. (2020) were used to construct the concept of **economic factors**.
- The concept of **knowledge** was constructed using insights from the interview analysis and one of the components of Rogers' five stages of the Innovation Decision Process for Technology Adoption (section 2.9.2).
- The concept of **trialability** was constructed using insights from the interview analysis, and one of the components of Rogers' (1995) suggested five innovation characteristics influencing the rate of adoption (section 2.9.2).
- The concept of **SWMS decision and adoption** was constructed using insights from the interview analysis and from the TOE framework and DOI theory (section 2.9.2 & 2.9.3).

Table 6.1: Definition of constructs

Theme (e.g., construct)	**Definition**	**References**
Technology factors	Refer to internal and external variables that affect an organisation's willingness to accept innovation. Internal technologies are practices and technologies in the organisation, while external technologies are those available on the market but not yet in use by the organisation. These factors include water management practices, ICT availability, water bypass, illegal connection, and SWMS as well as benefits of SWM in a Nigerian context.	(Tornatzky et al., 1990; Leung et al., 2015)
Organisation factors	Refer to the characteristics (e.g., size, business focus, management structure) and resources (both human and slack) within an organisation for the effective adoption and operationalisation of new technology. It covers factors such as acceptance to use SWMS, experts and technicians within the institution, logistics and adoption framework, and unaccounted-for water.	(Tornatzky et al., 1990; Davis, 1989; Bryan & Zuva, 2021)
Environment factors	Refer to the landscape where an organisation does business. This includes external factors that present possibilities and limitations for technological innovations within an organisation. The environmental factors for this study are service provider support, environmental concerns, government support, and government policy.	(Tornatzky et al., 1990; Azadegan & Teich, 2010; Leung et al., 2015; Tom et al., 2019)

Theme (e.g., construct)	Definition	References
Economic factors	Describe factors that present limitations and possibilities for the adoption of a SWMS. These factors are cost of implementing SWM, funding, and return on investment.	(Qin et al., 2020)
Knowledge	Refer to the stage at which a person is introduced to the existence of a new idea or innovation. This is when the person learns about the technology.	(Rogers, 1995; Palvalin et al., 2013)
Trialability	Refer to the need to conduct a small-scale pilot study to test an innovative idea before adopting it on a large scale. It acts as a feasibility study to help organisations understand how the proposed innovation would function in practice.	(Rogers, 1995)
SWMS decision and adoption	Refer to organisations' SWMS ability to take decision as established via the combination of *technological factors*, *organisational factors*, *environmental factors*, *economic factors*, *knowledge*, and *trialability*. This aids with the adoption and sustainability of SWMS to monitor water usage in buildings or residences for sustainable conservation of water resources and for a resilient city.	(Tornatzky et al., 1990; Rogers, 1995; Anandhavalli et al., 2018)

6.9 Conclusion to Chapter Six

Chapter Six discussed the emergent themes from the research findings, which aided in answering the research questions using prior published literature. This discussion was facilitated by applying three existing frameworks as the analytical lens to comprehend fundamental conceptual meanings and to ensure the validity and verifiability of the research findings. The research conceptual framework depicted in Figure 6.1 is developed based on the themes that have emerged, and they uncovered factors that could drive the adoption of a smart water meter system.

This research study concludes in Chapter Seven. It addresses the main aim of the research, which is to explore the reasons behind the failure of water utilities to adopt an IoT-based SWMS to improve the efficiency of water management for a sustainable future.

CHAPTER SEVEN: CONCLUSION

7.1 Introduction

The United Nations (UN) approved the 2030 Sustainable Development Agenda in September 2015. The agenda has global indicators for international corporations to attain sustainable development between 2015 and 2030. This study aligns with Goals 6, 12 and 13 of UN Sustainable Development Goals (SDGs) (2015–2030). These goals are basically about the need to implement an integrated water management system to help manage water and address water scarcity at all stages (United Nations, 2015). Consequently, the advancements in water metering and ICT have made it possible for household water usage data to be recorded by a smart water meters system (SWMS). A SWMS is an internet-capable device that monitors water usage in a building or residence (Anandhavalli et al., 2018).

The research problem stated in this study is that *current water resource management continues to use the traditional, manual or analogue meter for water management, and is therefore challenged with time-lag, errors in meter readings, additional labour force to process water bills, water leakage, and wastages. Despite the continuous growth and documented benefits of smart water metering (SWM) based on IoT, the uptake of this system has been slow because of a lack of understanding and no Information System (IS) framework in place to guide widespread adoption of a smart water meter system (SWMS). A sustainable IS framework for the adoption of SWM and the management of the associated technologies is needed*.

Therefore, gaining a comprehensive understanding of the challenges that could hinder SWMS adoption was crucial. This study explored people's perceptions towards adopting a SWMS. Findings indicate opportunities and challenging aspects of adopting a SWMS. While the gained understanding does not solve the issue, it does aid in the solution by highlighting the issues that the Water Institution (and government) should address. An embedded case design was adopted to accomplish the aim and objectives of the study. The sources of data collection were semi-structured interviews, documentation and a literature review. The participants are experts in water management (e.g., managers) and were therefore purposefully selected to participate in the research. Table 4.1. displays the profile of the participants.

Chapter Seven concludes this study by answering the primary research question and sub-questions posed in Chapter One (sections 1.5 & 1.6). Drawing on the knowledge gained from the research, a recommendation is made to promote the use of a SWMS. The chapter also discusses the contributions of the research as well as the limitations and suggests areas for future research.

7.2 Answers to research sub-questions

The research sub-questions are answered in this section.

7.2.1 What are the factors influencing the use and adoption of an IoT-based smart water metering system?

i) One of the factors influencing the use and adoption of a SWMS is a lack of awareness and understanding among stakeholders (government, the Water Institution and customers). Some participants were unfamiliar with the phenomenon being studied and mistook prepaid water meters for smart water meters. This demonstrates a knowledge gap and emphasises the importance of education and awareness campaigns to clarify the differences between different water metering technologies to promote the adoption of smart water meters.

ii) Some telecommunication companies' infrastructures in Nigeria may be below global standards, resulting in unreliable internet connections (e.g., network failures). This raised concerns among participants about the reliability of internet connectivity for carrying out processes if a SWMS is implemented.

iii) The high cost of water, particularly in Africa, poses a challenge to SWMS adoption, as findings show that customers attempt to manipulate billing. So, there is concern that some customers may try to disable SWMS updates to avoid accurate billing, thereby allowing them to manipulate or evade charges. This emphasises the importance of robust measures to prevent fraudulent behaviour and ensure the efficiency of SWM.

iv) A lack of logistical support could hinder the deployment and maintenance of smart water meters, which could in turn affect the widespread adoption and usefulness of SWM.

v) Management lacks the framework to guide the widespread adoption of a SWMS.

vi) The amount of unaccounted-for water with the Water Institution losing approximately 90% of its water supply, often indicates potential deficiencies in governance and in technical and managerial capacities within the water utility, thus hindering the ability to provide a reliable service.

vii) Management is in a situation where they are already experimenting with the prepaid water meter; it is therefore believed that if a SWMS is adopted, there could be challenges with the availability of spare parts, frequent battery failures, and a lack of experts to maintain the system.

viii) Management considers knowledge transfer as a possible hindrance to SWMS adoption as it is not always available. It is believed that service providers (suppliers) deliberately hide information from staff on how to maintain their systems.

ix) Electricity supply issues in Nigeria could be a further hindrance to SWMS adoption.

x) Certain buildings may not be suitable for the installation of a SWMS because of structural constraints and environmental factors. This includes inaccessible locations, the structure of a building, and limited pipeline water reticulation to some places.
xi) Government water policies do not have an impact on SWMS adoption.
xii) Lack of funding is another hindrance. SWM is considered expensive to adopt. This has an impact on budgeting, e.g., the cost of infrastructure and technology integration, especially during the initial investment. Operational expenses including maintenance, data management, cost of staff training and consulting fees for hiring SWMS experts add to the perceived cost burden.

7.2.2 How do people feel about using a smart water meter system to manage their water?

The findings reveal three major perspectives that emerged from the chosen Water Institution. These include:

i) Implementing a SWMS holds economic gains for water utilities and customers and holds potential benefits for the society and the environment (section 6.2.4).
ii) There are still technological, organisational, environmental, economic and knowledge gap challenges to address, including internet network failures in Nigeria, service provider support and government support.
iii) The adoption of a SWMS can be influenced by various factors like social awareness, and both the government and the Water Institution must agree and be eager to use a SWMS.

7.2.3 How can the Water Institution adopt a smart water meter system as part of their water management method?

The following answers address this specific research sub-question:

i) The Water Institution and customers should partner with a telecommunication company with global infrastructures for faster and sufficiently reliable internet connection coverage (e.g. 5G network).
ii) Management can install the SWMS for free or accept instalment payments to attract customers, as many are already overwhelmed by economic hardship and may be unable to pay in full.
iii) A robust management structure and a skilled workforce, including plumbers and engineers, add to the possibility of adopting a SWMS.
iv) Management should address logistical issues to make it easier for a SWMS to be installed and operated effectively.
v) A framework that provides guidance would help the Water Institution to successfully adopt a SWMS.

vi) Management should source a low-cost SWMS with immense benefits to attract customers because people complain about the enormous economic burden.

vii) To motivate adoption, the Water Institution can educate relevant stakeholders (government, water utility's management and customers) on SWM's immense benefits.

viii) The Water Institution can promote SWMS to their customers by mentioning that it comes with reduced costs for any neighbourhood or customer that accepts the implementation.

ix) The Water Institution should focus on the elitist zones as residents in those areas are sufficiently literate to understand the basic advantages of this type of technology in enabling sustainable water management.

x) A pilot study is needed to evaluate the effectiveness of a SWMS in terms of revenue generation, water management, leak detection and water wastage monitoring before widespread adoption.

xi) Management can collaborate with water utilities in different countries that have adopted a SWMS to further understand and verify the workability of the system.

xii) Management should negotiate for LPWAN smart water meters with high-quality batteries to avoid frequent battery failures.

xiii) Management can negotiate for solar energy harvesting SWM to avoid unreliable electricity supply in Nigeria.

xiv) Staff members require constant training from service providers to ensure proper maintenance of a SWMS.

xv) A SWMS can be added as part of water management practices (e.g., for elitist neighbourhoods with pipeline water reticulation).

xvi) External influences, for instance, full government support and a strong water policy, can drive the adoption of SWM to become part of its water management practices.

xvii) Government needs to be the visionary and supervise the sourcing and adoption process to ensure compliance with standards, best practices and regulations.

xviii) Governments and water utilities can work together to promote sustainable water management by looking into funding sources, grants and partnerships to mitigate financial challenges.

7.2.4 What is the role of government in facilitating and engaging institutions proactively in the use and adoption of an IoT-based smart water meter system?

The government has a major responsibility to support the Water Institution since it creates favourable environment for business growth; it supports, encourages and regulates the adoption of ICT/new technology. Available technology infrastructure is essential and encourages SWM adoption as water management approach.

Although the government provides monthly subvention, findings show that the support is limited and there is a need for additional funding or more extensive support to fully take advantage of technological advancements in water management (such as adopting a SWMS). The fact that most government agencies fail to pay their water bills further supports the findings that government water policies have no impact on SWMS adoption.

7.2.5 What practical evidence exists regarding the adoption of a smart water meter system by water utilities?

A systematic literature review was conducted to find practical evidence of SWMS adoption by water utilities, and this has been discussed in Chapter Two. It was found from the review that there are real-world examples of water utilities that have successfully implemented a SWMS in various cities around the globe. The key benefits and challenges of SWM adoption are presented in sections 2.6, 2.7 and 2.8. Stakeholders can evaluate the degree to which water utilities have implemented a SWMS and the outcomes in terms of customer engagement, operational efficiencies and water management before adoption.

This review produced the paper titled: *Smart water metering system (SWMS) adoption: A systematic literature review* (Okoli & Kabaso, 2023).

7.2.6 What are the current smart water application technologies for water management?

From the systematic literature review compiled in Chapter Two, current smart water application technologies used in managing water were identified. Findings show that various technologies such as microcontrollers, embedded programming languages, sensors, communication modules and protocols are used by researchers to accomplish their aim of designing IoT-based smart water solutions. Table 2.5 presents features of various IoT-based smart water applications.

None of the publications employed 5G mobile networks as a communication module for their smart water application development. Findings further show that integrating 3D printing and solar energy into IoT-based smart water applications is revolutionary and can increase the sustainability of the systems. As different sensors are being used to monitor various SWM parameters, 3D printing helps to reduce the possibility of system damage caused by negative environmental influences such as dust, wind, and rain (Khosravani & Reinicke, 2020). The benefits of 3D printing technology (e.g., fast fabrication, high accuracy, and low cost) have been demonstrated by Wong et al. (2021).

This review produced the paper titled: *Building a smart water city: IoT-based smart water technologies, applications, and future directions* (Okoli & Kabaso, 2024).

7.2.7 What framework can be developed to adopt a smart water meter system?

The SWMS conceptual framework presented in chapter Six (see Figure 6.1) is based primarily on the research findings and revolves around the TOE framework (Tornatzky et al., 1990), DOI theory (Rogers, 1995), and TAM (Davis, 1989).

The TOE theoretical framework explains technology adoption in organisations and highlights how various factors such as technological, organisational and environmental factors influence the adoption of technological innovations. To understand whether users would accept adopting technology for a purpose, the acceptance feature of TAM was used to describe concepts such as acceptance to use SWMS, staff expertise, logistics to enhance sustainable adoption, and the high percentage of unaccounted-for water. Furthermore, the trialability concept was constructed using insights from the interview analysis and was inferred back to one of the components of Rogers' (1995) suggested five innovation characteristics influencing the technology rate of adoption.

The developed SWMS conceptual framework could promote the widespread adoption of the system for sustainable conservation of water resources. This framework could be used to improve and support existing IS/IT theories, particularly in developing countries facing similar challenges to Nigeria. The next section concludes with the main research question.

7.3 Answer to the research question

Recall that the aim of the study was ***to explore the reasons behind the failure of institutions to adopt an IoT-based smart water meter system to improve the efficiency of water management for a sustainable future.*** The primary question posed was:

> **What are the adoption challenges for institutions in the use of an IoT-based smart water meter system?**

The Water Institution is constrained by various factors, namely, technological, organisational, environmental and economic factors as well as a knowledge gap. This includes internet network failures in Nigeria, associated cost and service provider support to maintain a SWMS, poor electricity supply, limited government support, government water policies, security concerns around SWMS, the lack of a SWMS framework and logistics, structural constraints and environmental factors, and a lack of awareness and understanding of a SWMS, among others. These factors hinder SWMS trials by stakeholders, resulting in the reasons attributed to slow SWMS adoption.

7.4 Recommendations to promote smart water meter system adoption

Specific issues need to be addressed to encourage the adoption of a SWMS. The recommendations are aimed at raising awareness for stakeholders regarding the need for a stringent water policy in the water sector to aid the widespread adoption of SWM. The recommendations cover water regulations/policy, technology infrastructure, standardisation, funding and incentives, awareness and education, evaluation and monitoring practice, and management support.

7.4.1 Water policy

This recommendation is based on the finding that governmental water policies have no impact on SWMS adoption. It is recommended that the government creates clear, stringent water policies and regulations in response to issues such as water scarcity, demand management and population growth. Indirect water policy interventions such as water efficiency, drought relief plans, water use reduction targets and water supply tax unintentionally promote smart water meter adoptions (section 2.8). Addressing water insecurity requires improved policy and water governance as evidenced in the Korean and Israeli water sectors.

7.4.2 Technology infrastructure

This study found limitations in internet network coverage in Nigeria as some telecommunication companies' infrastructures may be below global standards. Considering the noted limitations, the government should develop and promote broadband internet bandwidth that is accessible and affordable for social and business activities. For SWMS adoption, access to quality affordable technological infrastructure is significant for water utilities so that they can operate using the same network capacity available in advanced countries.

Furthermore, increased government involvement is required to create an environment conducive to broadband use. The government should encourage private participation through reduced import duties and subsidies. The recommended action will reduce the cost of services and equipment, making broadband more accessible and having greater spread and connectivity. For example, MTN's 5G network coverage allows for better connectivity at lightning-fast speeds.

7.4.3 Standardisation

According to the findings, some customers may attempt to disable SWMS updates to avoid accurate billing, thereby enabling them to manipulate or evade charges (water bypass). Governments play an important role in creating and implementing standards for SWMS adoption to ensure data security, interoperability and compatibility. Standardisation can help with SWMS adoption and integration into the current water infrastructure.

7.4.4 Funding and incentives

Based on the findings, there is a lack of funding within the Water Institution as the government offers little subvention monthly for water management because of limited funds; as such, a SWMS is considered expensive to adopt. The possibility of having a SWMS depends on full government support through funding to human resource management. Thus, governments and water utilities should work together to promote sustainable water management by exploring funding sources, grants and partnerships to mitigate financial challenges. Financial support could accelerate adoption and help offset the initial costs of implementation.

7.4.5 Awareness and education

Findings show a lack of awareness and understanding among stakeholders in the usage of a SWMS. It is recommended that the organisation dealing with SWM should approach both the Water Institution and government to introduce the system. Next, the government needs to educate stakeholders (government agencies, water utilities and customers) on the immense benefits of SWM, which include enhanced water conservation, cost savings and overall water management. Campaigns to raise awareness could aid in overcoming resistance to change and accelerate adoption.

Community engagement and social coordination are critical for the successful adoption and use of SWMS. Involving stakeholders like local communities, policymakers, water utility providers, in the early process promotes a sense of responsibility and ownership. This collaborative method helps in identifying and addressing concerns, as well as ensuring that the system aligns with local needs and values.

Community engagement can facilitate behavioural change, encouraging stakeholders to adopt and use the SWMS framework effectively for water conservation. Social coordination, in which stakeholders collaborate to make decision, enhances accountability and transparency, increasing trust and long-term commitment to the system's success. While increasing trust and long-term sustainability of the SWMS.

7.4.6 Evaluation and monitoring practice

It is recommended that SWMS evaluation be done as part of business practice for water institutions to reap the benefits of their investment. Management should monitor the adoption and efficiency of a SWMS, which include system performance and water usage. Doing so may help address challenges, identify best practices and refine policies to maximise the impact of the system.

7.4.7 Management support

As earlier established (section 4.2.2), the researched Water Institution is a licensed state-owned business in the water sector, with the Nigerian government as the main shareholder. The Governor of the State appoints the body that governs the Water Institution. Findings show that the government and the Water Institution must agree and be eager to use a SWMS for it to be adopted.

Support from management conveys to other stakeholders the significance of the initiative and encourages their involvement and commitment. Management's support and involvement enable more informed decision-making when selecting, installing and maintaining a SWMS. Their guidance guarantees that the selected systems meet institutional objectives and requirements. Thus, it is recommended that the Water Institution's management should promote collaborations among institutions (including research institutions), technology providers and other water sector stakeholders. Collaborative programmes can drive knowledge sharing, innovation and communal action towards selecting and adopting an appropriate SWMS.

7.5 Research contributions

The theoretical, practical and methodological contributions of this research are presented next.

7.5.1 Theoretical contributions

This study offers significant theoretical contributions to the IoT-based SWM field. Despite the advancements, the field has faced challenges particularly from the viewpoints of Nigeria and developing countries where there is limited literature on the phenomenon studied. The aim of this research was to bridge these gaps by creating new insights for a better understanding of SWM and proposing a sustainable SWMS framework to motivate a widespread adoption of an IoT-based SWMS.

The SWMS conceptual framework (Figure 6.1) presented in this thesis revolves around the TOE framework (Tornatzky et al., 1990), DOI theory (Rogers, 1995), and TAM (Davis, 1989). These contributions provide new insight into the TOE framework. Thus, the SWMS framework is an original contribution to IS literature in terms of introducing economic factors, knowledge, and trialability constructs. This research extends the theoretical borders of the IoT-based smart water systems field, presenting a more detailed understanding of an IoT-based SWMS.

The theoretical implication of this research is that it will be useful in IS/IT research. It can be used in the implementation of IoT technologies such as LPWAN for the application of smart water quality monitoring and leak detection. Researchers can explore these technologies to enhance system performance and integration. The framework can be used to improve and support existing IS/IT theories, particularly in developing countries facing similar challenges to Nigeria.

7.5.2 Practical contribution

By addressing current water resource management challenges, this study provides significant practical contributions to the water sector, which continues to follow traditional, manual and analogue water management practices. Despite the continuous growth and documented benefits of SWM based on IoT, the uptake of this system has been slow because of a lack of understanding and no Information System (IS) framework in place to guide the widespread adoption of the system. This research bridges the gap between theoretical knowledge and practical application by offering concrete insights into SWM and a proposing framework to guide the widespread adoption of the system.

The key practical contribution lies in the adoption of SWM for water management. This approach differs distinctly from existing practices, which have been challenged with time-lag, errors in meter readings, additional labour force to process water bills, water leakage, and wastages. Findings show that the implementation of a SWMS have potential benefits such as increased revenue for the Water Institution to improve water management, cost savings for both water consumers and water providers, leak detection and reduced water wastage, water conservation, time management in terms of rolling out water bills, accountability, increased water availability, reduced manual labour, real-time monitoring and communication, robustness, dual ability, and the ability to adapt a SWMS into the Water Institution's services.

The practical implications of the SWMS conceptual framework (Figure 6.1) are that it offers an evaluation tool and adoption framework for water utilities to change their water management practices for efficiency and sustainability of water. Furthermore, this research offers valuable insights for government in developing a water policy for the water sector, potentially leading to informed and effective decisions in the adoption of a SWMS. The long-term benefits of SWMS adoption can significantly benefit society in future, both environmentally and economically. It can reduce the carbon footprint of water supply systems through water conservation, water scarcity can be mitigated in the city, and users can save on costs, thereby providing people the right to a harmless environment.

7.5.3 Methodological contribution

The methodology applied in this study institutes a step forward in the smart water systems field. Much focus has been on the system's design (Gosavi et al., 2017; Suresh et al., 2017; Anandhavalli et al., 2018; Srivastava, 2018; Hasibuan & Fahrianto, 2019; Ray & Goswami, 2020), security architecture (Ntuli & Abu-Mahfouz, 2016; Ray & Ray, 2020), monitoring (Muhammetoglu et al., 2020), and system feedback (Britton et al., 2013; Visser et al., 2021).

At the time of this study, researchers have failed to propose a SWMS framework to motivate the coherent adoption of SWM. To address this gap, the researcher developed a new methodology that focused on interpretivist philosophy, employing an embedded case study strategy and qualitative data collection techniques. The qualitative data were gathered using semi-structured interviews with experts/managers of the Water Institution. The collected data were thematically analysed. The methods helped the researcher to better understand the reasons for the failure of water institutions to adopt an IoT-based SWMS to improve the efficiency of water management for a sustainable future.

The novelty of these methodological choices (see Figure 1.2) lies in the developed SWMS conceptual framework (see Figure 6.1). Existing methods mainly rely on areas such as system design and system feedback, resulting in the slow adoption of SWM, whereas the techniques in this study incorporate findings from the literature review, document review and semi-structured interviews. This provided answers to the research and research sub-questions (see sections 7.2 & 7.3).

The literature assisted the researcher with clearly defining the research problem. The semi-structured interview technique enabled the researcher to engage in an in-depth interview with the participants based on the study phenomenon and examining documents, with the interviews being the key source of the primary data collection. The in-depth interview helped the researcher in probing participants to elaborate on initial responses and to ask follow-up questions to clarify issues raised by the participants. To ensure validity and reliability, a pilot study was conducted, and the interview protocol was made available to the participants, which provided them with information regarding the study, such as the overview, title, aim and data collection methods. This enabled them to prepare and assemble supporting institutional documents. The study followed an inductive approach; as such, the findings were inferred back to existing constructs and theories in the literature (section 3.10.1).

These methodological choices gave the researcher the opportunity to capture the water management practices and perceptions of the water utility professionals on using SWM. The water utility professionals enjoyed the interview sessions and expressed their willingness to use the SWMS to increase revenue in their institution. Applying the embedded case study strategy and qualitative data collection techniques in this study is a novel way to better understand complex phenomena, topics or institutions to generate knowledge and/or inform policy development (see chapter Three for detailed methodological choices).

7.6 Limitations of the research

This study is limited to an embedded case study design, a government-owned water provider recognised as using ICT within their institution and with the potential to use a smart water meter system (SWMS). In total, eleven (11) officials participated in the study. The researcher ensured that data were collected from key informants in the identified Water Institution, and data saturation was obtained, which shows that resonance with data was achieved. A large sample size would likely have produced more prevalent reasons behind the failure of institutions to adopt a SWMS to improve the efficiency of water management for a sustainable future.

Therefore, the findings from this study may or may not be generalisable within the study's population because of the sampling methods used. The generalisation may be possible if the research is conducted in various government-owned water providers because they are responsible for sustainable water management. Further, government-owned water providers in other regions frequently face similar issues such as infrastructure challenges, and water waste. Studying the adoption of SWMS in the selected water institution can reveal strategies to address similar problems in others.

The researcher did not have access to opportunities and resources to include additional cases in this study. It was challenging to engage other governmental water utility provider institutions because of their unwillingness to participate, and partly because of their lack of awareness and understanding of the study's significance. Several emails and data collection forms were filled, and documents were submitted, but there was little positive response (Yin, 2018:62).

The researcher did not employ the services of an expert coder because of the sensitivity of the data and the cost associated. Hence, the researcher coded the data alone and the supervisor periodically reviewed it. Considering the researcher's epistemological position, the interpretation of reality is subjective, based on interactions with the participants, data and expertise.

7.7 Directions for future research

Taking into consideration limitation of this study, future research can broaden and complete the following:

i) Future research could concentrate on a larger sample size, particularly from government-owned water utilities across Africa where there is a dearth literature on the use and adoption of a SWMS. This may help generate more widespread reasons behind the failure of water institutions to adopt an IoT-based SWMS to improve the efficiency of water management for a sustainable future.

ii) Research is required to ascertain customers' readiness and acceptance to use SWM, linking it to demographic factors, e.g., age.

iii) It is recommended that water utilities publish case studies detailing their experiences with SWMS implementation, especially in developing countries where such publications are limited. The case studies could shed light on the reasons for adoption, implementation procedures, cost, benefits and takeaways.

iv) The conceptual framework (section 6.8) developed in this research should be tested to determine whether it applies to other regions, particularly developing countries.

7.8 Epilogue

If not carefully handled, a water utility's core function (e.g., to deliver water services in urban areas and to maintain facilities owned by the institution) may not be achieved. For instance, in most parts of the city (of the study area), pipe-borne water supplies are rare. The seasonal pattern of rainfall affects the urban areas' water supply. It is hoped that governments will create water policies that encourage SWMS adoption for sustainable water conservation and water management in general. It is intended that stakeholders, such as government agencies, water operators, research institutions, academia and private sectors would benefit from the richness of this research.

REFERENCES

Abbas, O., Abou Rjeily, Y., Sadek, M. & Shahrour, I. 2017. A large-scale experimentation of the smart sewage system. *Water and Environment Journal*, 31(4):515–521. doi:10.1111/wej.12273J

Abdelwahab, R.H., El-Habrouk, M. & Abdelhamid, T.H. 2019. Survey of communication techniques in smart grids. *Proceedings of the 21st International Middle East Power Systems Conference (MEPCON),* Cairo, Egypt, 17–19 December 2019. IEEE: 550–555. doi:10.1109/MEPCON47431.2019.9007961

Abel, D.W., Holloway, T., Harkey, M., Meier, P., Ahl, D., Limaye, V.S. & Patz, J.A. 2018. Air-quality-related health impacts from climate change and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary modelling study. *PLoS Medicine*, 15(7):1–27. doi:10.1371/journal.pmed.1002599

Abraham, S., Beard, J. & Manijacob, R. 2017. Remote environmental monitoring using Internet of Things (IoT). *Proceedings of the 2017 IEEE Global Humanitarian Technology Conference (GHTC),* San Jose, CA, USA, 19–22 October 2017. IEEE: 1–6. doi:10.1109/GHTC.2017.8239335

Adams, I. 2022. Barriers to technology adoption in the water treatment industry. Unpublished Honour's thesis, University of Akron, USA.

Adams, M.N. & Jokonya, O. 2022. An investigation of smart water meter adoption factors at universities. *Procedia Computer Science*, 196:324–331. doi:10.1016/j.procs.2021.12.020

Adelantado, F., Vilajosana, X., Tuset-Peiro, P., Martinez, B., Melia-Segui, J. & Watteyne, T. 2017. Understanding the limits of LoRaWAN. *IEEE Communications Magazine*, 55(9):34–40. doi:10.1109/MCOM.2017.1600613

Adhikary, A., Lin, X. & Wang, Y.P.E. 2016. Performance evaluation of NB-IoT coverage. *Proceedings of the 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall),* Montreal, QC, Canada, 18–21 September 2016. IEEE: 1–5. doi:10.1109/VTCFall.2016.7881160

Adoghe, A.U., Adeyemi-Kayode, T.M., Oguntosin, V. & Amahia, I.I. 2023. Performance evaluation of the prospects and challenges of effective power generation and distribution in Nigeria. *Heliyon*, 9(3):1–17. doi:10.1016/j.heliyon.2023.e14416

Ahile, S.I., Udoumoh, E.F. & Adzande, P. 2015. Residents coping strategies with water scarcity in Makurdi town, Nigeria. *Mediterranean Journal of Social Sciences*, 6(4):100–108. doi:10.5901/mjss.2015.v6n4s2p100

Alejandrino, R.S., Diomampo, M.C.G. & Balbin, J.R. 2022. Smart water meter with cloud database and water bill consumption monitoring via SMS and mobile application. *Proceedings of the 2022 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS),* Shah Alam, Malaysia, 25–25 June 2022. IEEE: 90–95. doi:10.1109/I2CACIS54679.2022.9815483

Ali, A. 2019. Exploratory study on digitalisation of Malaysian water services. Unpublished Master's thesis. EPFL.

Ali, A.S., Abdelmoez, M.N., Heshmat, M. & Ibrahim, K. 2022. A solution for water management and leakage detection problems using IoTs based approach. *Internet of Things*, 18:100504. doi:10.1016/j.iot.2022.100504

Allam, Z. & Dhunny, Z.A. 2019. On big data, artificial intelligence and smart cities. *Cities*, 89:80–91. doi:10.1016/j.cities.2019.01.032

Allen, M., Preis, A., Iqbal, M. & Whittle, A.J. 2012. Case study: A smart water grid in Singapore. *Water Practice and Technology*, 7(4):1–8. doi:10.2166/wpt.2012.089

Alves Coelho, J., Glória, A. & Sebastião, P. 2020. Precise water leak detection using machine learning and real-time sensor data. *IoT*, 1(2):474–493. doi:10.3390/iot1020026

Amadin, F.I., Egwuatu, J.O., Obienu, A.C. & Osazuwa, W.A. 2017. Internet of things (IoT): Implications of a wide scale use in Nigeria. *Computing, Information Systems, Development Informatics & Allied Research Journal*, 8(1):95–102.

Anandhavalli, D., Sangeetha, K.S., Dharshini, V.P. & Fathima, B.L. 2018. Smart meter for water utilisation using IoT. *International Research Journal of Engineering and Technology (IRJET)*, 5(4):1002–1005.

Andrić, I., Vrsalović, A., Perković, T., Čuvić, M.A. & Šolić, P. 2022. IoT approach towards smart water usage. *Journal of Cleaner Production*, 367:133065. doi:10.1016/j.jclepro.2022.133065

Antwi, S.K. & Hamza, K. 2015. Qualitative and quantitative research paradigms in business research: A philosophical reflection. *European Journal of Business and Management*, 7(3):217–225.

Appio, F.P., Lima, M. & Paroutis, S. 2019. Understanding smart cities: Innovation ecosystems, technological advancements, and societal challenges. *Technological Forecasting and Social Change*, 142:1–14. doi:10.1016/j.techfore.2018.12.018

Araral, E. & Yu, D.J. 2013. Comparative water law, policies, and administration in Asia: Evidence from 17 countries. *Water Resources Research*, 49(9):5307–5316. doi:10.1002/wrcr.20414

Arregui, F.J., Gavara, F.J., Soriano, J. & Pastor-Jabaloyes, L. 2018. Performance analysis of ageing single-jet water meters for measuring residential water consumption. *Water*, 10(5):612. doi:10.3390/w10050612

Arshad, Q.K.U.D., Kashif, A.U. & Quershi, I.M. 2019. A review on the evolution of cellular technologies. *Proceedings of the 2019 16th International Bhurban Conference on Applied Sciences and Technology (IBCAST),* Islamabad, Pakistan, 8–12 January 2019. IEEE: 989–993. doi:10.1109/IBCAST.2019.8667173

Ashton, K. 2009. That ‘Internet of Things’ thing. *RFiD Journal,* 22(7):97–114.

Ayoub, W., Samhat, A.E., Nouvel, F., Mroue, M. & Prévotet, J.C. 2019. Internet of mobile things: Overview of LoRaWAN, DASH7, and NB-IoT in LPWANs standards and supported mobility. *IEEE Communications Surveys and Tutorials*, 21(2):1561–1581. doi:10.1109/COMST.2018.2877382

Azadegan, A. & Teich, J. 2010. Effective benchmarking of innovation adoptions: A theoretical framework for e-procurement technologies. *Benchmarking: An International Journal*, 17(4):472–490. doi:10.1108/14635771011060558

Babbie, E. 2013. *The practice of social research*. 13th ed. Belmont: Wadsworth, Cengage Learning.

Bailey, K.D. 1982. *Methods of social research*. 2nd ed. New York: The Free Press, a division of Macmillan.

Beal, C. & Flynn, J. 2014. *The 2014 review of smart metering and intelligent water networks in Australia and New Zealand*. Report prepared for WSAA by the Smart Water Research Centre, Griffith University.

Beal, C.D. & Flynn, J. 2015. Toward the digital water age: Survey and case studies of Australian water utility smart-metering programs. *Utilities Policy*, 32:29–37. doi:10.1016/j.jup.2014.12.006

Beal, C., Makki, A. & Stewart, R. 2011. Identifying the drivers of water consumption: A summary of results from the South East Queensland residential end use study. *Science Forum and Stakeholder Engagement: Building Linkages, Collaboration and Science Quality*: 126–132.

Berg, B.L. 2001. *Qualitative research methods for the social sciences*. 4th ed. Oston: Allyn and Bacon.

Berger, M.A., Hans, L., Piscopo, K. & Sohn, M.D. 2016. *Exploring the energy benefits of advanced water metering*. https://escholarship.org/uc/item/9gx813t4 [Accessed: 28 June 2021].

Bernard, C. 2022. *Smart water management: 5 innovative solutions to water scarcity offered by the IoT.* SAFT2024. https://www.saft.com/energizing-iot/smart-water-management-5-innovative-solutions-water-scarcity-offered-iot#:~:text=Microcontrollers and sensors —such as,the water in real time [Accessed: 14 May 2023].

Bhattacherjee, A. 2012. *Social science research: Principles, methods, and practices*. 2nd ed. Florida: Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.

Boisguene, R., Tseng, S.C., Huang, C.W. & Lin, P. 2017. A survey on NB-IoT downlink scheduling: Issues and potential solutions. *Proceedings of the 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC)*, Valencia, Spain, 26–30 June 2017. IEEE: 547–551. doi:10.1109/IWCMC.2017.7986344

Bradley, J. 1993. Methodological issues and practices in qualitative research. *Library Quarterly*, 63(4):431–449.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101.

Brentan, B.M., Luvizotto Jr, E., Herrera, M., Izquierdo, J. & Pérez-García, R. 2017. Hybrid regression model for near real-time urban water demand forecasting. *Journal of Computational and Applied Mathematics*, 309:532–541. doi:10.1016/j.cam.2016.02.009

Britton, T.C., Stewart, R.A. & O'Halloran, K.R. 2013. Smart metering: Enabler for rapid and effective post meter leakage identification and water loss management. *Journal of Cleaner Production*, 54:166–176. doi:10.1016/j.jclepro.2013.05.018

Brown, E. 2016. *Who needs the Internet of Things?* https://www.linux.com/news/who-needs-internet-things/ [Accessed: 19 January 2024].

Bryan, J.D. & Zuva, T. 2021. A review on TAM and TOE framework progression and how these models integrate. *Advances in Science, Technology and Engineering Systems Journal*, 6(3):137–145. doi:10.25046/aj060316

Bryman, A. 2012. *Social research methods*. 4th ed. New York: Oxford University Press.

Bulkeley, H. & Castán Broto, V. 2013. Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers*, 38(3):361–375. doi:10.1111/j.1475-5661.2012.00535.x

Burrell, G. & Morgan, G. 1979. *Sociological paradigms and organisational analysis: Elements of the sociology of corporate life*. Routledge. doi: 10.4324/9781315242804

Businesstech. 2015. *Who is using all the water in South Africa?* https://businesstech.co.za/news/general/104441/who-is-using-all-the-water-in-south-africa/ [Accessed: 26 June 2021].

Cahn, A., Katz, D. & Ghermandi, A. 2020. Analysing water customer preferences for online feedback technologies in Israel: A prototype study. *Journal of Water Resources Planning and Management*, 146(4):06020002. doi:10.1061/(ASCE)WR.1943-5452.0001179

Carranza, R., Díaz, E., Sánchez-Camacho, C. & Martín-Consuegra, D. 2021. e-Banking adoption: An opportunity for customer value co-creation. *Frontiers in Psychology*, 11:621248. doi:10.3389/fpsyg.2020.621248

Centenaro, M., Vangelista, L., Zanella, A. & Zorzi, M. 2016. Long-range communications in unlicensed bands: The rising stars in the IoT and smart city scenarios. *IEEE Wireless Communications*, 23(5):60–67. doi:10.1109/MWC.2016.7721743

Chawira, M., Hoko, Z. & Mhizha, A. 2022. Partitioning non-revenue water for Juru rural service centre, Goromonzi district, Zimbabwe. *Physics and Chemistry of the Earth, Pars A/B/C,* 126(103113). doi:10.1016/j.pce.2022.103113

Chen, M., Miao, Y., Hao, Y. & Hwang, K. 2017. Narrow band Internet of Things. *IEEE Access*, 5:20557–20577. doi:10.1109/ACCESS.2017.2751586

Chia, R. 2002. The production of management knowledge: philosophical underpinnings of research design. In D. Partington (ed.), *Essential skills for management research*. London: Sage: 1–19.

Choi, G.W., Chong, K.Y., Kim, S.J. & Ryu, T.S. 2016. SWMI: New paradigm of water resources management for SDGs. *Smart Water*, 1:1–12. doi:10.1186/s40713-016-0002-6

Chuang, W.Y., Tsai, Y.L. & Wang, L.H. 2019. Leak detection in water distribution pipes based on CNN with mel frequency cepstral coefficients. *Proceedings of the 2019 3rd International Conference on Innovation in Artificial Intelligence,* New York, NY, United States, 15–18 March 2019. Association for Computing Machinery: 83–86. doi:10.1145/3319921.3319926

Chukwuma, O.M. 2017. Patterns and problems of domestic water supply to rural communities in Enugu State, Nigeria. *Journal of Agricultural Extension and Rural Development*, 9(8):172–184. doi:10.5897/JAERD2016.0802

City of Cape Town. 2018. *Find and fix leaks*. Cape Town, South Africa. https://resource.capetown.gov.za/documentcentre/Documents/Graphics and educational material/Find and Fix Water Leaks at home.pdf [Accessed: 30 December 2020].

Clarke, V. & Braun, V. 2013. Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning. *The psychologist*, 26(2):120–123. doi:10.4135/9781412963909.n451

Coetzee, L. & Eksteen, J. 2011. The internet of things-promise for the future? An introduction. In P. Cunningham & M. Cunningham, (eds.), *Proceedings of the 2011 IST-Africa Conference,* Gaborone, Botswana, 11–13 May 2011. IEEE: 1–9.

Cohen, L., Manion, L. & Morrison, K.R.B. 2007. *Research methods in education*. 6th ed. Oxon: Routledge.

Collis, J. & Hussey, R. 2009. *Business research*. 3rd ed. Basingstoke: Palgrave Macmillan.

Cooper, R. & Zmud, R.W. 1990. Information technology implementation research: A technological diffusion approach. *Management Science*, 36(2):123–139.

Creswell, J.W. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. 3rd ed. London: Sage.

Creswell, J.W. 2014. *Research design: Qualitative, quantitative, and mixed methods approaches*. 4th ed. Croydon: Sage.

Creswell, J.W. & Creswell, D.J. 2018. *Research design: Qualitative, quantitative and mixed methods approaches*. 5th ed. Los Angeles: Sage.

Creswell, J.W., Hanson, W.E., Clark Plano, V.L. & Morales, A. 2007. Qualitative research designs: Selection and implementation. *The Counselling Psychologist*, 35(2):236–264. doi:10.1177/0011000006287390

D'Ambrosio, E., Gentile, F. & De Girolamo, A.M. 2020. Assessing the sustainability in water use at the basin scale through water footprint indicators. *Journal of Cleaner Production*, 244:1–13.

Davis, F.D. 1986. A technology acceptance model for empirically testing new end-user information systems: Theory and results. Unpublished PhD thesis. Massachusetts Institute of Technology, USA.

Davis, F.D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of Information Technology. *MIS Quarterly*, 13(3):319–340.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. 1989. User acceptance of computer technology: A comparison of two theoretical models. *Management Decision*, 35(8):982–1003.

Dawaliby, S., Bradai, A. & Pousset, Y. 2016. In depth performance evaluation of LTE-M for M2M communications. *Proceedings of the 2016 IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob),* New York, USA, 17–19 October 2016. IEEE: 1–8.

Decker, A. 2014. Solar energy harvesting for autonomous field devices. *IET Wireless Sensor Systems*, 4(1):1–8. doi:10.1049/iet-wss.2013.0011

Department for Environment Food & Rural Affairs. 2018. *Water Conservation Report*. https://www.gov.uk/government/publications/water-conservation-report-2018 [Accessed: 30 December 2022].

De Paula, H.T., Gomes, J.B., Affonso, L.F., Rabelo, R.A. & Rodrigues, J.J. 2019. An IoT-based water monitoring system for smart buildings. *Proceedings of the 2019 IEEE International Conference on Communications Workshops (ICC Workshops),* Shanghai, China, 20–24 May 2019. IEEE: 1–5. doi:10.1109/ICCW.2019.8756905

Ding, J., Nemati, M., Ranaweera, C. & Choi, J. 2020. IoT connectivity technologies and applications: A survey. *IEEE Access*, 8:67646–67673. doi:10.1109/ACCESS.2020.2985932

Dodge Data and Analytics. 2020. *Digital capabilities of US water utilities.* https://www.construction.com/toolkit/reports/Digital-Capabilities-of-US-Water-Utilities [Accessed: 15 October 2022].

Dunko, G., Misra, J., Robertson, J. & Snyder, T. 2017. *A reference guide to the Internet of Things*. Bridgera LLC, 500.

Du Plooy-Cilliers, F., Davis, C. & Bezuidenhout, R.M. (eds). 2014. *Research matters*. Cape Town: Juta.

Easterby-Smith, M., Thorpe, R. & Jackson, P. 2008. *Management research*. 3rd ed. LA: Sage.

Emengini, E.J. & Unigwe, O. 2016. Development of a GIS-based system for management of water distribution network of Achara layout Enugu, Enugu state, Nigeria. *International Research Journal of Engineering and Technology (IRJET)*, 3(1):765–770.

Erickson, T., Podlaseck, M., Sahu, S., Dai, J.D., Chao, T. & Naphade, M. 2012. The Dubuque Water Portal: Evaluation of the uptake, use and impact of residential water consumption feedback. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Austin Texas, USA, 5 May. Association for Computing Machinery: 675–684. doi:10.1145/2207676.2207772

Ezenwaji, E.E., Anyaeze, E., Otti, V.I. & Obienusi, E.A. 2014. Manifestations of water supply shortages and implication for rural development in Anambra state, Nigeria. *Journal of Environmental Sciences and Water Resources*, 3(7):149–155.

Ezenwaji, E.E., Eduputa, B.M. & Okoye, C.O. 2016. Investigations into the residential water demand and supply in Enugu metropolitan area, Nigeria. *American Journal of Water Resources*, 4(1):22–29. doi:10.12691/ajwr-4-1-3

Farquhar, J.D. 2012. Philosophical assumptions of case study research. In *Case study research for business*. London: Sage: 1–19. doi:10.4135/9781446287910.n3

Ferrier, P. 2019. Cyberattacker demands ransom from Northern Colorado utility. *Coloradoan*. https://www.coloradoan.com/story/money/2019/03/14/cyberattacker-demands-ransom-colorado-utility/3148951002 [Accessed: 20 November 2022].

Fielding, K.S., Spinks, A., Russell, S., McCrea, R., Stewart, R. & Gardner, J. 2013. An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management*, 114:343–351. doi:10.1016/j.jenvman.2012.10.027

Fietkiewicz, K.J., Mainka, A. & Stock, W.G. 2017. eGovernment in cities of the knowledge society. An empirical investigation of smart cities' governmental websites. *Government Information Quarterly*, 34(1):75–83. doi:10.1016/j.giq.2016.08.003

Fikejz, J. & Rolecek, J. 2018. Proposal of a smart water meter for detecting sudden water leakage. *Proceedings of the 2018 ELEKTRO,* Mikulov, Czech Republic, 21-23 May 2018. IEEE: 1–4. doi:10.1109/ELEKTRO.2018.8398316

Fishbein, M. & Ajzen, I. 1975. *Belief, attitude, intention and behaviour: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Flyvbjerg, B. 2011. Case study. In N.K. Denzin & Y.S. Lincoln (eds.), *The Sage handbook of qualitative research*. California: Sage: 301–316.

Folgado, F.J., González, I. & Calderón, A.J. 2023. Data acquisition and monitoring system framed in Industrial Internet of Things for PEM hydrogen generators. *Internet of Things*, 22:100795.

Ford, N. 2008. Seeking water solutions for Africa. *African Business*, (338):1–2.

Ford, R., Pritoni, M., Sanguinetti, A. & Karlin, B. 2017. Categories and functionality of smart home technology for energy management. *Building and Environment*, 123:543–554. doi:10.1016/j.buildenv.2017.07.020

Foster, S., Bousquet, A. & Furey, S. 2018. Urban groundwater use in Tropical Africa - A key factor in enhancing water security? *Water Policy*, 20(5): 982–994. doi:10.2166/wp.2018.056

Fouché, C. & Delport, C. 2011. Introduction to the research process. In A.S. De Vos, H. Strydom, C.B. Fouché & C.S.L. Delport (eds.), *Research at grass roots, for the social sciences and human service professions*. Pretoria: Van Schaik: 61–76.

Fox, W. & Bayat, M. 2007. *Case study research: Principles and practices*. New York: Cambridge University Press.

Fuentes, H. & Mauricio, D. 2020. Smart water consumption measurement system for houses using IoT and cloud computing. *Environmental Monitoring and Assessment*, 192(9):602. doi:10.1007/s10661-020-08535-4

Furlong, P. & Marsh, D. 2010. A skin not a sweater: Ontology and epistemology in political science. *Theory and Methods in Political Science,* 184–211.

Gautam, J., Chakrabarti, A., Agarwal, S., Singh, A., Gupta, S. & Singh, J. 2020. Monitoring and forecasting water consumption and detecting leakage using an IoT system. *Water Supply*, 20(3):1103–1113. doi:10.2166/ws.2020.035

Gioia, D.A., Corley, K.G. & Hamilton, A.L. 2013. Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organisational Research Methods*, 16(1):15–31. doi:10.1177/1094428112452151

Gosavi, G., Gawde, G. & Gosavi, G. 2017. Smart water flow monitoring and forecasting system. *Proceedings of the 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT),* Bangalore, India, 19–20 May 2017. IEEE: 1218–1222. doi:10.1109/RTEICT.2017.8256792

Goulas, A., Goodwin, D., Shannon, C., Jeffrey, P. & Smith, H.M. 2022. Public perceptions of household IoT smart water "event" meters in the UK—implications for urban water governance. *Frontiers in Sustainable Cities*, 4:758078. doi:10.3389/frsc.2022.758078

Grasham, C.F., Korzenevica, M. & Charles, K.J. 2019. On considering climate resilience in urban water security: A review of the vulnerability of the urban poor in sub-Saharan Africa. *Wiley Interdisciplinary Reviews: Water*, 6(3):p.e1344. doi:10.1002/WAT2.1344

Gravetter, J.F. & Forzano, B.L. 2009. *Research methods for the behavioural sciences.* 3rd ed. California: Wadsworth Cengage Learning.

Gruber, T.R. 1995. Towards principles for the design of ontologies used for knowledge sharing? *International Journal of Human-Computer Studies*, 43(5–6):907–928.

Gubbi, J., Buyya, R., Marusic, S. & Palaniswami, M. 2013. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7):1645–1660. doi:10.1016/j.future.2013.01.010

Guibene, W., Nolan, K.E. & Kelly, M.Y. 2015. Survey on clean slate cellular-IoT standard proposals. *Proceedings of the 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing*, Liverpool, UK, 26–28 October 2015. IEEE: 1596–1599. doi:10.1109/CIT/IUCC/DASC/PICOM.2015.240

Güngör-Demirci, G. & Lee, J. 2022. Non-revenue water, what are their determinants? In *Embracing Analytics In The Drinking Water Industry*. IWA: 399–407. doi:10.2166/9781789062380_0399

Günther, M., Camhy, D., Steffelbauer, D., Neumayer, M. & Fuchs-Hanusch, D. 2015. Showcasing a smart water network based on an experimental water distribution system. *Procedia Engineering*, 119:450–457. doi:10.1016/j.proeng.2015.08.857

Guo, J., Ma, J., Li, X., Zhang, J. & Zhang, T. 2017. An attribute-based trust negotiation protocol for D2D communication in smart city balancing trust and privacy. *Journal of Information Science & Engineering*, 33(4):1007–1023.

Gupta, K., Kulkarni, M., Magdum, M., Baldawa, Y. & Patil, S. 2018. Smart water management in housing societies using IoT. *Proceedings of the Second International Conference on Inventive Communication and Computational Technologies (ICICCT),* Coimbatore, India, 20–21 April 2018. IEEE: 1609–1613.

Gurung, T.R., Stewart, R.A., Sharma, A.K. & Beal, C.D. 2014. Smart meters for enhanced water supply network modelling and infrastructure planning. *Resources, Conservation and Recycling*, 90:34–50. doi:10.1016/j.resconrec.2014.06.005

Hall, R.E., Bowerman, B., Braverman, J., Taylor, J., Todosow, H. & Von Wimmersperg, U. 2000. The vision of a smart city. *Proceedings of the 2nd International Life Extension Technology Workshop,* Paris, France, 28 September 2000, 1–6.

Hancock, D.R., Algozzine, B. & Lim, J.H. 2021. *Doing case study research: A practical guide for beginning researchers*. 4th ed. New York: Teachers College Press.

Harika, G.L., Chowdary, H. & Kiranmai, T.S. 2020. Cloud-based Internet of Things for smart water consumption monitoring system. *Proceedings of the 2020 5th International Conference on Communication and Electronics Systems (ICCES),* Coimbatore, India, 10–12 June 2020. IEEE: 967–972.

Harris, J., Balfour, F., Zwinkels, M., Gobel, T., Heyningen, P. & Frame, J. 2018. *Western Cape sustainable water management plan 2017–2022.* Western Cape Government, Environmental Affairs & Development Planning.

Harrison, H., Birks, M., Franklin, R. & Mills, J. 2017. Case study research: Foundations and methodological orientations. *Forum: Qualitative Social Research*, 18(1). doi:10.17169/fqs-18.1.2655

Hasibuan, A.A. & Fahrianto, F. 2019. Consumer's activity prediction in household water consumption based-IoT (Internet of Things). *Proceedings of the 2019 7th International Conference on Cyber and IT Service Management (CITSM),* Jakarta, Indonesia, 6–8 November 2019. IEEE: 1–7.

Hauber-Davidson, G. & Idris, E. 2006. Smart water metering. *Water*, 33(3): 38–41.

Herath, I.S. 2019. Smart water buddy: IoT based intelligent domestic water management system. *Proceedings of the 2019 International Conference on Advancements in Computing (ICAC)*, Malabe, Sri Lanka, 5–6 December 2019. IEEE: 380–385.

Hitchcock, G. & Hughes, D. 1995. *Research and the teacher*. 2nd ed. London: Routledge.

Hoglund, A., Bergman, J., Lin, X., Liberg, O., Ratilainen, A., Razaghi, H.S., Tirronen, T. & Yavuz, E.A. 2018. Overview of 3GPP release 14 further enhanced MTC. *IEEE Communications Standards Magazine*, 2(2):84–89. doi:10.1109/mcomstd.2018.1700050

Horsburgh, J.S., Leonardo, M.E., Abdallah, A.M. & Rosenberg, D.E. 2017. Measuring water use, conservation, and differences by gender using an inexpensive, high frequency metering system. *Environmental Modelling and Software*, 96:83–94. doi:10.1016/j.envsoft.2017.06.035

Hudiono, H., Taufik, M., Perdana, R.H.Y. & Rakhmania, A.E. 2021. Digital centralised water meter using 433 MHz lora. *Bulletin of Electrical Engineering and Informatics*, 10(4):2062–2071. doi:10.11591/EEI.V10I4.2950

Hutton, G. 2019. *Water meters: The rights of customers and water companies*. https://commonslibrary.parliament.uk/research-briefings/cbp-7342/ [Accessed: 30 December 2022].

Ikpehai, A., Adebisi, B., Rabie, K.M., Anoh, K., Ande, R.E., Hammoudeh, M., Gacanin, H. & Mbanaso, U.M. 2019. Low-power wide area network technologies for internet-of-things: A comparative review. *IEEE Internet of Things Journal*, 6(2):2225–2240. doi:10.1109/JIOT.2018.2883728

International Telecommunications Union. *ICTs, environmental sustainability and climate change. Committed to connecting the world.* https://www.itu.int/en/action/climate/Pages/default.aspx [Accessed: 9 January 2018].

Ismagilova, E., Hughes, L., Dwivedi, Y.K. & Raman, K.R. 2019. Smart cities: Advances in research—an information systems perspective. *International Journal of Information Management*, 47:88–100. doi:10.1016/j.ijinfomgt.2019.01.004

Israeli Water System. 2019. *A circular economy business model case*. https://milkeninnovationcenter.org/wp-content/uploads/2019/09/R2Pi_Case-Study-Report_Israel-Water_FINAL-2.pdf [Accessed: 12 August 2023].

Jacobs. 2022. *City of cleveland advanced metering infrastructure implementation.* https://www.jacobs.com/projects/cleveland-advanced-metering-infrastructure [Accessed: 22 October 2022].

Jisha, R.C., Vignesh, G. & Deekshit, D. 2019. IoT-based water level monitoring and implementation on both agriculture and domestic areas. *Proceedings of the 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT),* Kannur, India, 05–06 July 2019. IEEE: 1119–1123. doi:10.1109/ICICICT46008.2019.8993272

Johnston, H. 2021. Success story: Embracing IoT & smart metering for a water resilient Barcelona. https://utilitymagazine.com.au/success-story-suez-iot-barcelona/ [Accessed: 22 October 2022].

Jordan, A., Huitema, D., Van Asselt, H. & Forster, J. (eds.) 2018. *Governing climate change: Polycentricity in action?* Cambridge University Press.

Kainz, O., Karpiel, E., Petija, R., Michalko, M. & Jakab, F. 2021. Non-standard situation detection in smart water metering. *Open Computer Science*, 11(1):12–21.

Kartakis, S., Abraham, E. & McCann, J.A. 2015. Waterbox: A testbed for monitoring and controlling smart water networks. *Proceedings of the 1st ACM International Workshop on Cyber-Physical Systems for Smart Water Networks,* Seattle, WA, USA, 14–16 April 2015. Association for Computing Machinery: 1–6. doi:10.1145/2738935.2738939

Keegan, S., O'Hare, G.M. & O'Grady, M.J. 2012. Retail in the digital city. *International Journal of E-Business Research (IJEBR)*, 8(3):18–32. doi:10.4018/jebr.2012070102

Keele, S. 2007. *Guidelines for performing systematic literature reviews in software engineering*. Technical Report, Ver. 2.3. Ebse, 5:1–57.

Kesson, C., Morgan, G. & Green, C. 2018. *Resilient Cape Town: Preliminary resilience assessment.* Cape Town: Resilience Department in the Directorate of Corporate Services, City of Cape Town. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/CCT%20PreliminaryResilienceAssessment.pdf [Accessed: 18 September 2020].

Khosravani, M.R. & Reinicke, T. 2020. 3D-printed sensors: Current progress and future challenges. Sensors and Actuators A: physical, 305:111916.

Kim, D.H., Suh, J. & Park, K.H. 2015. An empirical investigation on the determinants of smart water grid adoption. *Indian Journal of Science and Technology*, 8(24):1–9. doi:10.17485/ijst/2015/v8i24/80178

Klein, H.K. & Myers, M.D. 1999. A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, 23(1):67–93. doi:10.1016/j.egypro.2011.02.243

Kondracki, N.L., Wellman, N.S. & Amundson, D.R. 2002. Content analysis: Review of methods and their applications in nutrition education. *Journal of Nutrition Education and Behaviour*, 34(4):224–230. doi:10.1016/S1499-4046(06)60097-3

Koranteng, K. 2012. Access and use of Information and Communication Technology for teaching and learning amongst schools in under resourced communities in the Western Cape, South Africa. Unpublished PhD thesis, Cape Peninsula University of Technology. South Africa.

Kothari, C.R. 2004. *Research methodology methods and techniques*. 2nd ed. Daryaganj, New Delhi: New Age International.

Koul, S. & Eydgahi, A. 2017. A systematic review of technology adoption frameworks and their applications. *Journal of Technology Management & Innovation*, 12(4):106–113. doi: 10.4067/s0718-27242017000400011

Koul, S. & Eydgahi, A. 2018. Utilising technology acceptance model (TAM) for driverless car technology adoption. *Journal of Technology Management & Innovation*, 13(4):37–46. doi:10.4067/S0718-27242018000400037

Krause, A., Perciavalle, P., Johnson, K., Owens, B., Frodl, D., Sarni, W. & Foundry, W. 2018. *The digitisation of water*. https://www.ge.com/sites/default/files/GE-Ecomagination-Digital-Water.pdf [Accessed: 12 August 2022].

Kumar, R. 2011. *Research methodology. A step by step guide for beginners*. 3rd ed. London: Sage

Laison, H. 2023. Key aspects of smart water meter reliability for African water utilities. *Smart Energy International*. https://www.smart-energy.com/industry-sectors/smart-water/key-aspects-of-smart-water-meter-reliability-for-african-water-utilities/ [Accessed: 4 April 2024].

Lalle, Y., Fourati, L.C., Fourati, M. & Barraca, J.P. 2019. A Comparative study of LoRaWAN, SigFox, and NB-IoT for smart water grid. *Proceedings of the 2019 Global Information Infrastructure and Networking Symposium (GIIS),* Paris, France, 18–20 December 2019. IEEE: 1–6.

Lalle, Y., Fourati, M., Fourati, L.C. & Barraca, J.P. 2021. Communication technologies for smart water grid applications: Overview, opportunities, and research directions. *Computer Networks*, 190:1–23. doi:10.1016/j.comnet.2021.107940

Leung, D., Lo, A., Fong, L.H.N. & Law, R. 2015. Applying the technology-organisation-environment framework to explore ICT initial and continued adoption: An exploratory study of an independent hotel in Hong Kong. *Tourism Recreation Research*, 40(3):391–406. doi:10.1080/02508281.2015.1090152

Li, J., Bao, S. & Burian, S. 2019. Real-time data assimilation potential to connect micro-smart water test bed and hydraulic model. *H2Open Journal*, 2(1):71–82. doi:10.2166/H2OJ.2019.006

Li, J., Yang, X. & Sitzenfrei, R. 2020. Rethinking the framework of smart water system: A review. *Water*, 12(2):1–25. doi:10.3390/w12020412

Lincoln, Y.S. & Guba, E.G. 2013. *The constructivist credo*. Walnut Creek, CA: Left Coast Press.

Liu, A., Giurco, D. & Mukheibir, P. 2017. Advancing household water-use feedback to inform customer behaviour for sustainable urban water. *Water Science and Technology: Water Supply*, 17(1):198–205. doi:10.2166/ws.2016.119

Lunsford, T.R. & Lunsford, B. 1995. The research sample, part I: Sampling. *Journal of Prosthetics and Orthotics*, 7(3):105–112.

Mahairas, A. & Beshar, P.J. 2018. A perfect target for cybercriminals. *The New York Times*. https://www.nytimes.com/2018/11/19/opinion/water-security-vulnerability-hacking.html [Accessed: 20 November 2022].

Malhotra, R. 2015. A systematic review of machine learning techniques for software fault prediction. *Applied Soft Computing*, 27:504–518. doi:10.1016/j.asoc.2014.11.023

March, H., Morote, Á.F., Rico, A.M. & Saurí, D. 2017. Household smart water metering in Spain: Insights from the experience of remote meter reading in Alicante. *Sustainability*, 9(4):1–18. doi:10.1016/j.asoc.2014.11.023

Marin, P., Tal, S., Yeres, J. & Ringskog, K.B. 2017. *Water management in Israel: Key innovations and lessons learned for water scarce countries*. Washington, DC: World Bank.

Marsal-Llacuna, M.L., Colomer-Llinàs, J. & Meléndez-Frigola, J. 2015. Lessons in urban monitoring taken from sustainable and liveable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change*, 90:611–622. doi:10.1016/j.techfore.2014.01.012

McKenna, K. & Keane, A. 2016. Residential load modelling of price-based demand response for network impact studies. *IEEE Transactions on Smart Grid*, 7(5):2285–2294. doi:10.1109/TSG.2015.2437451

Mekki, K., Bajic, E., Chaxel, F. & Meyer, F. 2018. Overview of cellular LPWAN technologies for IoT deployment: Sigfox, LoRaWAN, and NB-IoT. *Proceedings of the 2018 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom workshops),* Athens, Greece, 19–23 March 2018. IEEE:197–202. doi:10.1109/PERCOMW.2018.8480255

Mekki, K., Bajic, E., Chaxel, F. & Meyer, F. 2019. A comparative study of LPWAN technologies for large-scale IoT deployment. *ICT Express*, 5(1):1–7. doi:10.1016/j.icte.2017.12.005

Michael, E., Agajo, J., Osanaiye, O.A. & Oyinbo, A.M. 2019. Design of a green IoT based water monitoring system for metropolitan city. *Proceedings of the 2019 15th International Conference on Electronics, Computer and Computation,* Abuja, Nigeria, 10–12 December 2019. IEEE: 31–36. doi:10.1109/ICECCO48375.2019.9043294

Migabo, E., Djouani, K. & Kurien, A. 2021. Design of an energy efficient LoRaWAN-based smart IoT water meter for African municipalities. *Proceedings of the 2021 International Conference on Electrical, Computer and Energy Technologies (ICECET),* Cape Town, South Africa, 9–10 December 2021. IEEE: 1–6. doi:10.1109/ICECET52533.2021.9698443

Mohammadpour, R., Shaharuddin, S., Chang, C.K., Zakaria, N.A., Ghani, A.A. & Chan, N.W. 2015. Prediction of water quality index in constructed wetlands using support vector machine. *Environmental Science and Pollution Research*, 22:6208–6219. doi:10.1007/s11356-014-3806-7

Moher, D., Liberati, A., Tetzlaff, J. & Altman, D.G. 2010. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery*, 8(5):336–341.

Moldan, B., Janoušková, S. & Hák, T. 2012. How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators*, 17:4–13. doi:10.1016/j.ecolind.2011.04.033

Mone, G. 2015. The new smart cities. *Communications of the ACM*, 58(7):20–21.

Monette, D.R., Sullivan, T.J., De Jong, C.R. & Hilton, T.P. 2014. *Applied social research: A tool for the human services*. 9^{th} ed. Inter. California: Brooks/Cole, Cengage Learning.

Monks, I., Stewart, R.A., Sahin, O. & Keller, R. 2019. Revealing unreported benefits of digital water metering: Literature review and expert opinions. *Water*, 11(4):1–32. doi:10.3390/w11040838

Morote, Á.-F. & Hernández-Hernández, M. 2018. Unauthorised domestic water consumption in the city of Alicante (Spain): A consideration of its causes and urban distribution (2005–2017). *Water*, 10(7):851. doi:10.3390/w10070851

Mudumbe, M.J. & Abu-Mahfouz, A.M. 2015. Smart water meter system for user-centric consumption measurement. *Proceedings of the 2015 IEEE International Conference on Industrial Informatics (INDIN),* Cambridge, UK, 22–24 July 2015. IEEE: 993–998. doi:10.1109/INDIN.2015.7281870

Muhammetoglu, A., Albayrak, Y., Bolbol, M., Enderoglu, S. & Muhammetoglu, H. 2020. Detection and assessment of post meter leakages in public places using smart water metering. *Water Resources Management*, 34:2989–3002. doi:10.1007/s11269-020-02598-1

Muller, M. 2018. Lessons from Cape Town’s drought. *Nature*, 559(7713): 174–176.

Mumtaz, M., De-Oliveira, J.A.P. & Ali, S.H. 2019. Climate change impacts and adaptation in agricultural sector: The case of local responses in Punjab, Pakistan. In S. Hussain (ed.), *Climate change and agriculture*. London: IntechOpen: 69–82.

Mutchek, M. & Williams, E. 2014. Moving towards sustainable and resilient smart water grids. *Challenges*, 5(1):123–137. doi:10.3390/challe5010123.

Myers, M.D. 1997. Qualitative research in information systems. *MIS Quarterly*, 241–242. June.

Myers, M.D. & Newman, M. 2007. The qualitative interview in IS research: Examining the craft. *Information and Organisation*, 17(1):2–26.

Nahayo, L., Nsengiyumva, J.B., Mupenzi, C., Mind'je, R. & Nyesheja, E.M. 2019. Climate change vulnerability in Rwanda, east Africa. *International Journal of Geography and Geology*, 8(1):1–9. doi:10.18488/journal.10.2019.81.1.9

Neuman, L.W. 2011a. *Social research methods: Qualitative and quantitative approaches*. 6th ed. Boston: Pearson Educational.

Neuman, L.W. 2011b. *Social research methods: Qualitative and quantitative approaches*. 7th ed. Boston: Pearson Educational.

Nguyen, K.A., Stewart, R.A., Zhang, H., Sahin, O. & Siriwardene, N. 2018. Re-engineering traditional urban water management practices with smart metering and informatics. *Environmental Modelling and Software*, 101:256–267. doi:10.1016/j.envsoft.2017.12.015

Nikhil, R., Rajender, R., Dushyantha, G.R., Khadri, M.N.S. & Jagadevi, N.K. 2018. Water quality monitoring system using IoT Environment. *International Journal of Innovations in Engineering and Technology (IJIET)*, 10(4):74–78. doi:10.1109/AEEICB.2018.8480963

Ntuli, N. & Abu-Mahfouz, A. 2016. A simple security architecture for smart water management system. *Procedia Computer Science*, 83:1164–1169. doi:10.1016/j.procs.2016.04.239

Okoli, N.J. & Kabaso, B. 2023. Smart water metering system (SWMS) adoption: A systematic literature review. *Proceedings of the 2023 International Conference on Artificial Intelligence and its Applications*, Mahebourg, Mauritius, 9–10 November 2017, 172–180. doi:10.59200/ICARTI.2023.025

Okoli, N.J. & Kabaso, B. 2024. Building a smart water city: IoT smart water technologies, applications, and future directions. *Water*, 16(4):557. doi:10.3390/w16040557

Okpasuo, O.J., Aguzie, I.O., Joy, A.T. & Okafor, F.C. 2020. Risk assessment of waterborne infections in Enugu State, Nigeria: Implications of household water choices, knowledge, and practices. *AIMS Public Health*, 7(3):634–649. doi:10.3934/publichealth.2020050

Oliveira, T., Thomas, M. & Espadanal, M. 2014. Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information and Management*, 51(5):497–510. doi:10.1016/j.im.2014.03.006

Olmstead, S.M. 2014. Climate change adaptation and water resource management: A review of the literature. *Energy Economics*, 46:500–509. doi:10.1016/j.eneco.2013.09.005

Onimisi, A.T. 2023. The implication of unstable electricity power supply on the socio-economic activities in Nigeria: A case of Kogi State. *African Journal of Business and Economic Development*, 3(4):7658.

ONWASA. 2018. *Cyber-criminals target critical utility in hurricane-ravaged area*. Jacksonville, NC. https://www.onwasa.com/DocumentCenter/View/3701/Scan-from-2018-10-15-08_08_13-A?bidId= [Accessed: 21 November 2022].

Orlikowski, W.J. & Baroudi, J.J. 1991. Studying information technology in organisations: Research approaches and assumptions. *Information Systems Research*, 2(1):1–28.

Osman, N.I. & Abbas, E.B. 2018. Simulation and modelling of lora and Sigfox low power wide area network technologies. *Proceedings of the 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE),* Khartoum, Sudan, 12–14 August 2018. IEEE: 1–5. doi:10.1109/ICCCEEE.2018.8515816

Palvalin, M., Lönnqvist, A. & Vuolle, M. 2013. Analysing the impacts of ICT on knowledge work productivity. *Journal of Knowledge Management*, 17(4):545–557. doi:10.1108/JKM-03-2013-0113

Patel, C.S. & Gaikwad, J.A. 2019. Design and development of IoT based smart water distribution network for residential areas. *Proceedings of the 2019 International Conference on Communication and Electronics Systems (ICCES),* Coimbatore, India, 17–19 July 2019. IEEE: 2019–2023. doi:10.1109/ICCES45898.2019.9002053

Peng, G.C.A., Nunes, M.B. & Zheng, L. 2017. Impacts of low citizen awareness and usage in smart city services: The case of London's smart parking system. *Information Systems and e-Business Management*, 15:845–876. doi:10.1109/ICCW.2019.8756905

Pericli, A. & Jenkins, J.O. 2015. *Smart meters and domestic water usage*. Buckinghamshire, UK: Foundation for Water Research.

Pfeffer, J. & Veiga, J.F. 1999. Putting people first for organisational success. *Academy of Management Perspectives*, 13(2):37–48. doi:10.5465/AME.1999.1899547

Porwal, S., Akbar, S.A. & Jain, S.C. 2017. Leakage detection and prediction of location in a smart water grid using SVM classification. *Proceedings of the 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS),* Chennai, India, 1–2 August 2017. IEEE: 3288–3292. doi:10.1109/ICECDS.2017.8390067

Pramanik, M.I., Lau, R.Y., Demirkan, H. & Azad, M.A.K. 2017. Smart health: Big data enabled health paradigm within smart cities. *Expert Systems with Applications*, 87:370–383. doi:10.1016/j.eswa.2017.06.027

Priya, R. & Rameshkumar, G.P. 2017. A novel method to smart city's water management system with sensor devices and Arduino. *International Journal of Computational Intelligence Research*, 13(10):2391–2406.

PUB. 2022. Smart water meter. *Singapore's National Water Agency*. https://www.pub.gov.sg/smartwatermeter/about-swm.html [Accessed: 22 October 2022].

Qin, X., Shi, Y., Lyu, K. & Mo, Y. 2020. Using a TAM-TOE model to explore factors of building information modelling (BIM) adoption in the construction industry. *Journal of Civil Engineering and Management*, 26(3):259–277. doi:10.3846/jcem.2020.12176

Quevedo, J., Puig, V., Cembrano, G., Blanch, J., Aguilar, J., Saporta, D., Benito, G., Hedo, M. & Molina, A. 2010. Validation and reconstruction of flow meter data in the Barcelona water distribution network. *Control Engineering Practice*, 18(6):640–651. doi:10.1016/j.conengprac.2010.03.003

Quinlan, C. 2011. *Business research methods*. Andova, UK: Cengage Learning.

Raimi, M.O., Ayibatonbira, A.A., Anu, B., Odipe, O.E. & Deinkuro, N.S. 2019. “Digging deeper” evidence on water crisis and its solution in Nigeria for Bayelsa state: A study of current scenario. *International Journal of Hydrology*, 3(4):244–257. doi:10.15406/ijh.2019.03.00187

Randall, T. & Koech, R. 2019. Smart water metering technology for water management in urban areas. *Water e-Journal*, 4(1):1–14. doi:10.21139/wej.2019.001

Ranjan, V., Reddy, M.V., Irshad, M. & Joshi, N. 2020. The Internet of Things (IoT) based smart rain water harvesting system. *Proceedings of the 2020 6th International Conference on Signal Processing and Communication (ICSC*), Noida, India, 5–7 March 2020. IEEE: 302–305.

Rao, Y.R. 2017. Automatic smart parking system using Internet of Things (IoT). *International Journal of Engineering Technology Science and Research*, 4(5):225–228. doi:10.1109/CTS.2008.4543911

Rapelli, N., Myakal, A., Kota, V. & Rajarapollu, P.R. 2019. IoT based smart water management, monitoring and distribution system for an apartment. *Proceedings of the 2019 International Conference on Intelligent Computing and Control Systems (ICCS),* Madurai, India, 15–17 May 2019. IEEE: 440–443. doi:10.1109/ICCS45141.2019.9065369

Rashid, S., Akram, U. & Khan, S.A. 2015. WML: Wireless sensor network based machine learning for leakage detection and size estimation. *Procedia Computer Science*, 63:171–176. doi:10.1016/j.procs.2015.08.329

Ratasuk, R., Mangalvedhe, N., Bhatoolaul, D. & Ghosh, A. 2017. LTE-M evolution towards 5G massive MTC. *Proceedings of the 2017 IEEE GLOBECOM Workshops (GC Workshops),* Singapore, 4–8 December 2017. IEEE: 1–6.

Ravindra, W.M.T. 2019. Smart water meter base on IoT. Unpublished Master’s thesis, University of Colombo School of Computing.

Ray, A. & Goswami, S. 2020. IoT and cloud computing based smart water metering system. *Proceedings of the 2020 International Conference on Power Electronics and IoT Applications in Renewable Energy and its Control (PARC)*, Mathura, India, 28–29 February. IEEE: 308–313. doi:10.1109/PARC49193.2020.236616

Ray, A. & Ray, H. 2020. SSIWM: Smart secured IoT framework for integrated water resource management system. *Proceedings of the 2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC),* Vijiyapur, India, 8–10 October 2020. IEEE: 1–6.

Reddick, J. & Kruger, R. 2019. Water: Market intelligence report 2019, Cape Town. https://greencape.co.za/assets/Uploads/WATER-MIR-2019-WEB-01-04-2019.pdf [Accessed: 10 February 2021].

Rees, P., Clark, S. & Nawaz, R. 2020. Household forecasts for the planning of long-term domestic water demand: Application to London and the Thames Valley. *Population, Space and Place*, 26(2):1–25. doi:10.1002/psp.2288

Remenyi, D., Swartz, E., Money, A. & Williams, B. 1998. *Doing research in business and management: An introduction to process and method*. London: Sage.

Ringwood, F. 2015. Measure for measure: Metering. *Water & Sanitation Africa*, 10(5):52–55. doi:10.1017/S0956618X00004774

Rizzo, A. 2006. Apparent water loss control: Theory and application. *Proceedings of the Water Conference,* Ferrara, Italy, 17–19 May 2006.

Rogers, E.M. 1995. *Diffusion of Innovation*. 4th ed. New York, USA: The Free Press.

Rubin, G.T. 2019. Many company hacks go undisclosed to SEC despite regulator efforts. *The Wall Street Journal*. https://www.wsj.com/articles/many-company-hacks-go-undisclosed-to-sec-despite-regulator-efforts-11551218919 [Accessed: 2 November 2022].

Ryan, G.W. & Bernard, H.R. 2003. Techniques to identify themes. *Field Methods*, 15(1):85–109.

Salahshour Rad, M., Nilashi, M. & Mohamed Dahlan, H. 2018. Information technology adoption: A review of the literature and classification. *Universal Access in the Information Society*, 17:361–390. doi:10.1007/s10209-017-0534-z

Salam, A.E.U., Tola, M., Selintung, M. & Maricar, F. 2014. On-line monitoring system of water leakage detection in pipe networks with artificial intelligence. *ARPN Journal of Engineering and Applied Sciences*, 9(10):1817–1822.

Saldana, J. 2009. *The coding manual for qualitative researchers*. London: Sage.

Saldana, J. 2016. *The coding manual for qualitative researchers*. 3rd ed. London: Sage.

Sani, A.M. 2021. Smart water meter. Unpublished Bachelor thesis, Baze University, Abuja, Nigeria.

Sarangi, A.K. 2020. Smart water leakage and theft detection using IoT. *Proceedings of the 2020 International Conference on Industry 4.0 Technology (I4Tech)*, Pune, India, 13–15 February 2020. IEEE: 46–50.

Saravanan, M., Das, A. & Iyer, V. 2017. Smart water grid management using LPWAN IoT technology. *Proceedings of the 2017 Global Internet of Things Summit (GIoTS),* Geneva, Switzerland, 24 August 2017. doi:10.1109/GIOTS.2017.8016224

Saunders, M., Lewis, P. & Thornhill, A. 2009. *Research methods for business students*. 5th ed. Harlow: Pearson Education.

Saunders, M., Lewis, P. & Thornhill, A. 2012. *Research methods for business students*. 6th ed. Harlow: Pearson Education.

Saunders, M.N.K., Lewis, P. & Thornhill, A. 2019. *Research methods for business students*.

8th ed. Harlow: Pearson Education.

Schaffers, H., Ratti, C. & Komninos, N. 2012. Special issue on smart applications for smart cities – new approaches to innovation: Guest editors' introduction. *Journal of Theoretical and Applied Electronic Commerce Research*, 7(3):2–6. doi:10.4067/S0718-18762012000300005

Schiellerup, P. 2008. Stop making sense: The trials and tribulations of qualitative data analysis. *Area*, 40(2):163–171. doi:10.1111/j.1475-4762.2008.00817.x

Schultz, W., Javey, S. & Sorokina, A. 2018. Smart water meters and data analytics decrease wasted water due to leaks. *Journal – American Water Works Association*, 110(11):E24–E30. doi:10.1002/awwa.1124

Schwab, K. & Sala-i-Martín, X. 2014. *The Global Competitiveness Report*. Geneva. http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2014-15.pdf [Accessed: 19 October 2021].

Scotland, J. 2012. Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English Language Teaching*, 5(9):9–16. doi:10.5539/elt.v5n9p9

Shah, A., Patel, V., Shah, I.P. & Shah, K. 2020. People's attitude towards paying for water: An empirical study. *IAHRW International Journal of Social Sciences Review*, 8(4–6):98–101.

Shaikh, F.K., Zeadally, S. & Exposito, E. 2017. Enabling technologies for green Internet of Things. *IEEE Systems Journal*, 11(2):983–994. doi:10.1109/JSYST.2015.2415194

Silverman, D. 2017. *Doing qualitative research*. 5th ed. New Delhi: Sage.

Simons, H. 2009. *Case study research in practice*. London: Sage.

Sobczak, B. 2019. Hackers force water utilities to sink or swim. *E&E News*. https://www.eenews.net/stories/1060131769 [Accessed: 10 November 2022].

Soh, Z.H.C., Shafie, M.S., Shafie, M.A., Sulaiman, S.N., Ibrahim, M.N. & Abdullah, S.A.C. 2018. IoT water consumption monitoring & alert system. *Proceedings of the 2018 International Conference on Electrical Engineering and Informatics (ICELTICs)*, Banda Aceh, Indonesia, 19–20 September. IEEE: 168–172.

Somoye, O.A. 2023. Energy crisis and renewable energy potentials in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, 188:113794. doi:10.1016/j.rser.2023.113794

Sønderlund, A.L., Smith, J.R., Hutton, C. & Kapelan, Z. 2014. Using smart meters for household water consumption feedback: Knowns and unknowns. *Procedia Engineering*, 89:990–997. doi:10.1016/j.proeng.2014.11.216

Srivastava, S. 2018. Domestic water conservation by IoT (smart home). *International Research Journal of Engineering and Technology (IRJET)*, 5(8):328–330.

Stewart, A. 2014. Case study. In *Qualitative methodology: A practical guide*. London: Sage: 145–160. doi:10.4135/9781473920163

Stewart, R.A., Willis, R., Giurco, D., Panuwatwanich, K. & Capati, G. 2010. Web-based knowledge management system: Linking smart metering to the future of urban water planning. *Australian Planner*, 47(2):66–74. doi:10.1080/07293681003767769

Sun, Y., Peng, M., Zhou, Y., Huang, Y. & Mao, S. 2019. Application of machine learning in wireless networks: Key techniques and open issues. *IEEE Communications Surveys and Tutorials*, 21(4):3072–3108. doi:10.1109/COMST.2019.2924243

Suresh, M., Muthukumar, U. & Chandapillai, J. 2017. A novel smart water-meter based on IoT and smartphone app for city distribution management. *Proceedings of the 2017 IEEE Region 10 Symposium (TENSYMP)*, Cochin, India, 14-16 July. IEEE: 1–5. doi:10.1109/TENCONSpring.2017.8070088

TechTarget. *Sensor*. https://whatis.techtarget.com/definition/sensor [Accessed: 29 May 2023].

Teja, R. 2021. What is a sensor? Different types of sensors and their applications. *Electronics hub*. https://www.electronicshub.org/different-types-sensors/ [Accessed: 30 May 2023].

Thames Water. 2021. *Thames water hits half a million smart meter milestone.* https://www.thameswater.co.uk/news/smart-water-meter-milestone [Accessed: 23 October 2022].

Thomas, G. 2021. *How to do your case study*. 3rd ed. Thousand Oaks, CA: Sage.

Tom, A.M., Virgiyanti, W. & Rozaini, W. 2019. Understanding the determinants of infrastructure as-a service-based e-learning adoption using an integrated TOE-DOI model: A Nigerian perspective. *Proceedings of the 2019 6th International Conference on Research and Innovation in Information Systems (ICRIIS),* Johor Bahru, Malaysia, 02–03 December 2019. IEEE: 1–6.

Tornatzky, L.G., Fleischer, M. & Chakrabarti, A.K. 1990. *The processes of technological innovation*. Lexington: Lexington Books.

United Nations. 2015. *Transforming our world: The 2030 agenda for sustainable development*. UN Doc. A/RES/70/1 (September 25, 2015).

Visser, M., Booysen, M.J., Brühl, J.M. & Berger, K.J. 2021. Saving water at Cape Town schools by using smart metering and behavioural change. *Water Resources and Economics*, 34:100175. doi:10.1016/j.wre.2020.100175

Vithanage, J., De Silva, R., Karunaratne, K., Silva, M.D., Bogoda, P., Kankanamge, R., Kehelella, P., Jayakody, K.D. & Wijekoon, J.L. 2019. SmartOne: IoT-based smart platform to manage personal water usage. *Proceedings of the 2019 International Conference on Advancements in Computing (ICAC)*, Malabe, Sri Lanka, 5–6 December. IEEE: 398–403. doi:10.1109/ICAC49085.2019.9103373

Vogt, W.P., Gardner, D.C. & Haeffele, L.M. 2012. *When to use what research design*. New York: Guilford Press.

Wahyuni, D. 2012. The research design maze: Understanding paradigms, cases, methods and methodologies. *Journal of Applied Management Accounting Research,* 10(1):69–80.

Walliman, N. 2011. *Research methods the basics*. New York: Routledge.

Walton, B. 2016. *Water sector prepares for cyberattacks*. https://www.circleofblue.org/2016/world/water-sector-prepares-cyberattacks/ [Accessed: 20 November 2022].

Wen, J., Li, S., Lin, Z., Hu, Y. & Huang, C. 2012. Systematic literature review of machine learning based software development effort estimation models. *Information and Software Technology*, 54(1):41–59. doi:10.1016/j.infsof.2011.09.002

White House. 2013. *Presidential policy directive: Critical infrastructure security and resilience*. Washington DC. Technical report.

White House. 2017. *Presidential executive order on strengthening the cybersecurity of federal networks and critical infrastructure.* https://trumpwhitehouse.archives.gov/presidential-actions/presidential-executive-order-strengthening-cybersecurity-federal-networks-critical-infrastructure/ [Accessed: 12 February 2023].

Whitmore, A., Agarwal, A. & Da Xu, L. 2015. The Internet of Things—a survey of topics and trends. *Information Systems Frontiers*, 17(2):261–274. doi:10.1007/s10796-014-9489-2

Williams, R. 2021. Rolling out a smarter water future in London. *UtilityWeek*. https://utilityweek.co.uk/rolling-out-a-smarter-water-future-in-london/ [Accessed: 23 October 2022].

Wong, Y.J., Nakayama, R., Shimizu, Y., Kamiya, A., Shen, S., Rashid, I.Z.M. & Sulaiman, N.M.N. 2021. Toward industrial revolution 4.0: Development, validation, and application of 3D-printed IoT-based water quality monitoring system. *Journal of Cleaner Production*, 324:129230. doi:10.1016/j.jclepro.2021.129230

Wu, J., Guo, S., Huang, H., Liu, W. & Xiang, Y. 2018. Information and communications technologies for sustainable development goals: State-of-the-art, needs and perspectives. *IEEE Communications Surveys & Tutorials*, 20(3):2389–2406. doi:10.1109/COMST.2018.2812301

Yang, K.C. 2005. Exploring factors affecting the adoption of mobile commerce in Singapore. *Telematics and Informatics*, 22(3):257–277. doi:10.1016/j.tele.2004.11.003

Yang, L., Yang, S.H., Magiera, E., Froelich, W., Jach, T. & Laspidou, C. 2017. Domestic water consumption monitoring and behaviour intervention by employing the Internet of Things technologies. *Procedia Computer Science*, 111:367–375. doi:10.1016/j.procs.2017.06.036

Ye, Y., Liang, L., Zhao, H. & Jiang, Y. 2016. The system architecture of smart water grid for water security. *Procedia Engineering*, 154:361–368. doi:10.1016/j.proeng.2016.07.492

Yi, S., Ryu, M., Suh, J., Kim, S., Seo, S. & Kim, S. 2018. *Case study of Seosan smart water management*. https://www.iwra.org/wp-content/uploads/2018/11/2-SWM-Seosan-final.pdf [Accessed: 30 December 2022].

Yigitcanlar, T., Kamruzzaman, M., Foth, M., Sabatini-Marques, J., Da Costa, E. & Ioppolo, G. 2019. Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society*, 45:348–365. doi:10.1016/j.scs.2018.11.033

Yin, R.K. 2011. *Qualitative research from start to finish*. New York: The Guilford Press.

Yin, R.K. 2014. *Case study research: design and methods*. 5th ed. Thousand Oaks, California: Sage.

Yin, R. k. 2018. *Case study research and applications: design and methods*. 6th ed. California: Sage.

Yu, C. & Hazen, J. 2010. *Testing the water: Smart metering for water utilities*. https://www.ci.buffalo.mn.us/DocumentCenter/View/3580/Oracle-Smart-Metering-for-Water-Utilities [Accessed: 22 October 2022].

Zunino, K. 2015. *Advanced metering infrastructure: Feasibility & business case.* California: Urban Water Conservation Council AMI Symposium.

APPENDICES

Appendix A: Introductory letter for data collection

Cape Peninsula
University of Technology

Introductory letter for the collection of research data

Ms. Nwakego Joy Okoli (213073579) is registered for the Doctor of Philosophy (Informatics) degree at Cape Peninsula University of Technology. The thesis is titled: **Sustainable IS framework for the adoption of Smart water meter system**; and aims to **explore the reasons behind the failure of institutions to adopt an IoT smart water metering system to improve the efficiency of water management for a sustainable future**.

The supervisor for this research is:

Dr Boniface Kabaso
Head of Department, Information Technology
Faculty of Informatics and Design
Cape Peninsula University of Technology
Cape Town
South Africa
Tel: +27214603717
Email: kabasob@cput.ac.za

In order to meet the requirements of the university's Higher Degrees Committee (HDC) the student must get consent to collect data from organisations which they have identified as potential sources of data. In this case the student will use **interviews, and observations** to gather data from Water Utility Company Experts/utility managers. The interviews should take about 30 minutes to complete.

If you agree to this, you are requested to complete the attached form (an electronic version will be made available to you if you so desire) and print it on your organisation's letterhead.

For further clarification on this matter please contact either the supervisor(s) identified above, or the Faculty Research Ethics Committee secretary (Ms V Naidoo) at 021 4691012 or naidoove@cput.ac.za

Your cooperation is highly appreciated.

Yours sincerely
Dr Boniface Kabaso
Head of Department, Information Technology
Faculty of Informatics and Design
19 September 2021.

Appendix B: Permit for data collection at the Water Institution

I, [illegible] in my capacity as the Managing Director [illegible] Corporation give consent in principle to allow Nwakego Joy Okoli, a student at the Cape Peninsula University of Technology, to collect data in this Corporation as part of her PhD (I.T) research.

The student has explained to me the nature of her research and the nature of the data to be collected.

In addition, the Corporation's name may or may not be used as indicated below: (Tick as appropriate)

	Thesis	Conference paper	Journal article	Research Poster
Yes	✓	✓	✓	✓
No				

[illegible]

Managing Director

Appendix C: Ethics approval certificate

Cape Peninsula
University of Technology
creating futures

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[redacted]

[redacted]

Ms. Nwakego Joy Okoli
c/o Department of Information Technology
CPUT

Reference no: [redacted]

Project title: Sustainable IS framework for the adoption of smart water meter system.

[redacted]

This is to certify that the Faculty of Informatics and Design Research Ethics Committee of the Cape Peninsula University of Technology [redacted] approves the methodology and ethics of Ms. Nwakego Joy Okoli [redacted] for Doctor of Philosophy in Informatics.

Any amendments, extension or other modifications to the protocol must be submitted to the Research Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

[redacted]

Acting Chair: Research Ethics Committee
Faculty of Informatics and Design
Cape Peninsula University of Technology

Appendix D: Interview guide for the Water Institution experts

Cape Peninsula
University of Technology

Research Title: A sustainable information system framework for the adoption of a smart water meter system.

Smart water meter system encompasses two precise elements; meters that employ modern technology to gather data on water use; and communication systems that can gather and transmit information on water usage in real-time. The idea of a smart water meter automatically captures, gathers, and communicates real-time water usage readings. Precisely, a smart water meter is an internet-capable device that monitors water usage in a building or residence.

Its benefits are well documented and include a decrease in household water consumption, and residential leak reduction – that is fixing water leakages promptly can lead to a low cost of fixing water infrastructure/facility. It updates users and water distributors on daily water consumption and users can see their water tariff thereby making people responsible for their water use. Smart water meter systems can help realise sustainable development goals. Studies have shown that its implementation resulted in water saving by 89%, and decreased energy consumption by 30%. However, current water resource management continues to follow the traditional, manual, or analogue water management solutions and thus has been challenged with time lag, errors in meter readings, additional labour force to process water bills, water leakage, and wastages. Despite the continuous growth and documented benefits of smart water meter systems based on IoT, the uptake of this system has been slow because of a lack of understanding and Information Systems (IS) framework to guide widespread adoption of the system.

Research Aim: To explore the reasons behind the failure of institutions to adopt an IoT-based smart water meter system to improve the efficiency of water management for a sustainable future. The chosen strategy is the Case Study. It will use semi-structured interviews and documentation to collect data.

<table>
<tr><td>Main Research Question:</td><td>What are the adoption challenges for institutions in the use of an IoT-based smart water meter system?</td></tr>
<tr><td>Research sub-question 1:</td><td>What are the factors influencing the use and adoption of an IoT-based smart water meter system?</td></tr>
<tr><td colspan="2">Interview Question 1.1: Do you have smart water meter system in residences?
If no, would you want to have the smart water meter system if water board provided the chance? If no, why not? If yes, would you please tell me how that works (explain)?
Response (R):</td></tr>
<tr><td colspan="2">Interview Question 1.2: What type of ICT technology supports this institution in terms of water management? And how does it work/function?
Response (R):</td></tr>
<tr><td colspan="2">Interview Question 1.3: What would be the adoption challenges for your institution in terms of using an IoT-based smart water meter system? Please explain.
Response (R):</td></tr>
<tr><td colspan="2">Interview Question 1.4: What are the difficulties experienced in the process of acquiring a new technology? Please explain.
Response (R):</td></tr>
<tr><td>Research sub-question 2:</td><td>How do people feel about using a smart water meter system to manage their water?</td></tr>
<tr><td colspan="2">Interview Question 2.1: Generally, what is your perception towards using a smart water meter system to manage water?
Response (R):</td></tr>
<tr><td colspan="2">Interview Question 2.2: What is the possibility of using a smart water meter (internet-enabled meter) as a water management approach in your institution?
Response (R):</td></tr>
<tr><td>Research sub-question 3:</td><td>How can the Water Institution adopt a smart water meter system as part of their water management method?</td></tr>
<tr><td colspan="2">Interview Question 3.1: In your opinion, what are the factors that can drive the adoption of a smart water meter system to become part of your institution's water management method?
Response (R):</td></tr>
</table>

Research sub-question 4:	**What is the role of government in facilitating and engaging the institutions proactively in the use and adoption of an IoT-based smart water meter system?**
Interview Question 4.1: *Do the government actively support the institution in the adoption of ICT (smart water meter system) for water* management? **Response (R):**	
Interview Question 4.2: *Do government policies encourage technology-friendly atmosphere for the smart water meter system (new technology) adoption for water management?* **Response (R):**	
Interview Question 4.3: *How can the government play an active and enabling role in the use and adoption of Smart Water Meter Systems?* **Response (R):**	
Interview Question 4.4: *Do you think there is a need for the government to increase their support so that the Smart Water Meter System would be adopted?* **Response (R):**	

Thank you.

Appendix E: Individual consent for research participation

FID/REC/ICv0.1

FACULTY OF INFORMATICS AND DESIGN

Individual Consent for Research Participation

Title of the study: Sustainable IS framework for the adoption of smart water meter system.

Name of researcher: Nwakego Joy Okoli

Contact details: email: phone:

Name of supervisor: Dr Boniface Kabaso

Contact details: email: phone:

Purpose of the study: The study aims to explore the reasons behind the failure of institutions to adopt an IoT-based smart water meter system to improve the efficiency of water management for a sustainable future.

Participation: My participation will consist essentially of an interviewee.

Confidentiality: I have received assurance from the researcher that the information I will share will remain strictly confidential unless noted below. I understand that the contents will be used only for *Ph.D. thesis, journal articles, conference papers and workshops* and that my confidentiality will be protected by keeping data gathered from me safe in a password-protected computer and used only for the study unless for audit purposes.

Anonymity will be protected in the following manner; Pseudonyms (fake or false name) should be used so participants can remain anonymous.

Conservation of data: The data collected will be kept securely. It should be encrypted and kept in a password-controlled environment. The original or a copy of the data should be saved and used for purposes of the study unless for audit purposes.

Voluntary participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed.

Additional consent: I make the following stipulations (please tick as appropriate):

	In thesis	**In research publications**	**Both**	**Neither**
My image may be used:				
My name may be used:				
My exact words may be used:				
Any other (stipulate):				

Acceptance: I, ***(Name of respondent or participant)*** agree to participate in the above research study conducted by Nwakego Joy Okoli of the Faculty of Informatics and Design, Information Technology Department at the Cape Peninsula University of Technology, which research is under the supervision of Dr Boniface Kabaso.

If I have any questions about the study, I may contact the researcher or the supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the secretary of the Faculty Research Ethics Committee at 021 469 1012, or email naidoove@cput.ac.za.

Participant's signature: ______________________________ Date: _____________________

Researcher's signature: ______________________ Date: _____________________

Appendix F: Participants interview data transcription

Cape Peninsula
University of Technology

The Water Institution

Participant 1

Rank: Assistant Chief Scientific Officer

Research sub-question (SRQ), Question (Q), Response (R)

SRQ 1:	**What are the factors influencing the use and adoption of an IoT-based smart water meter system?**
Q1.1: Do you have a smart water meter system installed in residences in this state? **R:** Mmm No. We some time had some prepaid meters brought in, but I can't say for sure how viable that is. **Q: But in your own house, do you have a smart water meter installed?** **R:** No, no. **Q: OK, would you want to have it if provided a chance to?** **R:** Yes, if it benefits everyone. And we don't get to pay for water we don't use. So based on that, we would appreciate that. **Q1.2: Thank you. What type of (ICT) technology supports this institution in terms of water management?** **R:** More or less an analogue system. **Q: OK. Can you explain how that works?** **R:** That's the short answer because I don't think there is any smart water system. ***Q1.3: OK, what would be the adoption challenges for your institution in terms of using an IoT-based smart water meter system?*** **R:** Primarily enlightenment. People need to be enlightened. Most so the staff. The technical staff, all staff concerned and then the public. And then, proper monitoring. In that people get to monitor the system to know how to operate it. So, it will not be a challenge to the institution. And then again. Ability to enlighten the customers on the care, maintenance and proper management of the smart water meter system. Then again, the issue of cost. So, will it be cost effective for all concerned? So that we as an institution wouldn't use it to afflict the customers with huge demands. Then the customers, having understood properly the importance of the smart water meter would desire it and recommend it to others.	

NB: See DVD attached to the thesis for full interview transcription.

Appendix G: Finalised categories and themes

Codes (Phrases)	Categories	Themes	Number of participants
Smart water meter system not in use	No smart water meter system	Technological factors	11
Traditional analogue metering in use	Traditional analogue metering	Technological factors	6
Pre-payment meter (prepaid water meter)	Prepaid water meter	Technological factors	9
The institution uses estimation	Estimation	Technological factors	1
ICT resources available in the Water Institution (computers, internet connection, smartphones)	IT device availability	Technological factors	4
Internet network coverage/ Accessibility	Connectivity	Technological factors	4
Fraud by some customers bypassing the smart water meter	Water bypass and illegal connection	Technological factors	2
Increase the revenue of the institution (increase revenue)	Perceived benefits	Technological factors	3
It will save a lot of cost (save cost for consumers and water providers)	Perceived benefits	Technological factors	2
With a smart water meter, we will save a lot of water wastage (leak detection and water wastage)	Perceived benefits	Technological factors	5
It will help with time management (time management)	Perceived benefits	Technological factors	2
It helps with accountability (accountability)	Perceived benefits	Technological factors	1
Water will be available to more people with the use of smart water meter (water availability)	Perceived benefits	Technological factors	4
It will reduce manual labour (manual labour/manpower)	Perceived benefits	Technological factors	3
Adaptability	Perceived benefits	Technological factors	2
Real-time communication	Perceived benefits	Technological factors	2
Company participants interested in smart water meter system	Acceptance	Organisational factors	11
More than 90% of water produced are not being paid for	Unaccounted-for water	Organisational factors	5

Codes (Phrases)	Categories	Themes	Number of participants
People may say government want to defraud the populace with SWM	Acceptance	Organisational factors	1
50% of the populace may not appreciate the real value	Acceptance	Organisational factors	1
What people want is how to benefit more	Acceptance	Organisational factors	1
The institution and government agree to use the system/The zeal to adopt the smart water meter	Acceptance	Organisational factors	3
Users will be happy to have SWMS/I believe every household will buy into it (acceptance)	Acceptance	Organisational factors	5
Capacity building for the staff members/By training people on the new technology	Experts and technicians	Organisational factors	6
Logistics	Logistics/Adoption Framework	Organisational factors	1
Framework	Logistics/Adoption Framework	Organisational factors	1
Good environment (good personnel, good management and people who are ready to use SWM)	Experts and technicians	Organisational factors	2
Maintenance of the meter	Service provider support	Environmental factors	6
Knowledge transfer	Service provider support	Environmental factors	3
Steady electricity (electricity)	Environmental concerns	Environmental factors	1
Pipeline water reticulation	Environmental concerns	Environmental factors	2
Structure of the building	Environmental concerns	Environmental factors	1
Increased water production/ water production challenges (water production)	Environmental concerns	Environmental factors	3
Government to be the vision bearer	Government policy	Environmental factors	2
By enacting a law	Government policy	Environmental factors	2
Government must be involved	Government policy	Environmental factors	7

Codes (Phrases)	Categories	Themes	Number of participants
Government policies encourage new technology adoption (SWMS)	Government policy	Environmental factors	10
Not really, government agencies are not paying water bills*	Government policy	Environmental factors	1
Government support Water Institution towards new technology adoption	Government support	Environmental factors	11
Government support Water Institution partly through grants	Government support	Environmental factors	3
Technology support infrastructure	Government support	Environmental factors	2
Government should concentrate on analogue and prepaid meter	Government support	Environmental factors	1
Costly to acquire/Issue of cost	Cost and funding	Economic factors	4
Full government support by funding/Lack of funds	Cost and funding	Economic factors	6
Proper enlightenment/ Inform consumers/People should be aware/Sufficient and adequate down to earth sensitisation	Technology awareness	Knowledge	6
Requires training for consumers (consumer education*)	Users' education to accept change	Knowledge	4
Pilot scheme	Pilot scheme	Trialability	5