DEVELOPMENT OF RADIO FREQUENCY IDENTIFICATION ARCHITECTURE FOR THE ADOPTION BY UTILITY COMPANIES: A CASE STUDY OF NAIROBI CITY WATER AND SEWERAGE COMPANY

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DECLARATION

I declare that this document and the research it describes are my original work and that they have not been presented in any other university for academic work.

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DEDICATION

This study is dedicated with love to the following:

My parents Mr. and Mrs. Kuria

My siblings, Alex, Ann and Kelvin

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My deepest gratitude to God for giving me life, strength, knowledge and an opportunity to further my studies, my parents Mr. and Mrs. Kuria, my siblings Alex, Ann and Kelvin for encouraging and supporting me in so many different ways and to all the Nairobi City Water and Sewerage Company staff for enabling and supporting me to collect data in the company and for sharing with me their view points and the prevailing situation in the company and finally to my friends especially Kennedy Nga'nga, Bernard Ahenda and Sheilla Ruth for their encouraging words and support.

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ABSTRACT

Accurate meter readings, timely and correct bills have become an important aspect of water metering systems. Additionally, anomalies such as leakage and bursts in water pipelines have significant consequences to the environment and lead to financial constraints to the water companies. Since monitoring leakages and bursts in the water distribution networks, capturing accurate and dependable measurements for billing, troubleshooting and analysis is a challenging task, the need to develop a reliable and effective water metering system is essential for water loss reduction in the distribution networks and for accurate and timely bills and accurate measurements. Radio Frequency IDentification technology (RFID) has emerged as an effective technology for monitoring critical infrastructure such as water pipelines, and for meter reading. However, RFID is not monolithic, it is used in conjunction with other applications. In this study, an Automatic Meter Reading (AMR) system using RFID is presented. RFID based AMR, is the remote collection of consumption data from customers' utility meters using Radio Frequency (RF) technologies. It aims to eliminate the traditional method of recording meter readings manually whereby a meter reader visits every meter location usually at predetermined intervals or time and records the current meter values manually. The main objectives of this study were; to identify a viable RFID technology to enhance billing accuracy with streamlined meter reading and for leak detection; to establish and assess the effects of RFID technologies to the consumers and Water Service Provider (WSP) and to develop an RFID technology architecture for water based utility companies.The target population was all the 1,810 employees from the six different regions in Nairobi City Water and Sewerage Company (NCWSC). A sample size of 328 employees from the six different regions in NCWSC was used and Stratified sampling technique was adopted to determine the appropriate representation using Dempsey and Dempsey formula. Questionnaires were used as data collection tools, which focused on the company staff and descriptive analysis method was used for data analysis where Statistical Package for Social Sciences (SPSS) tool was used. Qualitative data from the open ended questions was analyzed using content analysis technique. The average score for effects of RFID technology on consumers was found to be 3.95, meaning respondents agreed that the adoption of RFID technology has great benefits to the consumers. The average score for effects of RFID technology on WSP was found to be 3.99, implying that the respondents agreed that RFID technology offers numerous solutions to the challenges faced by WSP's. The findings of this study are expected to be beneficial to utility companies more specifically a water-based industry. The study recommends the adoption and implementation of RFID based AMR technology in a water-based industry to enhance and improve efficiency and effectiveness in their operations.

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DEFINITION OF TERMS

For the purpose of this study, the following terms were defined as follows;

Commercial losses: Illegal connections or water theft, unmetered public consumption, metering errors, unbilled metered consumption and water use for which payment is not collected.

Customer Management System: This is a system that manages the company's customers in terms of how they pay their bills, how they are billed and management of their meters.

IP68: The water meter is protected from total dust ingress and from long term immersion of water up to a specified pressure (Flowmeters, 2015) .

Meter Interface Unit: A meter interface unit (MIU) for use in sending, via RF, utility consumption data from a utility meter to a remote location (Ali,2002).

Mobile Field Assistant: This is a tool used by NCWSC Finance and Commercial department to capture meter readings. On the financial end, it it used to manage the accounts belonging to the various meters on the ground.

Non-Revenue Water: Difference between the volume of water treated and pumped (produced) in distribution system and the volume of water billed to consumers measured in cubic meters. It is grouped into two categories; physical and commercial losses.

Physical losses: These are losses of water from the distribution network including burst or leakages and storage overflows (Farley & Trow, 2003).

Radio Frequency Identification: This is a form of communication that uses electronic tags to relay the identity of an object or person to a reader, using radio waves (Want, 2004)

Telemetry: Is an automated process of collecting and transferring readings and other related data that are at remote or inaccessible places to a central database for analysis and monitoring.

ABBREVIATIONS/ ACRONYMS

AMI: Advanced Metering Infrastructure

AMR: Automatic Meter Reading

CMS: Customer Management System

DCU: Data Collection Unit

ICT: Information and Communication Technology

IP: Ingress Protection

IWA: International Water Association

MDMS: Meter Data Management Software

MFA: Mobile Field Assistant

MIU: Meter Interface Unit

MMR: Manual Meter Reading

NCWSC: Nairobi City Water and Sewerage Company

NRW: Non-Revenue Water

RF: Radio Frequency

RFID: Radio Frequency Identification

SCADA: Supervisory Control and Data Acquisition

TAM: Technology Acceptance Model

WASREB: Water Services Regulatory Board

WSN: Wireless Sensor Network

WSP: Water Service Provider

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CHAPTER ONE

INTRODUCTION AND BACKGROUND INFORMATION

1.1 Introduction

The water utility industry is responsible for the safe and timely distribution of water and other related services. However, this industry is confronted by changing drivers in water management. External factors, including the impacts of climate change, rapid population growth, water scarcity combined with aging infrastructures (Jackson & Morrison 2007; Willis et al., 2011; Muthukumaran et al., 2011) have all been putting pressure on water service providers to improve water distribution system efficiency through reducing the amount of water lost in the network as well as adopting more sustainable approaches to water management (Mukheibir et al., 2011; Van de Meene et al., 2011; Rosegrant et al., 1997; The Top Issues in the Global Water Sector, 2012). Operational costs, monitoring non-revenue water and meeting customer demands for equity in billing in the face of rising water tariffs are some of the core challenges (Mukheibir et al., 2012; Hill et al., 2011). Although financial sustainability remains critical, the accompanying challenges to achieve sustainable water management have also become goals of strategic planning for water utilities. Undeniably, many water service providers have been gradually evolving from their traditional role as providers of water to embrace a variety of demand management strategies towards more sustainable water management (Turner et al., 2010) including the use of distributed and decentralised systems (Gregory et al., 2011). Measures that have been implemented to manage water demand include metering, water accounting and loss control, pricing and education. However, the success of these strategies critically requires accurate, adequate and reliable data that can be meaningfully and cost-effectively be interpreted to help utilities improve customer services, reduce water losses and manage demand (Godwin et al., 2012; Australian Water Association, 2010).

For this reason, recent advancements in metering and communications technologies have resulted in improved, more integrated methods of metering, communication, data storage, analytics, management of water resources benefiting both utilities and consumers. The highly granular, near-real time data and opportunity for automated control provided by these advanced systems yields operational benefits similar to those afforde by similar technologies in the energy sector. These advanced technologies namely, Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) have a major impact on water metering infrastructure (Michael et al., 2016). AMR technology is aimed at eliminating the need for physical meter readings at meter locations and the costs associated with doing so (Janković-Nišić et al., 2004). It has the ability to read meters and disseminate data online (it could be in intervals of minute, hourly, daily, weekly or monthly depending on the billing cycle of the utility company). This advanced water metering technology enables the water utility to reduce water loss through improved leak detection, reduce operating costs and enhance billing accuracy (Britton et al., 2013). On the other hand, AMI technology provides information about where, when and how water is consumed, which can enable water conservation (Pacific Institute, 2014). The smart meters have more capabilities which include data recording, real-time analytics, leak detection and remote shut-off (for example, when a leak is detected). The data collected by the smart meters is gathered and transmitted through communication mediums to the utility's central database where it is analyzed and stored (Michael et al., 2016).

In an AMR method, there are various communication links that can be used as the communication mediums they include radio frequency, Power Line Carrier, handheld, mobile and network technologies based on telephony platforms (wired and wireless). Additionally, AMR systems can take many forms walk-by, drive-by, or fixed network, but regardless of how the meter is read, the communication is one-way (Christodoulou et al., 2012) with RFID using Radio Frequency (RF). Duplex radio frequency systems and half-duplex radio frequency systems are used and they use both licensed and unlicensed RF bands with water companies preferring to use unlicensed RF bands (Chu & Hogg, 1986). In a duplex communication or 'wake up' system, signals are sent to a specific transmitter from a radio receiver, instructing it to wake up from an inactive state and transfer its data. These are normally used in battery powered water meters. In contrast, in a half-duplex/one-way communication or "bubble up" the meters periodically relay the readings continuously. They are used mainly in electric meters (Ali, 2011).

Radio Frequency Identification (RFID) has gained great popularity and it is beginning to transform processes and events as a recent technology (Orzturk & Hancer, 2015). The impact of this technology on our everyday lives and economic interactions is undeniable. In particular, water companies are more and more adopting radio frequency identification (RFID) technology based

AMR for collecting readings and detecting leaks. RFID technology can be used to optimize existing processes, improve reliability, offer new services and more broadly, increase productivity.

Pipeline networks are indispensable part of our modern life. Proactive monitoring and frequent inspection are critical for maintaining pipeline health. Fluid leak detection poses to be a big problem. Utility companies' leakage rates cause huge financial losses and are harmful to the commercial viability of those companies. According to a World Bank study, the amount of water lost in developing countries, would be supplied to around 90 million people if it was saved. Water utilities across the country are literally leaking money. They take in, treat, and pump water to their customers but can be losing as much as 40% of their product along the way to leaks in the distribution system. That's water that has been treated but will never be billed. Traditionally, finding leaks has been a manual process. A utility might have a few crews driving around the system in correlator trucks to listen for leaks, and if they find something, they dig it up. But it can take several years to cover an entire distribution system. And, in many cases, by the time a leak is discovered, it could have been leaking for years.

To improve the sustainability and performance of utility companies, a combination of several sensors, technologies and techniques can be established for monitoring pipeline so as to reduce the amount of water lost in distribution networks (Martinsanz, 2015). With an AMR based on RFID technology, the whole distribution network can be continuously monitored by hourly interval reads. Recent advancements in meter data management have transformed the vast spreadsheets and tedious data-mining activities of just a few years ago into push-button reports, allowing a water utility to find evidence of leaks before they hit the surface sometimes years before. It can prevent a small leak from becoming a big leak, or worse, a water main break. The data collected in relation to the status of the pipeline is sent to the utility database where it is analyzed (Almazyad et al., 2014). Water systems are typically underground, making it difficult to know the condition of its distribution system. But if a water utility has insight into how different parts of its distribution system are performing, such as AMI based on RFID technology can provide, it can better focus its attention on the pipes in most need of repair. This helps the utility better allocate resources by extending the life of capital assets.

1.2 Background of the Study

The volume of water losses or NRW worldwide is shocking. It is estimated that each year more than 32 billion cubic meters (m^3) of treated water are lost due to physical losses and an addition of 16 billion m^3 per year due to commercial losses or corruption (Farley et al., 2008). In developing countries, aging or poor quality infrastructure is the major source of high water losses. However, not all losses are as a result of aging or poor quality infrastructure and leaking conduits. Commercial losses from the distribution system, excessive use or misuse of water are often the result of local duties, combined with low charge structures or insufficient metering rules (Farley, 2003).

Nairobi Water Company as a water service provider measures the quantity of water consumed using the traditional method where consumptions are read through physical visits to the meter locations. This system calls for high costs related to hiring and maintaining large numbers of meter readers. It also contributes to heavy losses as a result of meters not being read in good time and an increased number of customer complaints. The amount of non-revenue water in NCWSC is estimated to be 40%. These losses are classified into commercial losses including; illegal consumption or connections, metering errors, billing anomalies and physical losses through overflows at utility reservoir's, pipe breaks and leaks in distribution networks, leakage on service connections (house connections) (IWA, 2002; Sharma, 2000).

With the current change in technology, it is possible for one to capture meter readings from the comfort of the office. Utility companies are adopting AMR technologies based on radio frequency (RF) communication to collect readings from the consumers' utility meters using radio frequency technologies (Ali et al., 2012). Meters are installed and linked to a server at central location where readings are transmitted as and when required. The transmitter is placed on or close to the water meter and the readings are transmitted via RF. The transmitted readings ensure maximum accuracy on the quantity of water consumed and reduces the number of customer complaints. It also reduces the number of staff engaged in reading and the related logistic costs. According to Hildebrandt (2007), automatic meter reading technology enhances billing accuracy, real- time data on water leaks, abnormal consumption, and previous consumption amounts. This technology eliminates the traditional method of meter reading in which a meter reader visits a customer premise and collects the readings manually. In addition, the automated meters are capable of submitting data related to the water pressures and flows within the service lines where they are connected. The meters also give an indication of leakages along the line.

Research shows that RFID technology has been implemented in developed countries. For example, a technology company in Uruguay called IDMeters, released an ultrahigh-frequency RFID solution for utility companies. This system is designed to help utility personnel in the identification of meters and pipes (below and above ground), carry out maintenance services via a handheld device, identify tampering and any related challenges in relation to pipes in the field. Similarly, Bravo Environmental, an underground utility maintenance and inspection company has buried radio frequency identification tags underground in order to create an automatic record of daily occurrences and to help it identify the locations of its infrastructure as well as the operations performed at those particular sites (Claire, 2014).

1.3 Statement of the Problem

Due to leaks, inaccurate usage measurements and theft, there has been shortage of water of about 28% which has created a global water problem. There have been recordings of more than 50% non-revenue water in most of the countries. It is therefore advisable for all countries to advance their metering technology and improve their communications software which will enhance accounting and reduction of the amount of water lost thus water problems will reduce drastically (Laura, 2016).

Nairobi City Water and Sewerage Company (NCWSC) is a Limited Liability Company incorporated under the Companies Act CAP 486 and empowered by the Water Act 2002 to provide efficient and sustainable water and sewerage services in Nairobi and its immediate environs. The company uses manual meter reading that calls for physical visits to be made by a team of marketing assistants to the customer premises on a monthly basis or in a predefined schedule depending on the billing cycle to record the volume of water used since the last reading. Notably, the company uses conventional or volumetric meters, the rate of stoppage of some of these meters is relatively high especially those connected not far from the main lines. Another cause is the loaded nature of water in the system and debris in the water. These destroys or dislodges the vanes of the meters leading to stoppage or at times complete damage of the meters. Other operational challenges associated with this method of measure include; meters not being located on the ground, denial of access by some customers, information on the ground being different from that in the system, meters installed behind locked gates or in difficult terrain which take longer to read and as such increase reading costs. Complains or customer disputes due to inaccurate manual meter readings is a significant problem, which takes time and money to resolve.

The company in its strategic plans recognizes the tremendous role that ICT has to play in meeting its laid goals. However, despite the usage of information systems in its operations, (CMS for handling customer and billing and MFA for meter reading) the company continues to experience a number of challenges during meter reading and billing, including prolonged and frequent downtime of systems, frequent downtime of Wide Area Network (WAN) which affect MFA devices and CMS systems. Additionally, NCWSC has a mandate of meeting all its operations and maintenance costs by generating its own revenue from the water and sewerage services it offers to Nairobi County. However, the company is reported to be operating with a negative capital. In 2015-2016, NCWSC liabilities stood at 4.2 billion with a negative working capital of 1.1 billion in revenue due to non-revenue water. The company lost 3.1 billion in revenue due to non-revenue water. In the year under review, the company produced 200,352.100 cubic meters of water but earned shilling 4.7 billion. Out of this, 121,146.600 cubic meters was billed to customers' while the remainder of 79,205.506 cubic meters; approximately 40 per cent of water produced resulted to non-revenue water (Julius, 2017). This is an indication of an inefficiency in the meter reading and billing system adopted by the company and as a result of poor infrastructure maintenance experienced in the company. Therefore, it is essential to implement real-time information techniques that reduces meter reading and billing costs; eliminate estimates, cancel-and-rebills, allows investigation of unusual consumptions or billing; enhances leak detection, identification of malfunctioning meters and timely identification of tampering or theft and for remote/inaccessible areas and a system that can reduce hazards to meter readers.

It is against this background that a research was necessary to investigate the adoption of a new technology in Nairobi City Water and Sewerage Company.

Table 1.1: *Nairobi City Water and Sewerage Company Revenue Collection (NCWSC, 2017)*

Production, Billing and NRW Figures 2015/16				
MONTH	**VOLUME ABSTRACTED (Mn M^3)**	**VOLUME PRODUCED (Mn M^3)**	**VOLUME BILLED (Mn M^3)**	**NRW (%)**
July,2015	17.62	16.75	10.69	36%
August, 2015	17.92	17.03	10.7	37%
Sept, 2015	17.34	16.48	10.2	38%
October,2015	17.67	16.89	10.3	39%
November,2015	17.03	16.18	10.34	36%
December, 2015	17.68	16.80	9.44	44%
January, 2016	17.94	17.05	10.36	39%
February, 2016	16.74	15.92	9.16	42%
March, 2016	17.61	16.74	10.01	40%
April, 2016	17.52	16.65	10.29	38%
May, 2016	18.13	17.24	9.88	43%
June, 2016	17.48	16.62	9.67	42%
TOTAL	**210.68**	**200.35**	**121.04**	**40%**

1.4 Purpose of the Study

The traditional metering systems has many shortcomings as it involves using the volumetric meters to collect readings. The meter reader is required to visit the place of the meter and record the readings at the end of each billing cycle. Sending bills to customers is also laborious and challenging. The conventional/traditional process has inadequacies such as meter reading errors, data handling errors, customer meter inaccuracies, external conditions affecting readings, customer unavailability during on-site visits (gate-locked), hostile customers and delayed work. This technique also requires huge manpower Amruta and Hate (2013).

The purpose of this research was to develop an RFID architecture for the collection of meter reading data and transferring it to a central database with the aim of billing and for leak or burst detection in the water distribution/pipeline system for utility companies.

1.5 Objectives of the Study

1.5.1 Overall Objective

The main objective of the study was to develop an RFID architecture that influences utility companies' overall performance specifically a water company.

1.5.2 Specific Objectives

The specific objectives of the study were:

i. To identify a viable Radio Frequency IDentification technology to enhance billing accuracy with streamlined meter reading and for leak detection,
ii. To establish and assess the effects of RFID technologies in a water based industry,
iii. To develop an RFID technology architecture for water based utility companies.

1.6 Research Questions

The following were the research questions:

i. What are the considerations for choosing a viable Radio Frequency IDentification technology that can be used in utility companies?
ii. What effects will RFID technology have in water based industry?
iii. How can RFID technology architecture be developed?

1.7 Significance of the Study

The adoption of RFID technology can help a water-based company to increase revenue through controlling and monitoring water supply and enhancing billing accuracy with streamlined meter reading and bill generation. The technology can help to improve customer service and relationship by providing accurate and timely bills. The adoption of RFID technology can reduce expenses through the reduction of on-site visits and reduction of water losses.

1.8 Scope of the Study

The study was based on utility companies a case study of Nairobi City Water and Sewerage Company. The choice of the company was based on the advancing technology of RFID in meter reading, billing services and for leak and or burst detection**.**

1.9 Delimitation of the Study

Radio Frequency Identification (RFID) technology is a vast subject of study. It is widely used for electronic identification and tracking. However, this study and the contents herein focused on development of RFID architecture for the adoption by the utility companies as a rapid solution to automating processes in a water based utility for reducing operational costs, enhancing billing accuracy, reducing non-revenue water (NRW) that is attributable to commercial and physical losses and other related anomalies.

1.10 Limitations of the Study

The study involved Radio Frequency Identification technology, one of the most recent and emerging technology in utility companies, especially in Nairobi City Water and Sewerage Company.

1.11 Assumptions of the Study

The study assumed that the respondents in the study would be cooperative and provide reliable and relevant responses to enable the study to be conducted within the stipulated time frame, that the adoption of RIFD would have social and economic effects on both the water service provider and the customers. It further assumed that the implementation of a viable radio frequency identification technology would enhance billing accuracy with streamlined meter reading, while also enabling leak detection in the water industry.

1.12 Theoretical Framework

Technology Acceptance Theory

The Technology Acceptance Theory (TAM) is a model related to technology acceptance and its' use and was introduced in 1989 by Davis. This model's main role is to ensure that computer users understand all aspects involed in computing technologies and encouraging all populations to embrace it. TAM provides a basis with which one traces how external variables influence belief, attitude, and intention to use. The model posits that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) determines an individual's intention to use a system. Perceived usefulness is when individuals believe that using a specific information systems would increase their performance while perceived use is where users expect to run their activities with less effort (Davis, 1989).

According to TAM, one's actual use of a technology is influenced directly affected by user's behavioral intentions, attitude, perceived usefulness, and perceived ease of use. TAM also proposes that external factors affect intention and actual use through mediated effects on perceived usefulness and perceived ease of use. External variables may include users' demographic characteristics, organizational characteristics (e.g. training method) and technology characteristics (e.g. user satisfaction). Legris et al. (2003) argues that when users are presented with a new technology, a number of factors influence their decision about how and when they want use it, namely: Perceived Usefulness (PU) and Perceived Ease of use (PEOU.

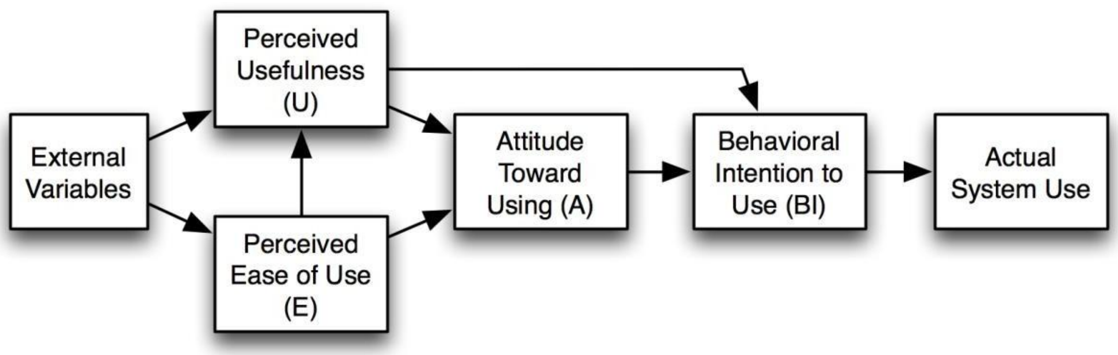

Figure 1.1: *Diagram***:** Technology Acceptance Model (Davis, 1989)

According to Davis (1989), practitioners evaluate systems for two purposes; firstly, to predict acceptability; secondly to diagnose the reasons resulting in lack of acceptance and to take proper measures to improve user acceptance. Technology acceptance model (TAM) has received empirical support for being robust in predicting technology adoption in various contexts and with a variety of technologies (Gao, 2005).

Researchers from different research settings have used this theory in their studies and have successfully validated its applicability. For example, Chan and Tan, (2004), expanded Technology Acceptance theory and proposed a theoretical model for studying. In their study, they used a number of factors to test the model. These factors include; product offerings, information richness, usability of storefront perceived trust and perceived service quality which have been impacted by acceptance of virtual store through the Web-based survey. To add weight on this fact, Luarn and

Lin (2005) did a study where they added perceived credibility, perceived self-efficacy and perceived financial cost to TAM model to make it more significant. The study was done on 180 Taiwan users of TAM where a structural equation modelling approach was used.

The results were the same on the factors that individulas considered in adoption of new technologies in mobile banking. TAM has been utilized and validated by various researchers for use with various technological domains. The level of individul's acceptance are predicted by TAM according to most of the studies concerning most of the organzitions on information technology (Hossain & Prybutok, 2008). Most of the universities in the US have adopted RFID technology and applied TAM and also most of the electronic retail sectors in Germany (Muller-Seitz et al., 2009). The research proposed by Davis et al. (1989) influenced the research done by Muller-Seitz et al., (2009) which included perceived usefulness, perceived ease of use and the intentions to use. On the other hand Hossain and Prybutok, (2008) added factors such as perceived cultural influence, perceived privacy, perceived regulation influence and perceived security to TAM and expanded the model further.

1.13 Conceptual Framework

A conceptual framework is not simply a number of concepts, but rather, a paradigm wherein each concept plays an essential function. It indicates the key elements, constructs, or variables, and posits relationships amongst them Miles and Huberman, (1994). The figure below shows the conceptual framework that guided this study. It included dependent and independent variables. The dependent variable in the study were effects of RFID technologies which comprised of economic and social impacts (to customers and to water service provider (WSP)). The first independent variable namely viable RFID technology comprised of billing accuracy with streamlined meter reading and bill generation, pipe identification and leak detection. The second independent variable which was RFID technology architecture, comprised of infrastructure. The infrastructure included the hardware and software.

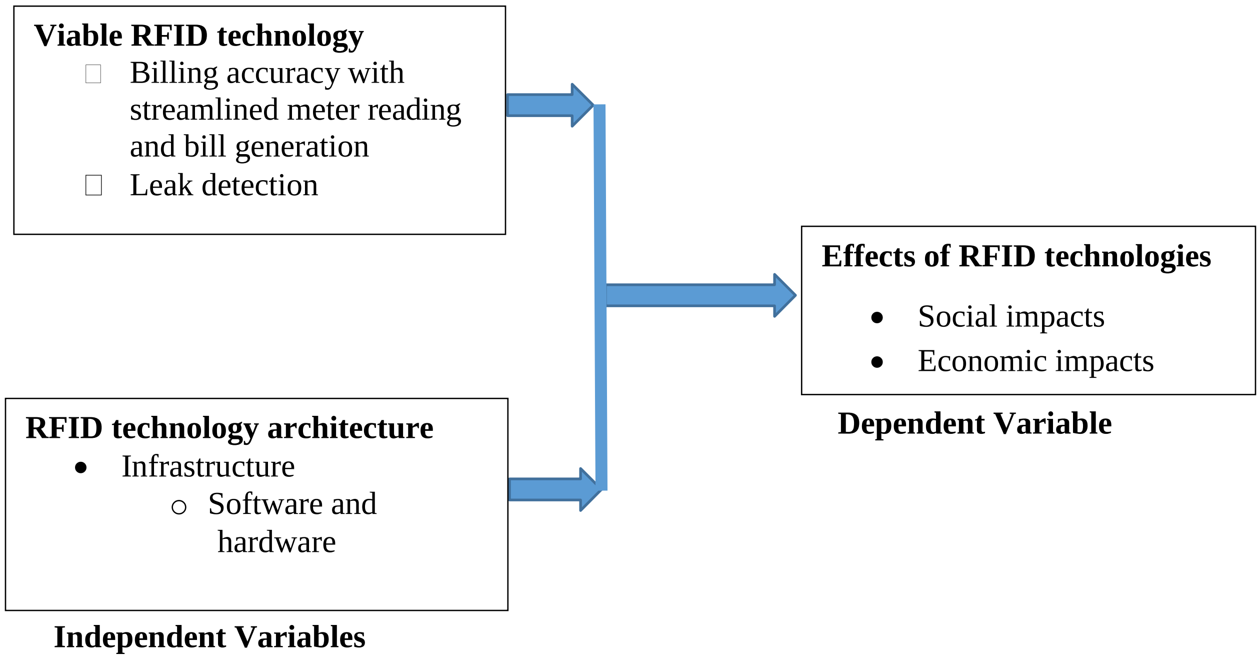

Figure 1.2: *Diagram:* Conceptual framework for adoption of RFID technology in a water-based company

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on adoption of RFID technology in utility companies specifically a water-based industry. It covers the following areas: theoretical framework, empirical review on literature and research gap.

2.2 Theoretical Framework

There has been various theories that have explained how individuls behave when it comes to adoption and intentons of a new innovation. One example is the technology acceptance model (TAM), which was introduced by Davis (1989) which gives a clear explanation on indivulas attitude to acceptance, uselfullness and prediction towards the use of new systems which affect the use and intentions of use. The theory of the Theory Reasoned Action (TRA) which was created by Ajzen and Fishbein (1975) bore TAM which is the most effective model that explains all aspects that involve how individuals react when it comes to adoption of innovation and new technologies. Globally, the use of TAM has been approved and thus embraced by most of the user groups as the most applied and most effective model (Kwon & Chidambaram, 2000; Chau, 1996; Cho & Agrusa, 2006; Pavlou, 2003).

2.3 Empirical Review on Literature

Most organzations are embracing Radio Frequency Identification (RFID) technology as it has been found to increase efficiency, improve productivity and it has also been found to be an interesting subjet of discussion by researchers. The use of wireless identification has been found to be influenced by this thechnology through commercial and technological solutions. The RFID system is composed of three basic components: a tag (also known as a transponder), a reader (also called interrogator) and a central database for processing information. Each tag has a unique identification number of the object or item to which it is attached and transmits information about the item to the RFID reader via radio frequency waves. The reader emits and receives information stored on the tags through radio waves and the collected data is processed by the data-processing equipment in the utility office (Madhusudhan, 2010; Finkenzeller, 1999). RFID is a technology that enables new processes in companies.

2.3.1 Identification of a Viable Radio Frequency IDentification Technology

Selecting the right system for the utility is critical to meeting goals and long-term operational success. Accurate and reliable water metering is imperative in today's water utilities. Although utility companies are facing financial challenges, it is important for the utilities to invest in their water metering infrastructure becasuse:

- Water meters are considered to be the utility's "cash registers," so ensuring accurate measurement of all water usage is essential for obtaining sufficient revenue.
- Customer service expectations are growing. Utility customers demand excellent service in the form of accurate bills and helpful communication from the utility, such as leak notifications. They also want to understand their usage patterns and how their bill is affected.
- Water conservation is crucial for utilities. Proper measurement and leak detection are key to reducing water waste and ensuring sustainability (Mark, 2017).

When selecting a meter reading method, there are several factors that need to be considered; type of meter (size, application, and expected flow rates), meter installation (pits, basements), the geographical area (open or hilly places), density of meter location and other obstacles e.g. buildings or whether the WSP is checking consumer consumption patterns in specific areas for example observing the consumption of high water consumers on a more frequent basis (Mark, 2017; Christodoulou et al., 2012). Choosing the right meter results in increased revenue, improved customer service, conservation of critical water resources, and environmental sustainability, correct size and type of meters helps in remedying locations of lost water. The appropriate meter type ensures that meters will record all the water that passes through it.

Additionally, different utilities have different driving forces towards the adoption of an economically viable technology. Some of the factors include: climate, population density, traffic conditions, safety, access and customer service or satisfaction, meeting requirements resulting from a law or mandate, to improve conservation, customer satisfaction, and or to increase revenue, accurate and timely billing. If the goal is more accurate and timely billing, then a mobile automatic meter reading system is more efficient, reliable and economically viable (Hawkins & Berthold, (2015).

There are various automatic meter reading (AMR) using RFID technology options available and they depend on budget availability and requirements. The more common ones include, ‘walk-by’ or handheld, ‘drive by’ and fixed network (as discussed below). Some of the most requirements/ features include: leak detection and notification, alarm signals, pressure controls, remote connect and disconnect, prepayment and select-date billing, customer interface, and monitoring and control.

2.3.1.1 Mobile or “drive-by” Meter Reading

It involves meter readers patrolling meter reading area in a vehicle fitted with communication devices collecting consumptions as they pass by customer premises. This method offers an efficient way of collecting data thereby reducing the time taken during on-site meter reading in a large population. The system can read dozens of readings, simultaneously as the vehicle drives slowly in the meter reading area. This, of course, greatly increases reading speed and is highly efficient (Moghavvemi et al., 2005).

The vehicle is installed with a meter reading device which transmits radio waves to awaken the tags fitted to the meters, which then responds to the signals by transmitting the readings to the vehicle. This method is advantageous since the meter readers are not required to access the customers’ properties to collect meter reading as it is required in the walk-by method. This method requires navigational and mapping features, laptop, a software, RF transceiver and an antenna mounted on the vehicle. To optimize the performance of the system the antenna should be mounted very high on the roof of the van (Christodoulou et al., 2012). This method utilizes a high and more powerful receiver, and allows meter readers to collect thousands of readings per day. This enhances speedy meter reading process and also enhances efficiency in billing and data analysis.

2.3.1.2 Hand-held or “walk by” Meter Reading Method

Handheld or “walk-by” meter reading is where a meter reader walks with a handheld device with an incorporated receiver or transceiver to gather consumptions from a capable meter. This is an exhaustive process since the meter readers walks by all the places with the installed meters collecting readings. It is important that the meter reader visits the area physically since the communication between the meter and the handheld reader utilizes low-frequencies due to the limitations of transmitter and the communication channel (Unhelkar, 2010).

2.3.1.3 Fixed Meter Reading Method

Fixed meter reading is installed permanently to collect meter readings. It consists of several antennas, mast, collection units, repeaters and other related infrastructure which are installed permanently for the purposes of collecting readings from automatic meter reading capable meters and transmitting the readings to a central database without any human intervention (Kavet & Mezei, 2010).

No human invention (meter assistants) is required in this method and the meter readings are transmitted directly to the utility. However, it uses high frequency transmitters (requires a lot of power) which are attached to the water meters and data collectors which are installed permanently throughout the meter reading area. The data gathering devices transmits meter readings to the utility for billing, analysis or other information for example leaks, vandalism or other anomalies.

2.3.2 Effects of Radio Frequency IDentification in a Water Utility

Developments in AMR using RFID technology have rapidly evolved to a great extent from various utility sectors (energy), where automated electricity and gas meters and communication infrastructure have already been introduced. In the recognition of the benefits of the traditional meter reading and the perceived opportunities presented by the evolving technology, water companies are progressively turning towards the adoption of automatic meter reading using RFID technology as a way of reducing water losses, conserving water, controlling costs, improving reliability and enhancing customer satisfaction (Thomas et al., 2013).

There are significant benefits of implementing automatic meter reading using radio frequency identification technology to the water service provider and to the customers. RF-based meter reading reduces meter reading and billing costs, eliminate estimates, cancel-and-rebills, reversals and other related anomalies, allow investigation of unusual consumptions or billing, enhances leak detection, identification of malfunctioning meters and timely identification of tampering or theft and track down unaccounted-for water. It also allows consumers to have a better control of their water consumption, costs and bills as well as increasing customer security. For remote/inaccessible areas, automatic meter reading can reduce hazards to meter readers and traffic disruption (Corey, n.d).

An automated meter reading system offers improved billing accuracy with streamlined meter reading and bill generation thus reducing billing complaints thereby increasing customer satisfaction in the long run. AMR provides more timely, accurate and granular reads and this helps to resolve customer billing complaints, provide insight into usage, and identify conservation violations. Massive data is generated using this method, this enables the utility's staff to plan, construct and optimize water distribution system thus enhancing efficiency and effectiveness.

Automatic meter reading using RFID aims at eliminating the costs incurred during manual meter reading which range from labor costs and meter locations. Other costs include salaries, on-site visits, operating costs, vehicle cost, telephone expenses and maintenance expenses. Implementing an automatic meter reading, costs can be reduced by collecting meter reading wirelessly or electronically by using a handheld RFID device (Sehgal, 2005)

Advanced water metering technology promotes more awareness since it is easier to track and monitor the volume of water consumed at particular places and in addition where water reductions can be made to improve efficiency and reduce costs. Comprehensive metering enables a water service provider to charge consumers based on actual readings rather than depending on estimates. Consumers are accountable and can control their own water usage. Due to the awareness of high and low water consumers, distribution is done fairly. The WSP, can easily track unaccounted-for water, leaks and vandalism/theft enabling them to respond to the situation quickly and limit extreme of water loss or significant theft. However, not all cases lead to the identification of the responsible party (ABB Group, 2017; Hawkins & Berthold, 2015).

Advanced water metering and communication technologies helps to identify and reduce leakages and non-revenue water. This investment has the ability to provide WSP with ways of reducing operational costs, while improving services and managing water supply which includes leakage identification, managing non-revenue water (NRW), establishing consumption patterns and using predictive analytics to control supply and having alerts to predict or prevent anomalies; a report done by Seth from Water and Water International. RFID, often in combination with other technologies, can help utility companies save time and money by speeding their ability to locate and identify assets, thereby facilitating inspections and services.

A lot of NCWSC water infrastructure was constructed two decades ago, the outdated infrastructure results to a lot of leaks. Therefore, leakages are noticed later than they are supposed to. It is important for the company to ensure that these problems are adhered to. Additionally, the company needs new infrastructure not just because the current system is old but also to meet new demands. But the numerous benefits of automatic meter reading using RFID technology in utility companies are yet to become driving forces in reducing NRW and in automating customer water meters in developing countries. This is as a result of poor financial management, corruption and lack effort required to find and fix leaks compared to building new treatment works or dams.

2.3.3 Radio Frequency Identification (RFID) Technology Architecture

2.3.3.1. What is RFID Technology and how does RFID system work?

Radio frequency identification (RFID) is an electronic device that has the capability to exchange information between RFID tags and RFID readers via radio signals from a distance or without a direct line of sight. The RFID system consists of: a tag, a reader, utility enterprise software and infrastructure for processing information (Want, 2004).

RFID tags: RFID tags are low-cost devices with limited data storage space. RFID tags are made of a microchip attached to a radio antenna that is then surrounded by some form of casing, usually plastic (Fink, Gillett, & Grzeskiewicz, 2007). RFID tag consists of a unique identification number of the object or item to which it is attached and transmits information about the item to the RFID reader via radio frequency waves (Want, 2004). The tags receives signals from and transmits to a reader. RFID tags can either be active, semiactive or passive and they can be read-write or read-only. Active RFID tags have a transmitter and are battery-powered. The communication range is long but are expensive. A passive RFID tag have no power source but rely on the power they get from the reader. Passive tags are cheaper and the communication range is short. Semi-passive tags use battery but communicates by drawing power from the reader (Chawla & Ha, 2007).

RFID reader: An RFID reader is an electronic device that generates signals to communicate with RFID tags (Huang & Shieh, 2010). Readers transmit signals to power the tags and then receive data stored on the chip of the tag (Fink, Gillett, & Grzeskiewicz, 2007). The reader emits and receives information stored on the tags through radio waves and the collected data is processed by the data-processing equipment in the utility office. RFID readers can be configured based on mobility, either by handheld or fixed reader. They can be classified based on function, as read-only and read-write readers. Fixed readers can only read data from tags by capturing the movement of tagged products or items as they pass through major choke points, such as dock doors. Handheld

RFID readers enable the deployment of RFID read points virtually everywhere within the operations stages (Motorola, 2007). “Fixed-mount readers are usually more expensive but also have a longer read range and can be less labor intensive than using hand-held” (Ross et al., 2009). RFID readers can either read data from an RFID tags only or read and write information to an RFID tag. “A passive-tag reader can constantly broadcast its signal or broadcast it on demand” (Weinstein, 2005). “Read/write readers can write new data to a suitably designed read/write memory tag, as well as read the information from it” (Curran, & Porter, 2007).

RFID requires the installation of information technology “infrastructure which is necessary to collect, filter and enrich raw RFID data before being processed by the backend systems” (Frischbier, Sachs, & Buchmann, n.d,). RFID infrastructure is also referred to as middleware. The term “middleware” broadly refers to hardware devices and software that are used to connect RFID readers and the collected data to enterprise applications/systems. “RFID middleware applies filtering, formatting or logic to tag data captured by a reader so the data can be processed by a software application” (Burnell, 2006). RFID middleware should meet the following application requirements (Floerkemeier, Roduner, & Lampe, 2007):

- RFID data disseminations
- RFID data aggregation
- RFID data filtering
- Writing to a tag
- Trigger RFID reader by external sensors
- Fault and configuration management
- RFID data interpretation,
- Sharing of RFID triggered business events
- Lookup and directory management
- Tag identifier management
- Privacy protection.

The utility software utilizes information stored on RFID tags. RFID enables businesses to integrate the captured data with internal business processes to create values such as reduced labor costs, enhanced service and improved efficiency. Utility software include MDMS and SCADA.

2.3.3.2. RFID in a Water-based Company

RFID technology has been used in the water industry and has offered many benefits to the WSP’s and water consumers. Water utilities are realizing alot of benefits associated with moving from their old, manual read meters to RFID based AMR systems. These benefits include: increased revenue from previously unaccounted for water; as meter age, particularly the mechanical type meters, they lose accuracy as they start wearing out. One of the immediate benefits of meter replacement with newer meters is that water that previously was not being recorded by the older meters is now captured by the newer meters, and billed to the customer. Other benefits include, reduced meter reading costs, improved employee security or safety, identifying and pinpointing losses for both customer and distribution system, monitoring system integrity and water conservation (Lon, 2008).

In a water utility, water meters are fitted with small data collection units and low power radio transmitters or transceivers. These units are also fitted with batteries with a 10 or more years of service. The readings are collected remotely either by ‘walk-by’, ‘drive-by’ receivers and computers. When applied to a fixed AMR in an apartment, RF frequently utilizes one or more radio repeaters to overcome transmission obstacles (Readdy, 2006). Readings are read through the transmitter which is connected to the meter and then the LED display displays the actual data. RF is also used in transmission of the data. The data is later on received by the receiver module and the microcontroller which is then displayed in the LED display. RF transmitter and receivers are used to transmit and receive the meter readings.

Massive data is generated by the automatic meter reading systems. To manage the vast data quantities being transmitted, a Meter Data Management System (MDMS) system or other database is implemented. Management Data System (MDMS) refers to a data collection instrument designed to assist in managing the massive amounts of metering data (customer information, consumption and meter data) from multiple collection system sources and can be used by handheld and mobile automatic meter reading technologies. It receives information from the handheld device, but it also can send information back to it and send water readings to the utility. MDMS delivers accurate, secure, reliable meter data transfer from end point devices for example utility meters to the utility applications and databases. Additionally, it allows the utility to detect anomalies such as leaks, back-flow, and vandalism by sending alerts wirelessly. The main benefit of deploying MDMS is the functionality for validating, editing and estimating (VEE) of data for billing and other purposes (Meter Data Management (MDM), n.d).

2.4 Summary of the Literature Review

Various utility companies have different goals of converting from the traditional meter reading to the telemetry method. Meter reading is a process for gathering readings and it enables utility companies to bill consumers based on actual consumptions. RFID based AMR is a technology aimed at improving this process by providing accurate and collecting multiple readings simultaneously. The meter records enable the utility personnel to timely and easily access each and every customer's information for billing and analysis.

This study focused on an Automatic meter reading system model based on radio frequency for a water-based company. This process includes taking meter reading, and transmitting the readings and leak detection via radio frequency to the central repository. In a water scarce environment, automatic meter reading technology can be beneficial to human resources. In addition, this technique helps to identify and reduce leakages and non-revenue water.

2.5 Research Gap

In Kenya a study has been done on adoption of RFID in university libraries but no study has been done in the adoption of RFID in a water company. Most studies on adoption of RFID technology in utility companies have been done in developed countries and they have focused more on the energy sector. However, there is paucity of literature in the adoption of RFID technology in a water-based company.

It is imperative that the research community on the adoption of RFID expand its knowledge on how a water-based company can leverage the most from the technology. Therefore, this study aims at proposing the adoption of an RFID based AMR technology that aids in automating meter reading process with the aim of streamlining meter reading process and billing, identification of pipes and leak or burst detection in the water distribution system in utility companies in order to improve the efficiency and effectiveness of the utilities operations.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLGY

3.1 Introduction to Research Methodology

In this chapter, the researcher explains and defends the instruments and techniques that were used to obtain primary data for the study. It describes the research design that was used, location of the study, target population, determination of sample size and research instruments. Finally, the chapter discusses data collection measures, data processing and analysis and legal and ethical issues considered.

3.2 Research Design

(Polit et al., 2001) defines research design as the researcher's blueprint for responding to the research questions or testing the research hypothesis. This study used a descriptive research design approach to collect in-depth information from the respondents from the predetermined population in Nairobi City and Sewerage Company. In this design, the respondents answered questions administered through questionnaires. A descriptive research was used to gather quantifiable information that was used for statistical inference on the target audience. According to Mugenda and Mugenda (2003), a descriptive research process determines and reports the way things are.

3.3 Research Site

According to Lisa (2008), a research site is the physical, social and cultural site in which the researcher conducts the study. The target site for this study constituted of NCWSC staff from the six regions. Nairobi City Water and Sewerage Company has six administrative regions namely; Northern, Eastern, Central, North Eastern, Southern and Western. The company has 1,810 employees in the six regions as at April, 2018.

Table 3.1: *Nairobi City Water and Sewerage number of employees (NCWSC, (2018)*

Region	**No of employees**
Central	245
Northern	321
North-Eastern	347
Western	264
Eastern	355

Southern	278
Total	**1,810**

3.4 Target Population

A target population refers a group of entities, event or object to which a researcher wants to generalize the results of study (Mugenda & Mugenda, 2008). Burns and Grove (2003) define population as all the entities that meet the criteria for inclusion in a study. The utility companies formed the population of the study, more specifically Nairobi City Water and Sewerage Company. The target population will be all the 1,810 employees from the six different regions in NCWSC.

3.5 Study Sample

3.5.1 Sampling Procedure

Sampling means selecting a given number of subjects to represent the population. Any statement made about the sample should also be true of the population (Orodho, 2003). Stratified sampling technique was used to sample the target population. The target population was divided into strata according to the six administrative regions, therefore, these regions formed six (6) strata; Central, Eastern, Northern, North-Eastern, Western and Southern.

3.5.2 Study Sample Size

A sample is described as a smaller but representative collection of entities from a population used to determine facts about that population (Field, 2005). NCWSC has 1810 employees in the six administrative regions. To determine the sample size, the following formula was adapted from Yamane, (1973) with 95% confidence level and P = .5 was assumed.

Thus,

$$n = \frac{N}{1+(N)e^2}$$

Where :

n = sample size required

N = population size

e = required sampling error (A 95% confidence level or .5 precision level, was assumed)

Substitute numbers in the formula

$$n = \frac{1810}{1 + (1810\ )0.05^2}$$

n =328

Additionally, proportional sampling was used to determine a suitable representation of the population. It involved identifying the percentage of the population each stratum contained. The population was then sampled proportionally based on these percentages using (Dempsey & Dempsey, 2000) formula.

Thus;

$$no\ of\ employees\ in\ each\ stratum = \frac{No\ of\ employees\ in\ stratum}{Total\ No\ of\ employees} * sample\ size(328)$$

Table 3.2: *Sampling Frame*

No	Stratum/category	No of employees	Sample
1	Central	245	44
2	Northern	321	58
3	North-Eastern	347	63
4	Western	264	48
5	Eastern	355	64
6	Southern	279	51
	Total	**1,810**	**328**

3.6 Data Collection Measures

3.6.1 Data Collection Instruments

This study used primary data which was collected using questionnaires and field observations. Questionnaires were used because they are familiar to most people (Berdie et al., 1986). The questionnaire was derived from the objectives of the study and focused on effects of adopting RFID to the customers and the utility company. Field observation gave the researcher an insight of how meter reading is carried out and the various obstacles meter readers encounter. These questionnaires were hand delivered to the respondents.

This study considered two variables; dependent and independent variables. The dependent variable in the study was; effects of adopting RFID technology which comprised of economic and social impacts to customers and water service provider (WSP). The first independent variable was viable RFID technology which comprised of billing accuracy with streamlined meter reading and bill generation and leak detection. The second independent variable which is RFID technology architecture comprised of infrastructure. The infrastructure included the hardware and software.

3.6.2 Pilot Testing of Research Instruments

Once the questionnaires were completed, they were subjected to pre-testing on a selected sample, with identical characteristics to those of the actual sample intended for the study. Pre-testing procedure was identical to the one that was used during the actual data collection so as to predict any problem of comprehension and to check the clarity of items in research instruments, thus enhancing the reliability and validity of the instrument. According to Mugenda and Mugenda (1999), the number of cases in the pre-test should not be very large, it should be between 1 percent and 10 percent. This study adopted 10 percent of the sample size for the pilot study. The questionnaire was reviewed based on the findings of the pilot study.

3.6.3 Instrument Reliability

Mugenda and Mugenda (2002) defines reliability as the extent to which the research instrument gives stable and consistent results or data after repeated trials. To establish reliability of the research instruments and that they yielded consistent results, pilot-testing was done to the sampled respondents from each region at two separate times at an interval of two weeks. This study used the test re-test technique to assess the reliability of the instruments. This process involved giving the same test twice to a number of respondents who had been selected for this cause with similar traits as the actual sample.

3.6.4 Instrument Validity

Kathuri and Pals (1993) define instrument validity as the extent to which outcomes acquired from the analysis of the data actually represent the phenomenon under study. Borg and Gall, (1989) states that instrument validity is enriched through expert judgment. Validity of the instruments was done through expert judgment where the researchers' supervisor was requested to evaluate the appropriateness of the content, adequacy of the instruments and gave his input to enrich them.

3.7 Data Processing and Analysis

The data that was collected was classified, summarized and analyzed. This study used descriptive statistics for data analysis to enable the researcher describe the phenomena using Statistical Package for Social Sciences (SPSS).

Section A of the questionnaire which was the general information of the respondent was analyzed using descriptive statistics with a view of means to calculating percentage, ratio or frequency as the ranking method. Content analysis method was used to analyze open ended questions. Section B, was analyzed by having Likert scale of five ordinal measures of agreement which were used towards each statement (1, 2, 3, 4, and 5) courtesy of Statistical Package for Social Science (SPSS) to compute the mean score for each factor in view to determine the relative ranking. Presentation of data was presented graphically using pie charts and tables.

3.8 Legal and Ethical Considerations

It is the researcher's ethical responsibility to ensure that the respondents comprehend the purpose of the research. Therefore, an explanation was given to the participants about the study and that the study was for academic purposes only. Caution was exercised while administering questionnaires to ensure trust between the respondents and the researcher. Additionally, the respondents were reassured of confidentiality of the information they gave.

The researcher sought permission to carry out the research from Nairobi City Water and Sewerage Company. The researcher obtained a research permit from the Ministry of Education

National Council for Science Technology and Innovation (NACOSTI) in Nairobi and the County Administration Offices to be allowed to carry out the study.

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter discusses the data analysis and findings of the study, as set out in the research methodology. It outlines the study findings in accordance with the research objectives. The results are presented on development of Radio Frequency IDentification architecture for adoption in utility companies; a case study of Nairobi City Water and Sewerage Company. The findings were utilized to formulate recommendations on development of RFID architecture in the water industry.

4.2 Characteristics of the Respondents

This section of the questionnaire consisted of response rate, NCWSC directorates, age, gender, knowledge of loss of water, causes of water loss, measures to be undertaken to handle the water loss, effects of water loss to customers, systems used, effectiveness of the systems used and the challenges encountered when using the systems.

4.2.1 Response Rate

The response rate according to Mitchell, (1989), is the completion rate and return rate which is normally the result of dividing the number of people who returned questionnaires by the total number of people in the sample. The instrument used in collecting primary data from a sample of 328 from NCWSC was questionnaire. The response rate for all the employees from the six different regions in the company is presented in Table 4.1.

Table 4.1: *Response Rate*

Response	**Frequency**	**Percentage**
Responded	253	77
Not Responded	75	23
Total	**328**	**100**

The study targeted 328 respondents. Out of the targeted respondents, 253 filled and returned the questionnaires giving an overall response rate of 77%. This response rate was adequate and representative and conforms to Mugenda and Mugenda (2003) stipulation that a response rate of 50% is acceptable while a response rate of 70% and over is excellent for analysis and reporting.

4.2.2 Respondents Regions

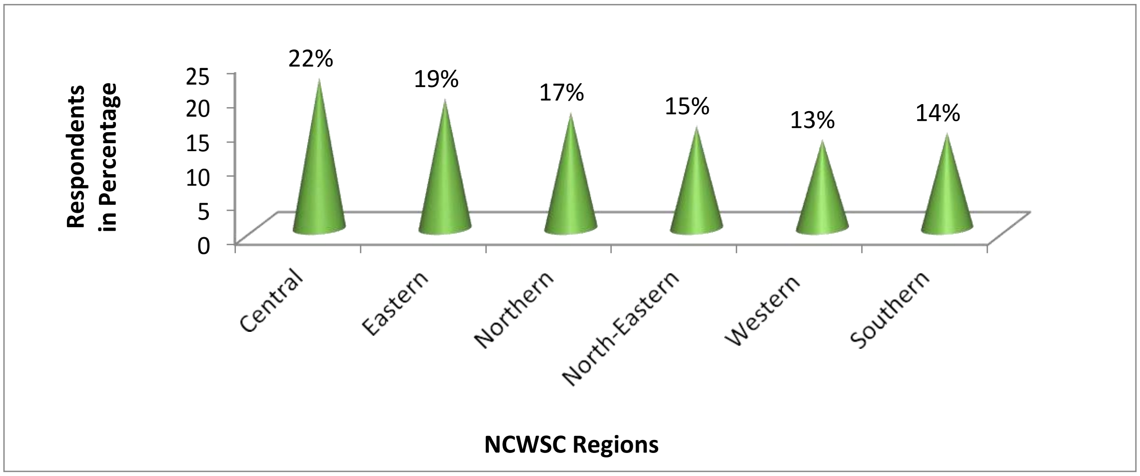

Figure 4.1: *Graph***:** Respondents Regions

Findings in Figure 4.1 show that most (22%) of the respondents belonged to the Central region, 19% belonged to the Eastern region, 17% belonged to the Northern region, 15% belonged to the North-Eastern region and 13% belonged to the Western region while 14% belonged to the Southern region.

4.2.3 Respondents Directorate

Table 4.2: *Distribution of Respondents by Their Directorate*

	Frequency	**Percent**
Managing Director	5	2
Human Resource and Administration	5	2
Legal	10	4
Technical	63	25
Commercial	71	28
Finance	61	24
ICT	18	7
Risk and Audit	20	8
Total	**253**	**100**

Findings in Table 4.2 show that most (28%) of the respondents belonged to the Commercial directorate, 25% belonged to the Technical directorate, 24% belonged to the Finance directorate, 8% belonged to the Risk and Audit directorate,7% belonged to the ICT directorate, 4% belonged to the Legal directorate whereas 2% belonged to the Managing, Human Resource and Administration directorate respectively. These shows that majority of the employees at Nairobi City Water and Sewerage Company was in the technical, finance and commercial directorates.

4.2.4 Gender of Respondents

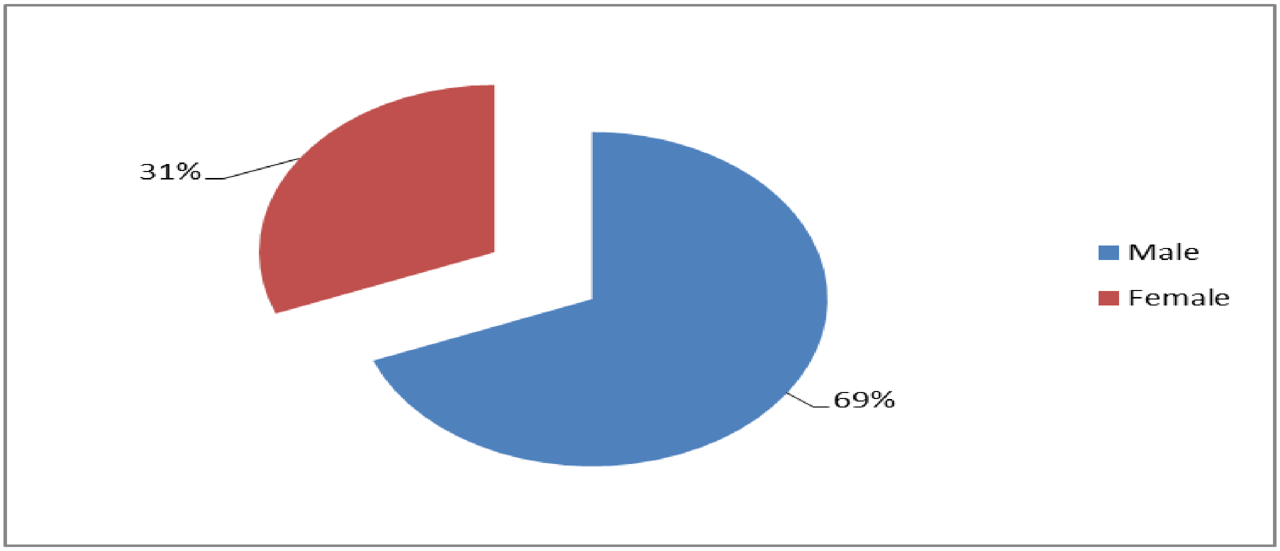

Figure 4.2: *Graph*: Composition of Respondents by Gender

Figure 4.2 shows that 69% of the respondents, who were the majority, were male while 31% were female. This shows that both genders were represented in the study however, there was gender disparity.

4.2.5 Age of Respondents

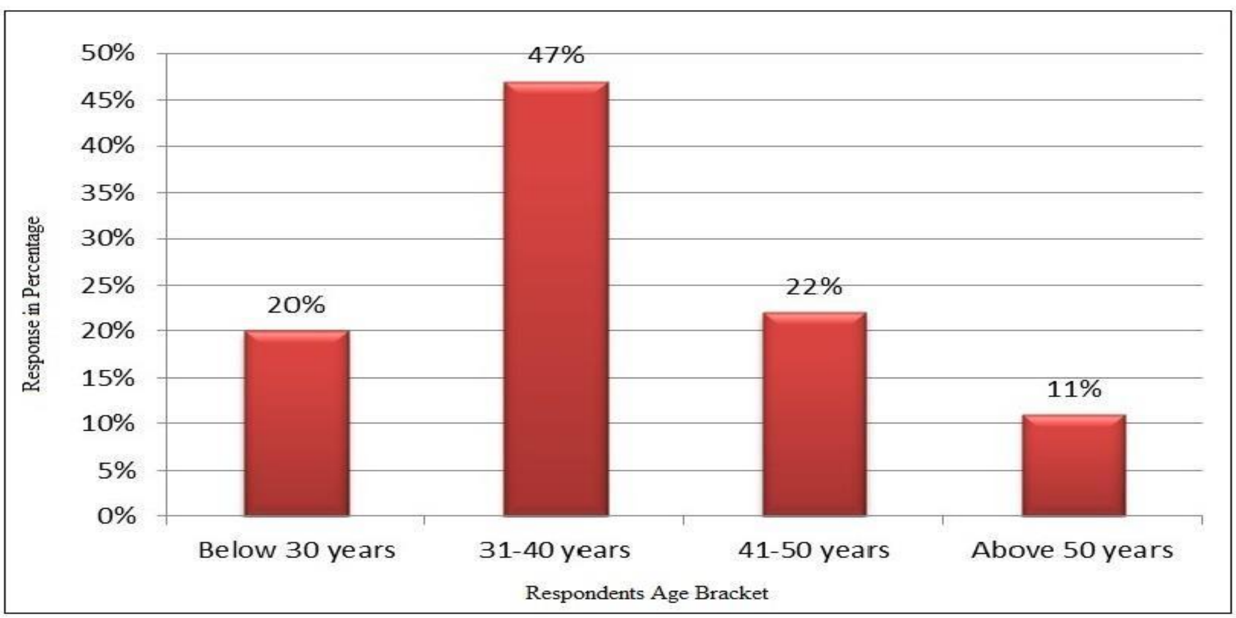

Figure 4.3: *Graph*: Distribution of Respondents by Age

According to Figure 4.3, 47% of the respondents who were the majority were between 31 and 40 years, 22% were between 41 and 50 years, 20% were below 30 years while 11% were above 50 years. This shows that majority of the respondents were in their middle age considering the high number of the commercial directorate team that responded to the questionnaire.

4.2.6 Respondents Working Period

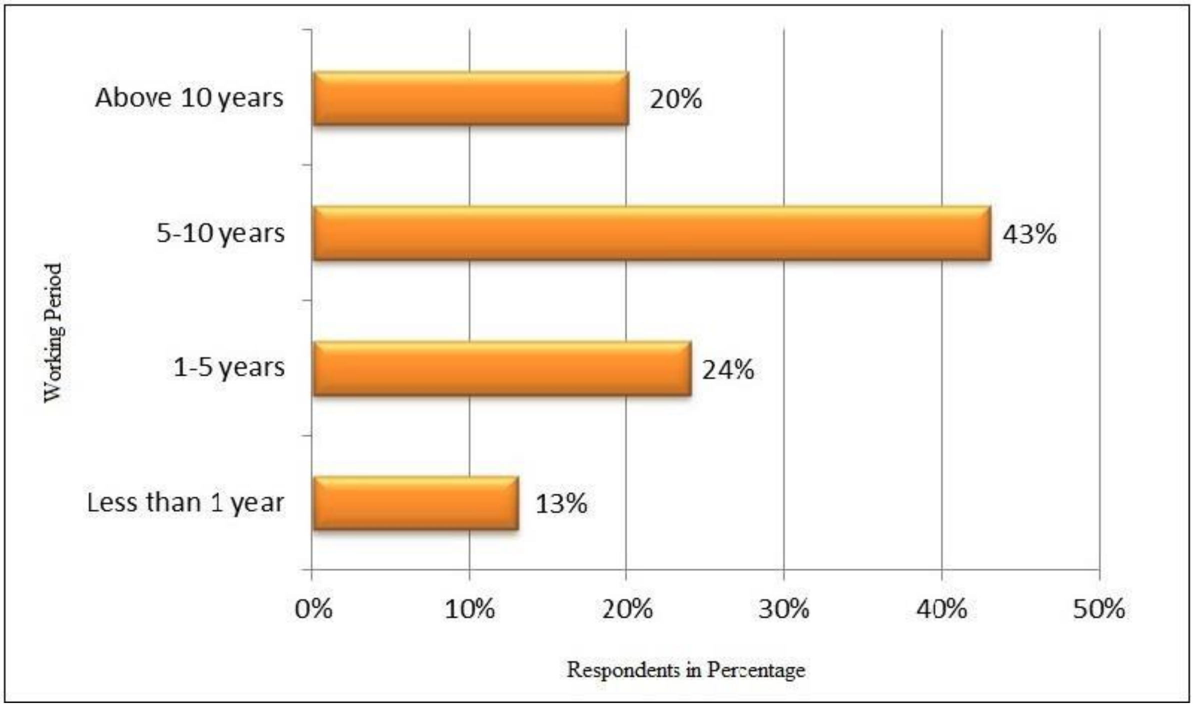

Figure 4.4: *Graph*: Distribution of Respondents by Their Working Period

It was evident from Figure 4.4 that 43% of the respondents who were the majority had worked at Nairobi City Water and Sewerage Company for a period between 5 and 10 years, 24% had worked at Nairobi City Water and Sewerage Company for a period between 1 and 5 years, 20% had worked at Nairobi City Water and Sewerage Company for a period above 10 years whereas 13% had worked at Nairobi City Water and Sewerage Company for a period of less than 1 year. This shows that respondents had worked for a period long enough to understand the level of adoption of radio frequency identification technology in their company.

4.2.7 Loss of Water at NCWSC

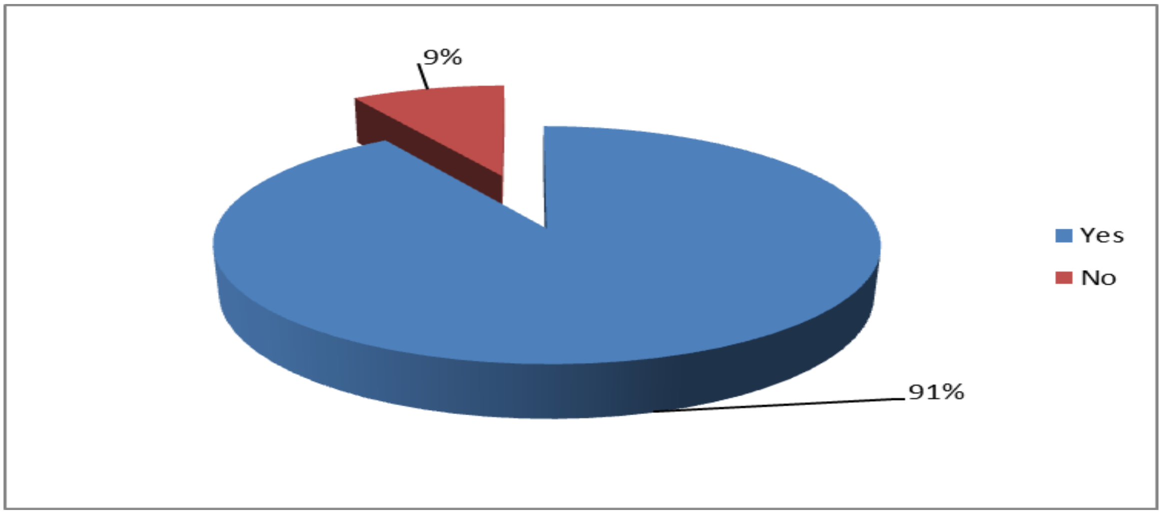

Figure 4.5: *Graph***:** Loss of Water at NCWSC

Respondents were asked whether they knew that NCWSC lost 40% of the water it produced, 91% of the respondents who were the majority were aware that NCWSC lost 40% of the water it produced.

4.2.8 Causes of Water Loss at NCWSC

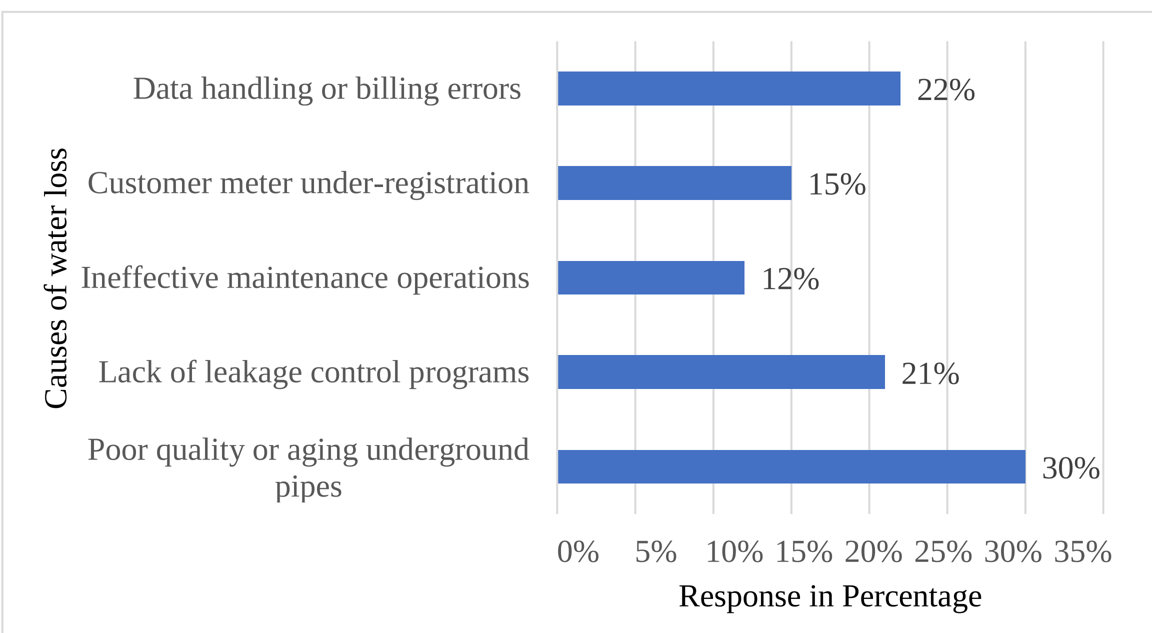

Figure 4.6: *Graph***:** Causes of Water Loss at NCWSC

Findings in Figure 4.6 show that 30% of the respondents who were the majority indicated that loss of water at NCWSC was caused by poor quality and aging underground pipes, 22% indicated that loss of water at NCWSC was caused by data handling or billing errors, 21% indicated that loss of water at NCWSC was caused by lack of leakage control programs, 15% indicated that loss of water at NCWSC was caused by customer meter under-registration while 12% indicated that loss of water at NCWSC was caused by ineffective maintenance operations.

4.2.9 Measures to Ensure Loss of Water at NCWSC is Handled

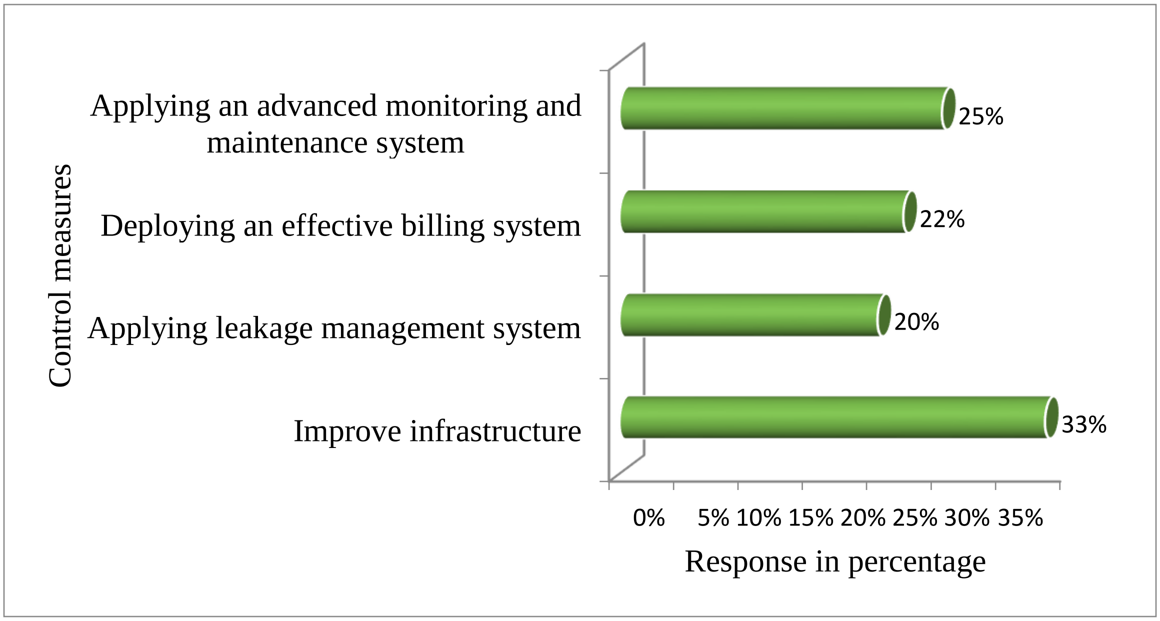

Figure 4.7: *Graph*: Measures to Ensure Loss of Water at NCWSC is Handled

According to Figure 4.7 above, 33% of the respondents who were the majority indicated that loss of water at NCWSC could be handled by improving infrastructure, 25% indicated that loss of water at NCWSC could be handled by applying an advanced monitoring and maintenance system, 22% indicated that loss of water at NCWSC could be handled by deploying effective billing systems while 20% indicated that loss of water at NCWSC could be handled by applying leakage management systems.

4.2.10 Effects of Water Loss to Consumers

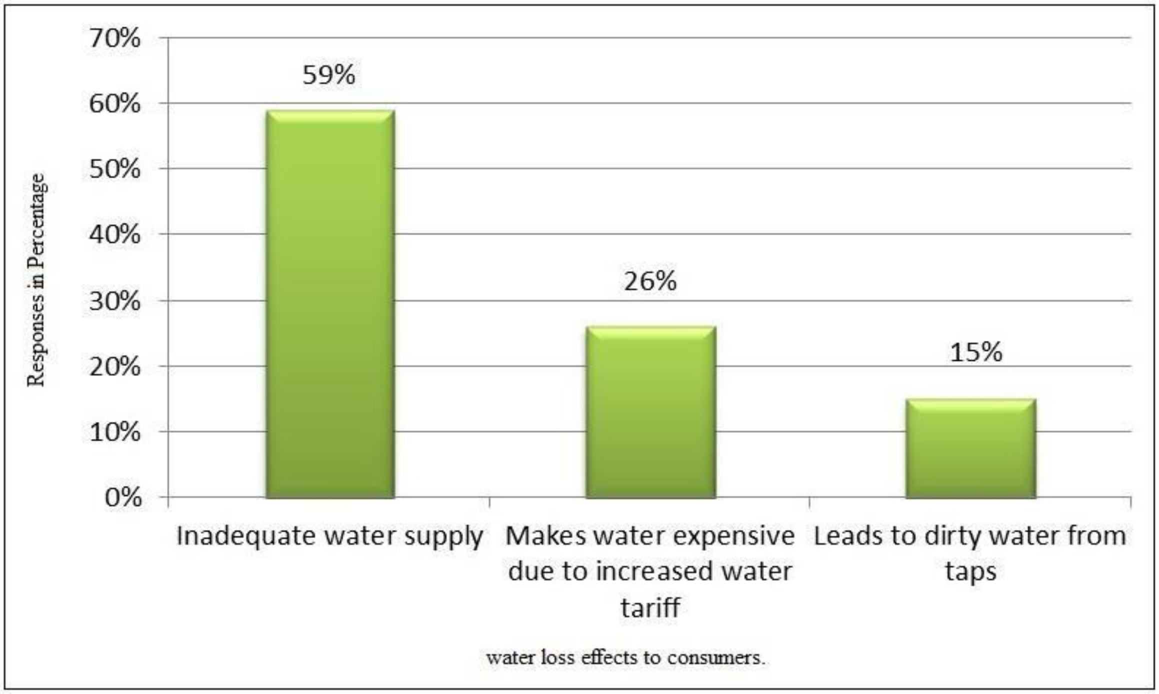

Figure 4.8: *Graph*: Effects of Water Loss to Consumers

The study also sought to find out how the water lost at NCWSC affected customers. Figure 4.8 shows that 59% of the respondents who were the majority indicated that loss of water at NCWSC resulted to inadequate water supply to the customers, 26% indicated that loss of water at NCWSC resulted to expensive water bills due to increased water tariff while 15% indicated that loss of water at NCWSC resulted to customers being supplied with dirty water from taps.

4.2.11 Systems used at NCWSC

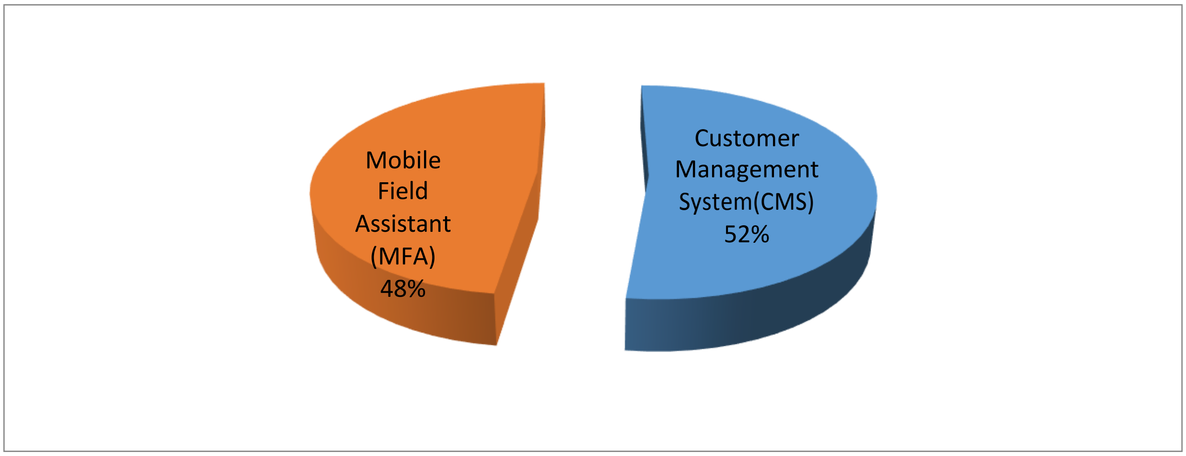

Figure 4.9: *Graph*: Systems used at NCWSC

The study also sought to find out the systems used at NCWSC. From the study findings, majority (52%) of the respondents indicated that Customer Management System (CMS) was used at Nairobi City Water and Sewerage Company while slightly less than half (48%) indicated that Mobile Field Assistant (MFA) was used at Nairobi City Water and Sewerage Company. This implies that both systems are used at Nairobi City Water and Sewerage Company.

4.2.12 Effectiveness of the Systems

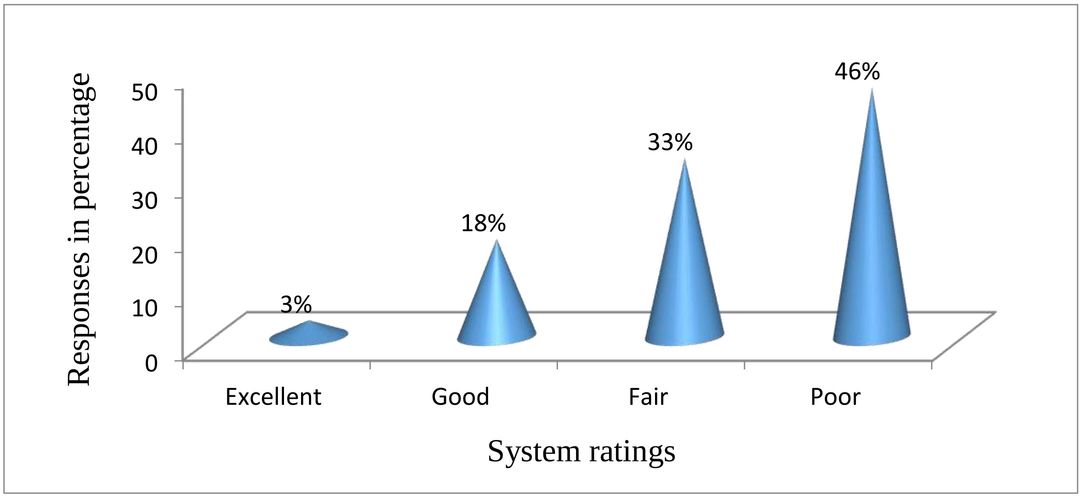

Figure 4.10: *Graph*: Effectiveness of the Systems

The study also sought to establish the effectiveness of the systems used at NCWSC. From the study findings, most (46%) of the respondents indicated that the system used at Nairobi City Water and Sewerage Company were poor, 33% indicated that the systems were fair and 18% indicated that they were good while 3% indicated that they systems used at Nairobi City Water and Sewerage Company were excellent. This implies that the systems used at Nairobi City Water and Sewerage Company are not effective and therefore there is a need to develop a more effective system which this study seeks to achieve.

4.2.13 Challenges encountered when using MFA

Majority of the respondents indicated the following as the challenges encountered when using MFA; estimates due to inaccessible, gate-locked, misty or malfunctioned meters, the system does not allow cancel-and-rebills; does not allow investigation of unusual consumptions or billing; don’t enhance leak detection and does not identify malfunctioning meters, does not allow identification of tampering or water theft. Some pointed out that poor network, hostility from customers affect the meter reading process.

4.2.14 Challenges encountered when using CMS

Majority of the respondents indicated the following as the challenges encountered when using CMS; frequent downtime of network affecting the billing process, fewer or more current reading than the previously read meter readings, lack of system integration with MFA.

4.3 Presentation of Research Analysis, Findings, and Interpretation

4.3.1 Effects of Radio Frequency IDentification Technology

This section sought to answer the questions on the effects of adopting radio frequency identification technology on consumers and WSP. The responses were rated on a five point Likert scale where: 5= Strongly Agree, 4= Agree, 3= Neutral, 2= Disagree and 1 = Strongly Disagree. The mean and standard deviations were generated from SPSS and findings were illustrated in tables below.

4.3.3.1 Effects of Radio Frequency IDentification Technology on Consumers

Table 4.3: *Effects of Radio Frequency IDentification Technology on Consumers*

Statements	**Mean**	**Std. Deviation**
The consumers will receive actual water consumption readings from the company	4.09	1.264
With the adoption of RFID technology, the customers will receive bills on time	3.92	1.215
The RFID technology will enable more timely, accurate and granular data to resolve customer billing issues/disputes	4.01	1.455
The RFID technology will enhance billing accuracy due to streamlined meter reading and bill generation	3.89	1.168
The adoption of RFID technology at NCWSC will improve customer relations due to available and clear information given to the consumer	3.91	1.288
The improved system will enhance equitable supply of water to all the customers	3.85	.786
There will be improved accountability on water consumption with the adoption of RFID technology at NCWSC	4.00	.712
Total	**27.67**	**7.888**
Average	**3.95**	**1.126**

Table 4.3 shows that respondents agreed with statements on effects of adoption of Radio Frequency identification technology in Nairobi City Water and Sewerage Company on consumers to a great extent as shown by an average score of 3.95. Respondents agreed that the consumers would receive actual water consumption readings from the company to a great extent as shown by a mean score of 4.09, respondents agreed that the RFID technology would enable more timely, accurate and granular data to resolve customer billing issues/disputes to a great extent as shown by a mean score of 4.01, respondents agreed that there would be improved accountability on water consumption with the adoption of RFID technology at NCWSC to a great extent as shown by a mean score of 4.00.

Respondents agreed that bills would be received on time to a great extent as shown by a mean score of 3.92; respondents agreed that adoption of RFID at NCWSC would improve customer relations due to available and clear information given to the consumer through improved technology to a great extent as shown by a mean score of 3.91, respondents agreed that the RFID technology would enhance billing accuracy due to streamlined meter reading and bill generation to a great extent as shown by a mean score of 3.89 and respondents agreed that the adoption of the improved system would enhance equitable supply of water to all the customers to a great extent as shown by a mean score of 3.85.

These findings are supported by Thomas et al., (2013) who argued that in the recognition of the benefits of the traditional meter reading and the perceived opportunities presented by the evolving technology, water companies are progressively turning towards the adoption of RFID technology as a way of reducing water losses, conserving water, controlling costs, improving reliability and enhancing customer satisfaction. There are significant benefits of implementing automatic meter reading using radio frequency identification technology to the water service provider and to the customers. This technology reduces meter reading and billing costs; eliminate estimates, cancel-and-rebills, reversals and other related anomalies; and allows investigation of unusual consumptions or billing.

4.3.3.2 Effects of Radio Frequency Identification Technology on the Water Service Provider

Table 4.4: *Effects of Radio Frequency Identification Technology to the Water* Service *Provider*

Statements	Mean	Std. Deviation
Adoption of RFID at NCWSC increase revenue from previously unaccounted- for water usage through an improved technology	4.11	.533
The deployment of RFID technology will result in staff safety and security	4.02	1.737
With the deployment of RFID systems, fewer on-site visits will be required therefore reducing operational costs	3.99	.563
There will be improved water theft detection and location pin pointing with the adoption of RFID technology	4.01	.554
There will be increased data enhancing staff planning and optimizing water distribution with the adoption of RFID technology	3.82	1.692
The RFID technology will help in early leak detection leading to reduction of potential damage and water waste while saving money and improving conservation	3.93	.696
The adoption of RFID will improve the meter-to-bill process for the purpose of revenue enhancement	4.09	1.844
Total	**27.97**	**7.619**
Average	**3.99**	**1.088**

Table 4.4 shows that respondents agreed with statements on effects of adoption of Radio Frequency identification technology in Nairobi City Water and Sewerage Company on WSP to a great extent as shown by an average score of 3.99. Respondents agreed that the adoption of RFID technology at NCWSC would improve customer relations due to available and clear information given to the consumer to a great extent as shown by a mean score of 4.11, respondents agreed that the adoption of RFID will improve the meter-to-bill process for the purpose of revenue enhancement to a great extent as shown by a mean score of 4.09.

Respondents agreed that the deployment of RFID technology would result in staff safety and security to a great extent as shown by a mean score of 4.02, respondents agreed that there would be improved water theft detection and location pin pointing with the adoption of RFID technology to a great extent as shown by a mean score of 4.01.

Respondents agreed that with the deployment of RFID systems, fewer on-site visits would be required therefore reducing operational costs to a great extent as shown by a mean score of 3.99, respondents agreed that the RFID technology would help in early leak detection leading to reduction of potential damage and water waste while saving money and improving conservation to a great extent as shown by a mean score of 3.93 and respondents agreed that there would be increased data enhancing staff planning and optimizing water distribution with the adoption of RFID technology to a great extent as shown by a mean score of 3.82.

The findings are in line with Seth from Water and Water International (2002) in that utility companies are integrating advanced ICT solutions into their operations. Automatic meter reading helps to identify and reduce leakages and non-revenue water. This investment has the ability to provide WSP with ways of reducing operational costs, while improving services and managing water supply which includes leakage identification, managing non-revenue water (NRW), establishing consumption patterns and using predictive analytics to control supply and having alerts to predict or prevent anomalies.

4.4 RFID Architecture for the Collection and Analysis of Meter Reading Data

4.4.1 Factors to Consider in RFID Architecture Construction

Yang, Prasanna & King (2009) describe RFID as a generic term for technologies that use radio waves to automatically identify and track people or objects. The method is used to store a unique identification numbers in a microchip, an antenna is attached to the chip so that the identification number can be transmitted. The chip and its antenna together are called an RFID transponder or an RFID tag. To receive and identify the information sent by tags, an RFID reader is required to communicate with the RFID tags. The RFID reader then forwards the information collected from the RFID tags to an information system. RFID readers can be fixed, handheld or mobile. The readers communicate with the tags and collect data. These data then pass through and are stored on local software ready for processing. The following section provides detailed information about each of the four main components of the RFID system.

RFID Tags

They are low-cost devices with limited data storage space. RFID tags have an inbuilt microchip which is attached to a radio antenna that is then surrounded by some form of casing, usually plastic (Fink, Gillett & Grzeskiewicz, 2007). RFID tag uses a unique identifier which associate with the item in which it is attached to. When the system reads these unique tags then information associated with that tag is retrieved and stored in the RFID memory Ahsan (2011). The tag is comprised of a small microchip attached to an antenna and communicates using radio frequency signals with a reader or transceiver (Sharma, 2008). RFID tags contain an integrated circuit for processing information, an antenna for collecting, transmitting and receiving data and a non-volatile memory for storing information received from the tags. The tag memory can either be read-only or re-writable, which depend on the type of tag and its application within the RFID solution. Tags are designed specific to its applications and environment Garfunkel & Rosenberg (2005).

RFID tags can be classified according to a number of characteristics. First, active, passive or semi-passive and they are all powered differently. Second, read-write tags and read-only tags. These tags differ in terms of memory, design, use,cost, range, security, types of data they can record and frequency.

Active tags. An active tag has an inbuilt battery which continuously powers it and its RF communication circuitry. Active tags have the longest read range (100 meters) and are the most expensive due to the battery and transmitter cost (Shain, 2011). Active tags operate on higher frequencies ranging from 850 MHz to 950 MHz or from 2.4 GHz to 2.5 GHz" (Parker, Bishop, & Sylvestre, 2008). RFID active tags can achieve high data and sensor activity rates, but the use of batteries as a source of power is considered disadvantageous for the tag's cost, lifetime, weight, and volume (Sample et al., 2008).

Passive tags. A passive tag operates without a battery or has no internal power supply though it derives its power from the reading unit or reader This lack of power source on a passive tag makes it smaller in size and cheaper than active tags but have limited capabilities (McCullagh, 2003; Bouet & Aldri, 2008). Relying on external sources of power makes passive tags "significantly less expensive than active tags, but this limits their reading range and makes them not be considered exactly real time. Their level of reading accuracy is more in the 20-foot range, making them most appropriate for outdoor, yard management use" (Specter, 2009). Passive tags operate on frequencies of 30 KHz to 500 KHz (Parker, Bishop, & Sylvestre, 2008). Because passive tags have no battery, they are smaller and lighter in weight than the active tags.The read range is limited by the transmitted power density necessary to achieve sufficient voltage for the chip to activate.

Semi-passive tags. Semi-passive tags use battery but communicates by drawing power from the reader (RFID Journal, 2003). This allows the tag to respond to the reader from a slightly longer distance (Koelsch, 2007). Semi-active tags remain inactive until they are energized by a signal from the reader. This results in conserving their battery life (Parker, Bishop, & Sylvestre, 2008).

Read-write vs. read-only tags. "Tags can be read-only (stored data can be read but not changed), read/write (stored data can be altered or re-written), or a combination, in which some data (such as the serial number identification) is permanently stored while other memory is left accessible for later encoding or updates" (Sandoval-Reyes & Soberanes Perez, 2005). RFID readers can store, read, modify, and erase data stored in read-write tags. The stored data can be overwritten and re-used. "These are more expensive than the read-only tags that can only be used for the one product that the original information is written for" (Hingley, Taylor & Ellis, 2007). Read-only passive tags are cheaper than read-write tags and are better-suited for item, case or pallet level tagging of goods.

RFID system is based upon tags and reader's communication and range of communication/reading depends on operating frequency (Bohn, 2008). There are various operating frequency ranges used in RFD which include Low Frequency (LF, 125kHz), High frequency (HF,13.56Hz), Ultra-High Frequency (UHF,433MHz, 860-960MHz) and Microwave (2.45GHz, 5.8GHz). However, these frequency bands do not require a license if the transmitted power is limited (Shain, 2011). The tag performance is dependent on environment, the material in which it is tagged (tagged material) and tag position. The tagged materials can interfere with the tag operation due to detuning the tag, therefore tags designed for metals or moist materials should be considered. There are times when the tag is placed in a position where the RF signal from the reader is unable to power it. Therefore, the tag must be parallel to the surface of the reader antenna (perpendicular to the RF waves) and if linear antenna is in use, the tags dipole has to be in the same plane (RFID Architecture Components, 2016).

RFID Readers

An RFID is a device that produces signals to communicate with RFID tags. "Readers can execute read, write and overwrite commands on each tag over the wireless interface" (Huang & Shieh, 2010). A reader or interrogator is a device that uses the antenna to send and receive radio signals from the tag (RFID Journal, 2015). An RFID reader acts as an interface between the tag and user applications. RFID reader is the central part of the RFID system and communicates with tags and computer program, it sends tags information to a computer program after reading each tags unique identity. It can also perform writing onto tag, if the tag is supported (Sandip, 2005). RFID readers emit radio waves so that all tags in their range can answer by broadcasting their embedded information (Solanas & Castellà-Roca, 2008).

Antennas

Antennas are an important part in the RFID system. They are used to transmit the readers signal and receive signal from the tag. Notably, antennas come in different sizes and shapes. The size of the antenna depends on frequency: when frequency increases, wavelength and antenna size decreases and by increasing antenna size, the read range increases (RFID Architecture Components, 2016). In a water utility, tag antennas are connected to the water meter and data is transmitted from the meters and the RFID readers via radio frequency signals Hawkins & Berthold (2015). In drive-by option, to optimize the performance of the system the antenna should be mounted very high on the roof of the van (Christodoulou et al., 2012).

4.4.2 RFID Architecture

Components of RFID architecture

I. Meter Interface Unit or Data Collection Unit

Meter Interface Units (MIUs) are smart network devices that receive, process, and store meter reading information. RFID based AMR system starts at the meter. Water meters are fitted with small data collection units (DCU), low power radio transmitters or transceivers and an antenna embedded in a transmitter device. These units are also fitted with batteries with a 10 or more years of service. MIU/DCU is used in sending via radio frequency signals utility consumption data from a utility meter to a remote location (Ali, 2002). The tags are attached to water meters where each tag has a unique identification number which is associated with the customer's information. The reader is used to read each specific identification number, record the reading and update the database.

MIUs forward this information to a control center located at the utility. Data collection can be done through the use of handheld units where a meter reader carries a handheld computer with a built-in or attached receiver/transceiver or by "drive-by" metering where a reading device is installed in a vehicle. When applied to a fixed AMR in an apartment, RF frequently utilizes one or more radio repeaters to overcome transmission obstacles (Readdy, 2006). Computers at the utility's control center collects, validates, processes and stores data transmitted by MIUs. It provides billing, customer service, operations, and other utility departments with timely access to comprehensive account information.

I. Communication system

It is used for the transmission of data and control send signals between the Meter Interface Units and the Central office. RFID technology utilizes Radio Frequency signals.

II. Central office systems

Central office equipment includes:

i. Internet/ modem
ii. Central server- the RFID Server will be hosted at the NCWSC premises.

Minimum AMR Server Hardware Specifications

- Pentium IV compatible processor, 1.6 GHz or faster
- 2 GB RAM (4 GB)
- 320 GB available hard disk space
- Monitor with 1024 x 768-pixel resolution
- DVD drive

Minimum Operating systems

  - Windows® 7 Professional 32/64 bit
  - Windows® Server 2008

iii. Software (MDMS) for data acquisition and data analysis

Meter Data Management System (MDMS) is used for generating bills and reports. It is also used for maintenance of meter and customer information. MDMS should maintain the following information in the database in relation to NCWSC company.

- Unique meter number
- Meter readings
- Date and time of reading
- Customer Account Number and Address
- Facility to allow data export in various formats e.g. text, Excel, PDF
- Statistical analysis for reporting facility
- Search facility
- Ability to create groups for meters with similar characteristics
- Ability to remotely read and collect data for individual customers or group of customers

The MDMS should have facility to create automatic reading jobs with programmable frequency of reading in

i. Minutes
ii. Hourly
iii. Daily
iv. Weekly
v. Monthly
vi. Yearly

The MDMS should be scalable with capacity to support more than 20,000 metering points. It should also be able to support automatic reading (fixed AMR) and semi-automatic (walk-by and drive-by system). Table 4.5 shows the functions of MDMS when used as a billing system.

Table 4.5: *MDMS Functionality as a Billing System*

a. Supporting Interface database and application	The software should be able to provide an interface based on commonly used data exchange formats such as DOC, XML,XLS, API, PDF, CSV
b. Web Interface	The application to be web-enabled
c. Security/User Accounts	Ability to create, amend and remove users to the system. Users to be allocated user level authentication and profiles
d. Audit Trail	System to maintain an audit trail according to user activity
e. TCP/IP connectivity to any relational database.	Interface to be able to connect to any relational database
f. Interface to any relational database.	Ability to create an XML Web service to interface the AMR system with any relational database. The web service should capture the following data elements as a minimum: i. Account number ii. Meter Number iii. Spatial data iv. Customer Name v. Date, time (of reading) vi. Consumption volume
g. Upload of consumption data to any relational database.	The interface should have ability to: i. Define billing date ii. Upload both the monthly reading and the calculated consumption volume in cubic meters (m^3) on the pre-defined date to the billing system iii. This process should allow data interrogation to eliminate duplicates with exception reports on unsuccessful uploads.

h. Management Reporting	Ability to provide the following: i. Monitoring reports ii. Exception reports a. Identifying customers with tampered meters b. Identifying and locating physical losses caused by meter tamping or equipment problems. c. Checking for negative consumption to identify meters with potential theft. d. Identifying customer meters that have consumption on inactive accounts, and meters with zero readings on active accounts where consumption is expected iii. Report viewer with a. Graphical representation b. Management Reports c. Creation of ad-hoc reports as needed by NCWSC

CHAPTER FIVE

DISCUSSION, SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter the conclusions derived from the findings of this study on development of an RFID architecture for the adoption by utility companies are discussed. The conclusions were based on the purpose, research questions and the results of the study. The implications of these finding and the resultant recommendations were also discussed. In addition, recommendations for further research were also discussed.

This research sought to develop an RFID based architecture for the automation of meter reading, billing services, and for leak or burst detection in the water distribution system for utility companies. The following were the objectives of the study:

i. To identify a viable Radio Frequency identification technology to enhance billing accuracy with streamlined meter reading and for leak detection;
ii. To establish and assess the effects of RFID technologies in a water-based company;
iii. To develop an RFID technology architecture for water based utility company.

5.2 Discussion

5.2.1 Identification of a Viable RFID Technology

Here the first research question (what are the considerations when choosing of a viable Radio frequency identification technology that can be used in utility companies?) was answered.

By selecting the right meter reading method, utilities can reduce non-revenue water, increase revenue, improve customer service, conserve water resources and increase operational efficiency Moghavvemi et al., (2005). The findings indicated that NCWSC lost 40% of the water it produced due to poor quality and aging underground pipes, ineffective maintenance operations, lack of leakage control programs, customer meter under-registration and data handling or billing errors. The study also found that the loss of water at NCWSC could be handled by improving infrastructure, applying leakage management systems, deploying effective billing systems and applying advanced monitoring and maintenance systems. RFID technology provides rapid solutions to these challenges. The technology offers the utility company the capability to track unaccounted-for water, leaks and vandalism/theft enabling them to respond to the situation quickly and limit extreme of water loss or significant theft.

According to the findings, aging underground pipes cause water loss in NCWSC. This is in-line with Wang et al. (2013) who indicated that most utility company water pipelines are outdated. Leakages in the pipelines cause major financial losses and possible environmental damages. Water leakages are noticed when water flows out of the ground due to huge leaks in pipes. A utility might have a few crews driving around the system in correlator trucks to listen for leaks, and if they find something, they dig it up. But it can take several years to cover an entire distribution system. And, in many cases, by the time a leak is discovered, it could have been leaking for years.

Recent advancements in meter data management have transformed the vast spreadsheets and tedious data-mining activities of just a few years ago into push-button reports, allowing a water utility to find evidence of leaks before they hit the surface sometimes years before. It can prevent a small leak from becoming a big leak, or worse, a water main break. With an RFID system the whole distribution network can be continuously monitored by hourly interval reads. RFID system using low power RFID tags are attached to water pipes (underground) therefore assisting the utility personnel in identifying any breaks or leaks in the pipes from long distances using powerful RFID readers by monitoring pressure of fluid flowing in pipes. The reader receives and process the signal. After receiving and processing the signal, the readers communicate with the central database. The central database processes the signal received and allows an easy and repeatable identification of leakage if it happens (Trinchero et al., 2009).

The RFID tags use batteries hence the power consumption should be considered. In order to minimize the power consumption, reducing the transmitting power and implementing a sleep mode is advisable. Due to the huge attenuation caused by environment under which pipes are buried, Lin et al., (2008) suggests transmitting the data from below to above ground using an underground to above ground radio propagation. The radio propagation model include parameters such as the operating range, the RFID tag transmitting power and receiver sensitivity. The propagation model suggest the use of 2.4 GHz signal and an operating range of (73 m to 100 m).

The findings indicate that ineffective maintenance operations cause water loss in NCWSC. Water systems are typically underground, making it difficult for the utility company to know the condition of its distribution system. But if a water utility has insight into how different parts of its distribution system are performing, such as RFID based AMR can provide, it can better focus its attention on the pipes in most need of repair. This helps the utility better allocate resources by extending the life of capital assets. This is supported by Felemban and Sheikh (2013) who indicated that RFID systems can be used to enhance operational effectiveness and efficiency in utility company. In this system, all the pipes are labelled with RFID tags (with an operating range of 73 meter to 100 meters) and the information is stored in the utility's database. All the maintenance logs for the equipment's are stored in the utility database. When they are brought to the utility workshop for maintenance, it's history is retrieved using the database and its RFID tag.

When selecting a meter reading method, there are several factors that need to be considered; type of meter (size, application, and expected flow rates), meter installation (pits, basements), the geographical area (open or hilly places), density of meter location and other e.g. buildings or whether the WSP is checking consumer consumption patterns in specific areas for example observing the consumption of high water consumers on a more frequent basis (Christodoulou et al., 2012). Type and proper sizing of the water meter is vital for water conservation and revenue generation for the water industry.

Residential homes use small to medium size meter while industries use bulk meters. The following are the specifications of the recording device for bulk and small to medium size consumer meters respectively as shown in Table 5.1 and 5.2 below.

Table 5.1: *Recording Device for Bulk Consumer Meters*

Sensor Technology	
a) Measuring Principle	A battery operated non-intrusive meter with no moving parts thus resistant to solids and debris in the water supply.
b) Power Supply	Battery operated for the sensor and calculator with battery life of minimum 10 years to ensure recording at all times even in absence of mains power
c) Protection Class	IP68-rated (waterproof/submersible) designed for indoor and outdoor operation

Metrological Data	
d) Approvals and certifications	The meter should be type approved and verified according to international water meter standard ISO 4064, OIML R49 and MI-001 MID (Measuring Instrument Directive)
e) Accuracy	+/-2% or better over typical operating range and temperatures.
f) Calibration	3-Point calibration with calibration data stored in each unit and certificate available for each unit
Mechanical Data	
g) Material	Stainless Steel housing
h) Pressure Rating	Working pressure ≥ 10 bars
i) Environmental Temperature	O °C to 50 °C
j) Lockable Cabinet	Weather proof mountable cabinet for the electronics and should not cause obstruction to the RF signal
Features	
k) Data Protection and Tamper Proof	The meter should be tamper proof with suitable data protection of calibration and revenue parameters.
l) Advanced self-diagnostics for error detection.	The meter should have advanced diagnostics with active alarm indicated on display.
m) Access to information	Display with ≥ 8 digits for main information. Index, menu and status symbols for dedicated information
n) Flow Unit	Volume in M^3 and flow rate in M^3/h
Communication Interface	
o) Remote Communication interface	The electronic meter to be RF enabled and configured to work with common AMR systems using suitable RF module
p) Power Supply	Power supply to RF module to be Internal 230 VAC or 24 VAC. The supply mounted in the meter together with the module to support periodic readings of the meter.

Table 5.2: *Recording Device for Mmall to Medium Size Consumer Meters*

ITEM	SPECIFICATION
a) Measuring Principle	A battery operated composite non-intrusive ultrasonic flow meter with no moving parts with integral data communication for RF.
b) Battery Lifetime	Battery operated for the sensor and calculator with battery life of minimum 10 years to

	ensure recording at all times even in absence of mains power
c) Protection Class	IP68
Metrological Data	
d) Approvals and certifications	The meter should be type approved and verified according to international water meter standard ISO 4064, OIML R49 and MI-001 MID (Measuring Instrument Directive)
e) Accuracy	+/-2% or better
f) Calibration	3-Point calibration with calibration certificate available for each unit
Mechanical Data	
g) Material	The water meter body should be made of corrosion resistant material like brass or bronze or composite plastic
h) Pressure Rating	Working pressure ≥ 10 bars
i) Environmental Temperature	O ^{o}C to 50 ^{o}C
Features	
j) Data Protection and Tamper Proof	The meter should be tamper proof with suitable data protection of calibration and revenue parameters.
k) Advanced self-diagnostics for error detection.	The meter should have advanced diagnostics with active alarm indicated on display e.g. leak, dry
l) Access to information	Display with 7 digits for main information.
m) Flow Unit	Volume in m^3 and flow rate in m^3/h
Communication Interface	
n) Remote Communication interface	The meter should be equipped with remote reading via license-free radio frequency
o) Remote Reading Terminal	The water meter should have remote reading terminal via walk-by or drive-by via RF
p) Monthly Volume Storage	The meter should be able to store the meter reading on the first day of the month. At time of remote reading both the stored monthly data volume and the current meter reading volume should be read.

There are different driving forces towards the adoption of an economically viable technology. The reason for the system change over include; meeting requirements resulting from a law or mandate, to improve conservation, customer satisfaction, and or to increase revenue (Chelsea & Allen, 2015).

5.2.2 Effects of RFID Technology to the Customers and WSP

Here, the second research question (What effects do RFID technology have in a water based company (to both Water Service Providers and to the customers)? was answered.

The research findings indicate that adoption of Radio Frequency identification technology in Nairobi City Water and Sewerage Company would have significant effects on consumers in that; the consumers would receive actual water consumption readings from the company, the RFID technology would enable more timely, accurate and granular data consumption to resolve customer billing issues/disputes, there would be improved accountability on water consumption and finally customers would receive bills on time. The study also found that the adoption AMR using RFID technology at NCWSC would improve customer relations due to available and clear information given to the consumer, the improved system would enhance equitable supply of water to all the customers and it would enhance billing accuracy due to streamlined meter reading and bill generation.

There study found that the adoption of RFID technology would result in staff safety and security, there would be improved water theft detection and location pin pointing, fewer on-site visits would be required therefore reducing operational costs, the technology would help in early leak detection leading to reduction of potential damage and water waste while saving money and improving conservation and there would be increased data, enhancing staff planning and optimizing water distribution with the adoption of RFID technology.

These findings agree with Thomas (2018) and, (Britton et al., 2013), that with the recognition of the benefits of the traditional meter reading and the perceived opportunities presented by the evolving technology, water companies are progressively turning towards the adoption of advanced metering using RFID technology and more advanced meter data management systems as a way of reducing water losses through improved leak detection, reducing operational costs, conserving water, improving reliability, enhancing customer satisfaction and billing accuracy.

5.2.3 Radio Frequency Architecture in a Water-based Company

Ozturk (2002) asserted that adopting and implementing an innovative technology is a mechanism for organizations to achieve competitive advantage. NCWSC however, is yet to realize the full potential an improved technology. The studies highlighted in the literature review have shown that in the recognition of the benefits of the traditional meter reading and the perceived opportunities presented by the evolving technology, water companies are progressively turning towards the adoption of RFID technology.

The RFID system consists of: a tag, a reader, antenna, utility enterprise software and infrastructure for processing information. RFID uses RF to transmit readings to the utility central repository. RFID is not monolithic, it used in the conjunction of other applications. RFID based AMR aims to eliminate manual meter reading of water meters in which meter readers visits every meter depending on the billing cycle manually. RFID based AMR is a method in which meter readings (consumption data) are collected automatically from a customer meter. This data is used for billing purposes; to analyse usage and manage consumption, and to identify or resolve technical problems. RFID based AMR is composed of MIU/DCU, Central office system and a communication medium.

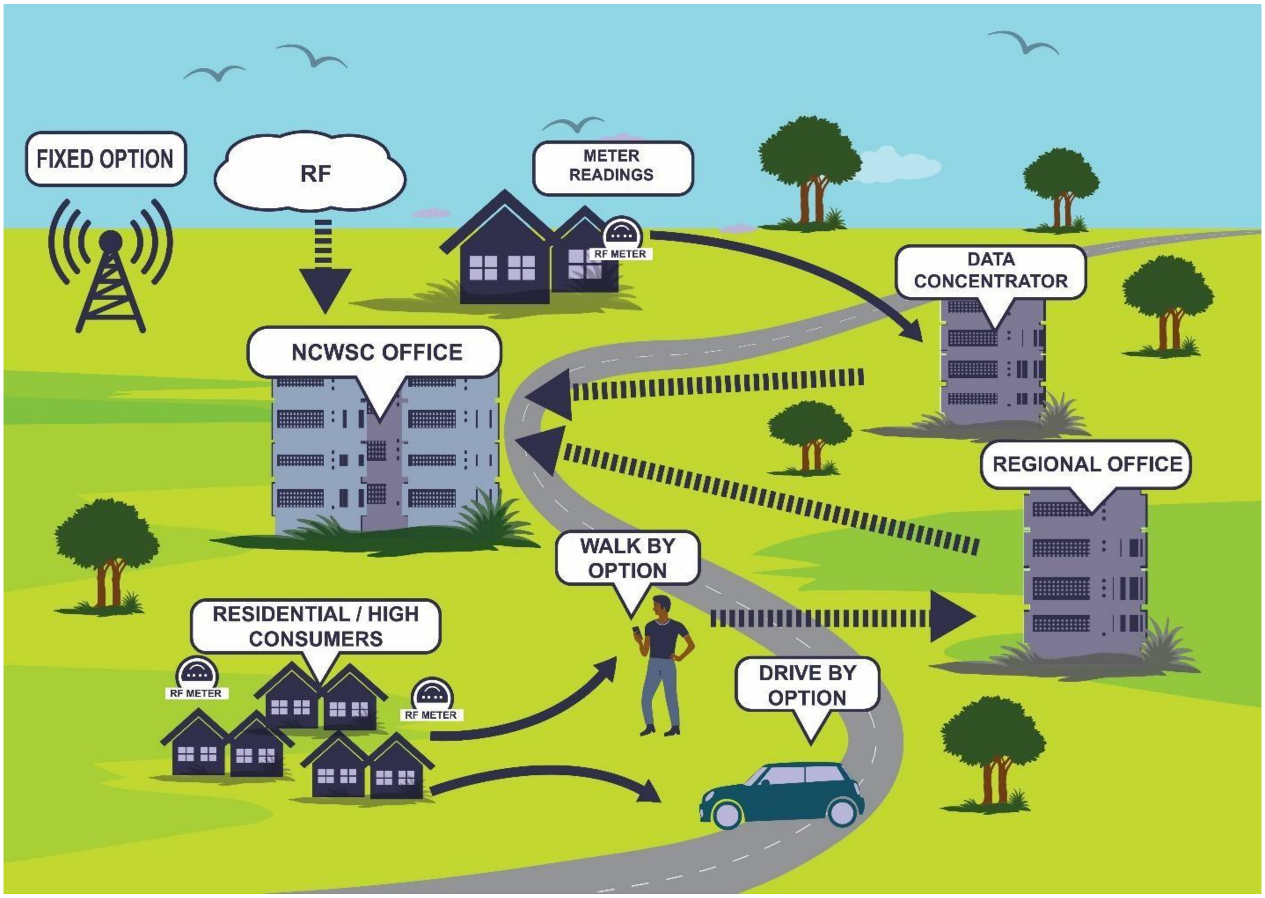

Figure 5.1: *Diagram*: Proposed RFID Architecture

5.2.3.1 Implementation Strategy

Pilot project

The overall aim of this study was to develop a RFID architecture as solution that influences utility companies' overall performance more specifically a water company. In this regard the pilot project will target medium level consumers and one bulk consumer. The project will involve installation of flow meters with remote capability via RF to explore the viability of the AMR solution to NCWSC. The meters to be deployed will be:

- Ten (10) DN15(1/2 inches) electronic flow meters with drive-by remote reading via RF for small to medium consumers. Five (5) meters will be installed in Central Region and another five (5) in the North Eastern region.
- One (1) DN80 (3 inches) flow meter with remote reading via RF for bulk consumer will be installed in Central region.

Pilot location

The selection of the specific consumers to be targeted will be done in two regions namely Central and North-Eastern. The format of details is shown in Table 5.3 below

Table 5.3: *Pilot Details*

No	Account Number	Customer Name	Existing Meter Number	RFID Meter Number	Model	Flow Rate	Nominal Diameter (DN)	Installation Date

Installation and Implementation Steps

Steps

The project will be undertaken using the following steps – each of which is important as part of the installation process and as well a learning tool.

1. Site Survey – this is a critical step so as to:

    a. Determine or estimate the flow rate of the site in order to size the meter accurately.
    b. Identify all the components required for the installation including necessary civil and mechanical works e.g. pipe cutting, building of chambers, flange adaptors, liners etc.

2. Cutting the water supply

3. Installation and configuration on the RFID based AMR system of the new meter on the pipe in series with the existing mechanical meter this includes both medium and bulk consumer meters. For big size meters this may require heavy lifting equipment.

4. Mount the cabinet with electronics. In this case, drilling equipment's will be required.

5. Provide power to the cabinet with electronics. This would need mains supply to be extended to where the meter is installed.

6. Installation of the remote reading communication system. This will entail;

    a) Installing the software in a mobile laptop

b) Testing the remote reading to identify range of reading

4. Collection of the meter reading data remotely from the new flow meters using the RF reader to determine among others:

a) Workability: Deploy the two solute ions namely drive-by and fixed meter reading and practically test how each works.
b) Speed of reading for the drive-by: Determine how fast a meter reader is able to collect the readings for all the meters installed within a certain distributed vicinity using this method and compare with manual reading.
c) Drive-by meter reading range: Determine the range of the wireless m-bus reader and effects of other environmental conditions e.g. communication masts, in-door installations etc.
d) Fixed meter reading signal strength: Test and determine acceptable signal strength for this method as some meters may be installed in man-holes where the signal may be weakened. Take corrective measures to improve strength e.g. use of an external aerial
e) Document the observations recorded.

5. Collecting regular readings manually from the mechanical meters to compare with the readings from the new meters so as to determine:

a) The accuracy of the existing mechanical meters versus the electronic or digital meter.
b) If there is substantial loss attributable to under recording from the existing mechanical meters.

5.3 Summary of Findings

The findings show that majority of the respondents were aware that NCWSC lost 40% of the water it produced due to poor quality and aging underground pipes, ineffective maintenance operations and lack of leakage control programs. The study also found that the loss of water at NCWSC could be handled by improving infrastructure, applying leakage management systems, deploying effective billing systems and applying advanced monitoring and maintenance systems. Loss of water at NCWSC resulted to inadequate water supply to the customers, expensive water bills due to increased water tariff and customers being supplied with dirty water from taps.

Respondents agreed with statements on effects of adoption of Radio Frequency identification technology in Nairobi City Water and Sewerage Company on consumers in that; the consumers would receive actual water consumption readings from the company, the AMR using RFID technology would enable more timely, accurate and granular data to resolve customer billing issues/disputes, there would be improved accountability on water consumption with the adoption of RFID technology at NCWSC, bills would be received on time, adoption of AMR using RFID at NCWSC would increase revenue from previously unaccounted-for water usage through improved technology, the technology would enhance billing accuracy due to streamlined meter reading and bill generation and it would improve the meter-to-bill process for the purpose of revenue enhancement.

The study also found that respondents agreed with statements on effects of adoption of Radio Frequency identification technology in Nairobi City Water and Sewerage Company on employees to a great extent in that; the adoption AMR using RFID technology at NCWSC would improve customer relations due to available and clear information given to the consumer, the improved system would enhance equitable supply of water to all the customers, the deployment of AMR using RFID technology would result in staff safety and security, there would be improved water theft detection and location pin pointing with the adoption of AMR through RFID technology, with the deployment of an improved system, fewer on-site visits would be required therefore reducing operational costs, the technology would help in early leak detection leading to reduction of potential damage and water waste while saving money and improving conservation and there would be increased data enhancing staff planning and optimizing water distribution with the adoption of RFID technology.

Customer Management System (CMS) was used compared to MFA and indicated that the two systems were poor. Respondents also indicated that they faced challenges of reading incorrect figures, complains of high bills from consumers, insecurity in some areas, transport challenges and bad weather when meter reading, poor net work, current reading being too low or too high from the previous readings, inaccessible meters, and finally lack of system integration.

5.4 Conclusions

Water metering is very important in today’s water utilities. Accurate measurement of all water usage, obtaining correct bills, monitoring leakages, bursts and other anomalies is a challenging task which requires advanced technologies. Radio Frequency IDentification (RFID) is one such technology which provides robust solutions to these challenges. It is perceived that RFID is very important for resource optimization, increasing efficiency, enhancing improved service delivery and making organizational staff overall experience better.

In this study, an RFID-Automatic Meter Reading (AMR) based architecture is presented. The system is based on fitting water meters with small Data Collection Units (DCUs) or Meter Interface Unit (MUI) and low power radio transmitters or transceivers. These units are also fitted with batteries with a 10 or more years of service. The readings are collected remotely either by handheld (walk-by), mobile (drive-by) receivers and computers and transmitted to the central office via radio waves. In a fixed AMR, Radio Frequency (RF) frequently utilizes one or more radio repeaters to overcome transmission obstacles. The Meter Data Management Software (MDMS) takes data from the communication network and transforms it into actionable information. Findings show that, to optimize the performance of drive-by meter reading system, the antenna should be mounted very high on the roof of the vehicle.

There are numerous benefits of adopting of RFID-AMR based technology in the water utilities. These includes; allows customers to have better control of their water consumption, costs and bills, leak detection, identification of malfunctioned meters, timely identification of tampers or theft, tracking down unaccounted-for water, improve staff security, enhance equitable water supply, increase revenue, reduce operational costs, ensures accurate meter readings, and enables timely bills.

In conclusion, since RFID-AMR equipment are installed and used in unfavorable weather conditions, such as very humid and are exposed to other external conditions, it is important that such meters with all the units be robust and have at least an IP 68 rating. Additionally, since the equipment are installed in areas uncontrollably accessed by the public who may have destructive tendencies. The installation in these cases should be done inside covered concrete chambers (they should be able to transmit from there). Some of the equipment that will be installed in the open, should have a rigid nondestructive housing to operate from.

5.5 Recommendations

The study recommends the following; that Nairobi City Water and Sewerage Company (NCWSC) should liaise with the Water Services Regulatory Board (WASREB) so that they can put in place strategies on how to revamp their old and dilapidated infrastructure, which in return would increase revenue and reduce non-revenue water. Furhermore, the company in the recognition of global changes in regards to technology, should adopt and implement an innovative information systems to enhance efficiency and effectiveness in their operations.

5.6 Areas for Further Research

Since Information Communication and Technology (ICT) is dynamic and exhibits new challenges and opportunities, it will be imperative to repeat this study after a few years and establish the situation as around then. This study should be compared with findings from other counties as the study concentrated on Nairobi County in order to establish the similarities and differences that may be evident. This will assist the ICT sector to benchmark with other sectors. Other research tools should also be used like interview guides as well as focus group discussion in order to compare results.

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APPENDICES

Appendix 1- ANU Research Authorization Letter

AFRICA NAZARENE
UNIVERSITY

Our Ref: ANU/CIT/MSCIT/2018 February 26, 2018

National Commission for Science, Technology and Innovation (NACOSTI)
Utalii House, Off Uhuru Highway
P.O Box 30623,00100 GPO
NAIROBI

Dear Sir/Madam,

RE: LICENSING OF RESEARCH FOR DORCAS N. KURIA - REG NUMBER: 17J03EMIT007

The above named is a bone fide student pursuing a Master of Applied Information Technology in the School of Science and Technology, Computer Information Technology department, Africa Nazarene University. As part of the course, students are required to undertake a research project. The student is currently carrying out her research project entitled: "**ADOPTION OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGY IN UTILITY COMPANIES: A CASE STUDY OF NAIROBI CITY WATER AND SEWERAGE COMPANY".**

We would be grateful if you could assist her obtain a license to conduct the research.

In case of any queries about the exercise feel free to contact me via email on agichamba@anu.ac.ke.

Yours Sincerely,

AFRICA NAZARENE UNIVERSITY
CHAIRMAN
SIGN:
COMPUTER SCIENCE
P.O. Box 53067, NAIROBI

Dr.Amos Gichamba
Head of Department, Computer and Information Technology
Africa Nazarene University

P.O Box 53067 - 00200 Nairobi, Kenya • Tel: 020 252 71701 - 5 • Fax: 020 201 2253 • Cell: 0733 574 111 • Email: [illegible] • www.anu.ac.ke

Appendix 2- Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref No. **NACOSTI/P/18/11306/21771**

Date: **20th March, 2018**

Kuria Dorcas Njuhi
Africa Nazarene University
P.O. Box 53067-00200
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Adoption of radio frequency identification technology in utility companies: A case study of Nairobi City Water and Sewerage Company,"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **20th March, 2019.**

You are advised to report to **the Managing Director, Nairobi City Water and Sewerage Company, the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The Managing Director
Nairobi City Water and Sewerage Company.

The County Commissioner
Nairobi County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix 3- Research Clearance Permit

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 17985

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MISS. KURIA DORCAS NJUHI
of AFRICA NAZARENE UNIVERSITY, 1109-1000 THIKA,has been permitted to conduct research in *Nairobi County*

on the topic: *ADOPTION OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGY IN UTILITY COMPANIES: A CASE STUDY OF NAIROBI CITY WATER AND SEWERAGE COMPANY.*

for the period ending:
20th March,2019

....
Applicant's Signature

Permit No : NACOSTI/P/18/11306/21771
Date Of Issue : 20th March,2018
Fee Recieved :Ksh 1000

....
Director General
National Commission for Science, Technology & Innovation

Appendix 4- Nairobi City Water and Sewerage Company Authorization Letter

NAIROBI WATER

NAIROBI CITY WATER & SEWERAGE COMPANY LTD.
KAMPALA RD, P. O. Box 30656-00100, Nairobi, Kenya
Tel: +254 0703 080 000
Email: info@nairobiwater.co.ke
www.nairobiwater.co.ke

NCWSC/HRD/VOL.I/714/MNT/mkm

5 April 2018

Dorcas Kuria
P. O. Box 1109
THIKA

Dear Dorcas,

RE: AUTHORITY TO COLLECT DATA ON RADIO FREQUENCY IDENTIFICATION TECHNOLOGY IN WATER UTILITIES

Reference is made to your letter dated 2018 on the above mentioned subject.

Approval is hereby granted for you to conduct research on Adoption of radio frequency identification technology in utility Companies a case study of Nairobi City Water and Sewerage Company Limited. All findings/information on Company matters should be accorded utmost confidentiality. By a copy of this letter, the Research and Development Manager and the Training and Change Management Coordinator are requested to give all the necessary support.

Kindly submit a report of your research upon completion to the office of the undersigned.

Monica Tuli
Ag. Director Human Resource and Administrative Services

Appendix 5- Questionnaire

DEVELOPMENT OF RADIO FREQUENCY IDENTIFICATION ARCHITECTURE FOR THE ADOPTION BY UTILITY COMPANIES: A CASE STUDY OF NAIROBI CITY WATER AND SEWERAGE COMPANY

My name is Dorcas Kuria a student at African Nazarene University school of Computer Studies carrying out a research on adoption of radio frequency identification at Nairobi City Water and Sewerage Company.

Please take a few minutes of your time to complete this questionnaire. Your involvement in this research will be appreciated and you are requested to answer the questions with honesty. The responses given will be confidential and will not be linked with any account and shall be used for this study only.

Please answer all the questions by either filling in the blank spaces or ticking an option where applicable.

SECTION 2A: DEMOGRAPHICS

1. **In which Nairobi City Water and Sewerage Company region do you belong to?**

a) Central ☐
b) Eastern ☐
c) Western ☐
d) Northern ☐
e) Southern ☐
f) North-Eastern ☐

2. **In which Nairobi City Water and Sewerage Company directorate do you belong to?**

a) ICT ☐
b) Legal ☐
c) Finance ☐
d) Technical ☐
e) Commercial ☐
f) Risk and Audit ☐
g) Managing Director ☐
h) Human Resource and Administration ☐

3. **Kindly indicate your gender**

Male ☐

Female ☐

4. **What is your age bracket?**

Below 30 years ☐

31-40 years ☐

41-50 years ☐

Above 50 years ☐

5. **How long have you worked at Nairobi City Water and Sewerage Company?**

Mark one only

a. Less than 1 year ☐
b. 1-5 years ☐
c. 5-10 years ☐
d. Above 10 years ☐

SECTION 2B

6. **Do you know that NCWSC loses 40% of the water it produces?**

☐ Yes

☐ No (*skip to 9*)

7. **What do you think is the cause of [5] above?**

a. Poor quality or aging underground pipes ☐
b. Lack of leakage control programs ☐
c. Ineffective maintenance operations ☐
d. Customer meter under-registration ☐
e. Data handling or billing errors ☐
f. Others (specify)…………………………………………………………………….

____

8. How do you think the issue in [5] above should be addressed by the company?

a) Improve infrastructure ☐

b) Applying leakage management system ☐

c) Deploying an effective billing system ☐

d) Applying an advanced monitoring and maintenance system ☐

e) Others (specify)……………………………………………………………………

9. How do you think the loss of water affects NCWSC customers?

a. Inadequate water supply ☐

b. Makes water expensive due to increased water tariff ☐

c. Leads to dirty water from taps ☐

d. Others (specify)……………………………………………………………………

10. Which of the following NCWSC systems do you use?

a. Customer Management System (CMS) ☐

b. Mobile Field Assistant (MFA) ☐

11. How effective are the above systems?

☐ Excellent

☐ Good

☐ Fair

☐ Poor

12. What challenges do you encounter when using MFA?

………………………………………………………………………………………………

………………………………………………………………………………………………

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13. What challenges do you encounter when using CMS?

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………………………………………………………………………………………………

SECTION 2C: EFFECTS OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGY

Radio Frequency IDentification technology is used for collecting consumption, diagnostic, and status data from water meters and transferring that data to a central database for billing, troubleshooting, and analyzing. This technology can also be used to optimize existing processes, improve reliability, more broadly, increase productivity in a water based company.

1. To what extent do you agree with the following statements on effects of Radio Frequency IDentification (RFID) technology to consumers?

Use the scale 1 to 5. Where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Neutral (N), 4 = Agree (A) and 5 = Strongly Agree (SA).

Mark one for each activity

Statements of effects of Radio Frequency IDentification (RFID) technology on consumers	SD 1	D 2	N 3	A 4	SA 5
The consumers will receive actual water consumption readings from the company	○	○	○	○	○
With the adoption of RFID technology, the customers will receive bills on time	○	○	○	○	○
The RFID technology will enable more timely, accurate and granular data to resolve customer billing issues/disputes	○	○	○	○	○
The RFID technology will enhance billing accuracy due to streamlined meter reading and bill generation	○	○	○	○	○
The adoption of RFID technology at NCWSC will improve customer relations due to available and clear information given to the consumer	○	○	○	○	○
The improved system will enhance equitable supply of water to all the customers	○	○	○	○	○
There will be improved accountability on water consumption with the adoption of RFID technology at NCWSC	○	○	○	○	○

2. **To what extent do you agree with the following statements on effects of Radio Frequency Identification (RFID) technology to Nairobi City Water and Sewerage Company (NCWSC)?**

Use the scale 1 to 5. Where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Neutral (N), 4 = Agree (A) and 5 = Strongly Agree (SA).

Mark one for each activity

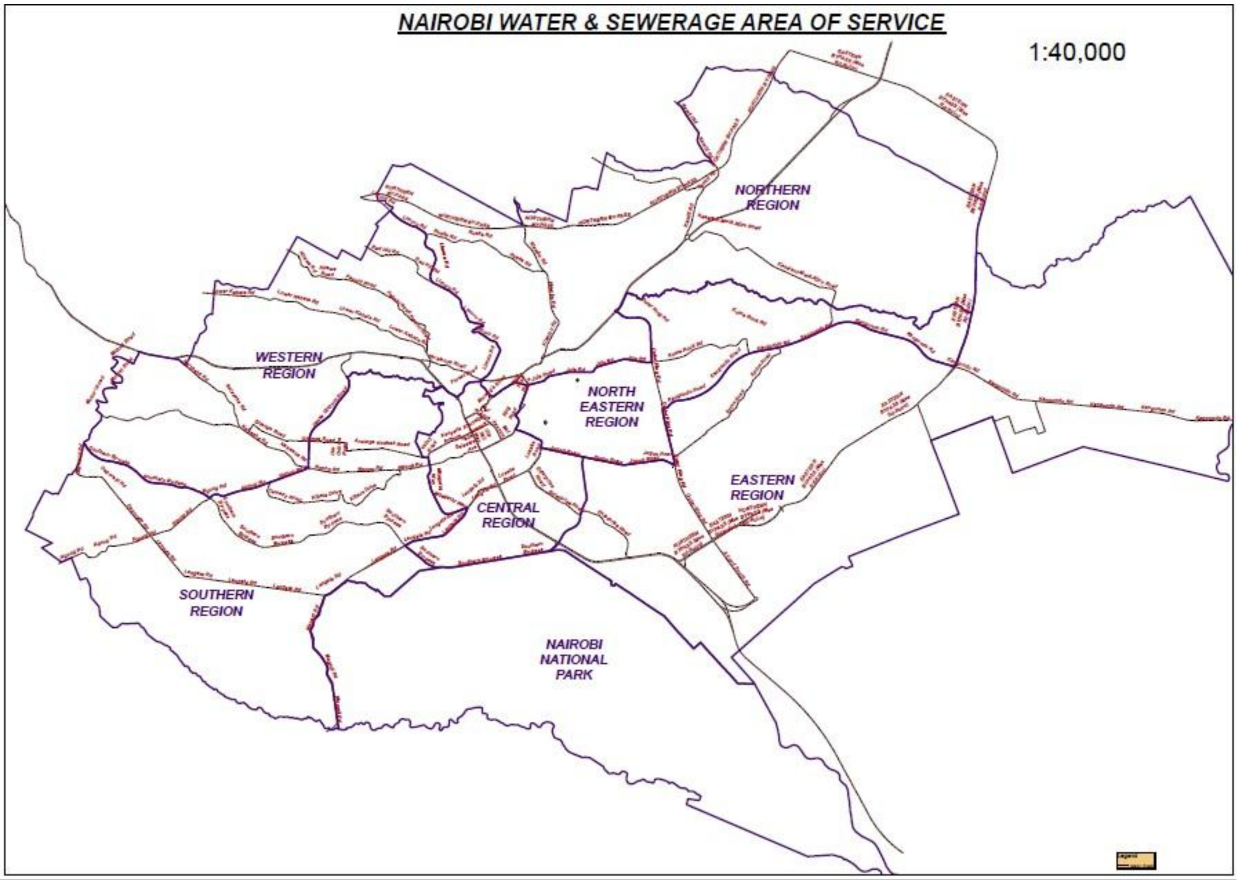
Statements of effects of Radio Frequency IDentification (RFID) technology on to NCWSC	**SD 1**	**D 2**	**N 3**	**A 4**	**SA 5**
Adoption of RFID at NCWSC will increase revenue from previously unaccounted-for water usage through an improved technology	○	○	○	○	○
The deployment of RFID technology will result in staff safety and security	○	○	○	○	○
With the deployment of RFID systems, fewer on-site visits will be required therefore reducing operational costs	○	○	○	○	○
There will be improved water theft detection and location pin pointing with the adoption of RFID technology	○	○	○	○	○
There will be increased data enhancing staff planning and optimizing water distribution with the adoption of RFID technology	○	○	○	○	○
The RFID technology will help in early leak detection leading to reduction of potential damage and water waste while saving money and improving conservation	○	○	○	○	○
The adoption of RFID will improve the meter-to-bill process for the purpose of revenue enhancement	○	○	○	○	○

THANK YOU FOR TAKING YOUR TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix 6- Responses from Open Ended Questions

Type of system	**Challenges encountered**
Mobile Field Assistant (MFA)	Estimates due to inaccessible, gate-locked, misty or malfunctioned meters The system does not allow cancel-and-rebills Does not allow investigation of unusual consumptions or billing Does not enhance leak detection and does not identify malfunctioning meters Does not allow identification of tampering or water theft Poor network, hostility from customers affect the meter reading process Information on the ground being different from that in the system
Customer Management System (CMS)	Frequent downtime of Wide Area Network affecting the billing process Frequent downtime of CMS Fewer or more current reading than the previously read meter readings Lack of system integration with MFA

Appendix 7- Map of Nairobi City Water and Sewerage Company Administrative Regions



Appendix 8- Project Work Plan

Month / Activity	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Dec	Jan	Aug
Project title selection												
Proposal preparation												
Development of research tool												
Proposal Presentation												
Pilot study												
Validation of research tool												
Data collection												
Data entry, analysis and interpretation												
Project findings report												
Finalize research project												
Project presentation and corrections												
Submit research project												