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Innovative water metering to improve provision of water services in peri-urban areas: A comparison of the Delegated Management Model and the Communal Prepaid Meter

BY

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A thesis submitted in fulfillment for the Degree of Doctor of Philosophy in Environmental Engineering, in the Department of Environmental and Biosystems of the University of Nairobi

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Declaration

I, Robert T. Hanjahanja, hereby declare that this thesis is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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This thesis has been submitted for examination with our approval as university supervisors.

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Dedication

I dedicate this thesis to my wife and best friend, Mphatso Hanjahanja.

She has been my friend for 28 years and my wife for 24 years. Without her stamina, support, love for Jesus and encouragement, I probably would never have done this research.
I also dedidate this to my late brother, Eric Chintokoma Hanjahanja, an ardent economist and servant of Malawi. His passion for the underprivileged was unwavering and inspiring to the very end of his brief but well lived life.

I also dedicate this to the precious urban poor and underprivileged people of Malawi.

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The numbers of people to be acknowledged is way too long and if you are not acknowledged here please bear with me, but I must mention Dr. Wisdom Changadeya, Dr. Gracious Gadama and Professor Elijah Biamah for the poignant support and guidance when it mattered most. In short, I am thankful for friends innumerable who have been supportive through this endearing process.

Abstract

Water utilities are continually finding it challenging to provide decent water services to peri-urban areas. Utilities need to deal with these challenges, and one way is to innovate in order to help contribute towards achieving Sustainable Development Goal # 6, universal access to safe drinking water for all by 2030. The objective in conducting this study was to assess the suitability of communal prepaid metering (CPM); and the delegated management model (DMM) in water service provision. In the CPM, which was installed in Nakuru, the customers interact with the meters through tokens which they use to purchase credit prior to consumption. In Kisumu where the DMM was applied, a master meter registers and monitors flow into a pre-defined area. As per the study design, each of the two towns were differentiated in that the sites without either the DMM or CPM were served by conventional postpaid meters. Samples were collected randomly in each of the study areas. Standard performance indicators were used to evaluate the performance of the CPM and the DMM against provided thresholds, and the data was collected through prevalent literature, existing service provider data, field visits and interviews. Results showed that CPM and DMM improved service delivery in comparison to conventional metering. CPM led to improving the performance of the following parameters by 70%, the cost of water and the time taken to fetch water. DMM led to improving the performance of the following parameters by 90% that is non-revenue water and coverage. It was concluded that the two metering technologies were found to improve the provision of water services among peri-urban areas in Kisumu and Nakuru. The study found that CPM impacted positively on coverage, water borne diseases, time to fetch water and potable water while DMM positively impacted on customer service, cost of water and non-revenue water. It was concluded that the DMM is suitable for Water Service Providers focused on commercialization and profitability while the CPM is suitable for utilities with customer service orientation. It is recommended that the two models used in this study be used as innovative technologies to assist water utilities in water provision in peri-urban areas, and that in order for more individual strengths to me identified, they be cross tested.

Key Words: Urban Poor, Utilities, Delegated Management Model, Communal Prepaid Metering

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List of Abbreviations

AfDB	African Development Bank
ANOVA	Analysis of Variance
CCODE	Centre for Community Organization and Development
DAWASCO	Dar es Salaam Water and Sewerage Corporation
DfID	Department for International Development, UK
DMM	Delegated Management Model
DTF	Devolution Trust Fund, in Zambia
DWAF	Department of Water Affairs and Forestry, South Africa
GoK	Government of Kenya
GoM	Government of Mozambique
HH	Household
IT	Internet Technology
jc	Jerry Can
JMP	Joint Monitoring Programme for Water Supply
JMP	WHO/UNICEF Joint Monitoring Programme
JWSRB	Jakarta Water Supply Regulatory Board
KES	Kenyan Shillings
KES/jc	KES per 20 Litre jerry can
KIWASCO	Kisumu Water and Sewerage Company Limited
KPI’s	Key Performance Indicators
L/c/d	Litres per capita per day
L	Litres
MDG	Millennium Development Goal
MO	Master Operator
MW&I	Ministry of Water and Irrigation (Kenya)
NAWASSCO	Nakuru Water and Sanitation Services Company Limited
NCWSC	Nairobi City Water and Sewerage Company Limited
NGO	Non-governmental Organization
NRW	Non-Revenue Water

NWASCO	National Water and Sanitation Council, Zambia
NWSC	National Water and Sewerage Corporation, Uganda
OR	Odds Ratio
PPIP	Pro-poor Implementation Plan
PPP	Public-Private Partnerships
PRSP	Poverty Reduction Strategy Papers
PSP	Private Sector Participation
SDG	Strategic Development Goal
SUWASA	Sustainable Water and Sanitation in Africa
UFW	Unaccounted for Water
UN	United Nations
UN-DESA	United Nations Development Economic and Social Affairs
UNDP	United Nations Development Programme
UNFPA	United Nations Fund for Population Agency
UNHABITAT	United Nations Human Settlement Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene
WASREB	Water Services Regulatory Board
WHO	World Health Organization
WSB	Water Service Board
WSP	Water Service Provider
WSS	Water Supply and Sanitation
WSSCC	Water Supply and Sanitation Collaborative Council
WSTF	Water Services Trust Fund

NOTES ON CURRENCY

1 USD$ = KES 100

Prices for water are reported in Kenyan shillings in the denominations as follows:

KES 1.2 per 20 litre jerry cans = USD$ 0.75 per cubic meter

KES 2 per 20 litre jerry cans = USD$ 1.30 per cubic meter

KES 3 per 20 litre jerry cans = USD$ 1.88 per cubic meter

KES 4 per 20 litre jerry cans = USD$ 2.50 per cubic meter

KES 5 per 20 litre jerry cans = USD$ 3 per cubic meter

KES 8 per 20 litre jerry cans = USD$ 5 per cubic meter

NOTES ON TERMINOLOGY

In this study, the following terms were used interchangeably:

1. Peri-Urban Areas, Low Income Communities and the Urban Poor
2. Water Service Provider, Service Provider, Utility and Water Board

CHAPTER ONE: INTRODUCTION

1.0 BACKGROUND

Water utilities are continually challenged as they provide water especially among peri-urban areas (Easterly, 2009). Due to little focus given when serving low income communities, there is low coverage, high cost of water, low quality infrastructure, poor maintenance, prevalence of unauthorized water connections, and occurrences of vandalism resulting in high non-revenue water. Further to that, frequent breakdowns and interruptions lead to poor services, and since the WSs do not have adequate finances, they often consider service to the poor as an unwanted distraction; hence there are rarely strategies that focus on the urban poor.

The most prevalent problem is the incident of non-revenue water, which in Sub-Sahara Africa can be as high as 50%. (Tremolet & Hunt, 2016). Non-revenue water (NRW) is defined as water produced and fully treated and is lost and untraced before it is billed to the customer base (Kamani et al., 2012). This is a big dent on the cash flow of WSPs, but also since there are leaks and illegal practices, in such WSPs, water quality cannot be assured. Improving water flow monitoring by improving the technology around water metering is one way to overcome high non-revenue (Tsitsifli et al., 2017). Meters are used both for monitoring and measuring tool in water service delivery. It is used by WSPs for billing (If your metering strategy is effective, you will have an opportunity for increased billing as bills are generated from reading meter), identifying leaks, forecasting water demand, among other uses (Maddaus, 2001).

There are various types of meters and metering technologies that are available for use and adoption, literature suggests. are many water metering models that have been noted in literature, and these meters directly impact on water resource management (Van Zyl, 2011). Meters also tend of have an impact on how WSPs do their billing and approach meter reading. There are varying technologies available, such as meters that have to be read physically and periodically where there are meters that are accessed remotely through telemetry (Marais et al., 2016). There also exists prepaid meters that are uploaded with credit in advance and the user can consume water up until the credit expires, but in some of the more disorganized water sectors where meter reading can be considered as too tedious, WSPs opt for flat rate billing, so that they circumvent the challenges that come with meter reading (Gambe, 2015).

Each of the models described comes with its own challenges but these challenges are magnified when applying the technologies in low income communities which are usually high density and very disorganized in terms of planning. WSPs often face challenges because of issues around non-revenue water, poor water quality, erratic electricity supply, the high cost to produce and supply water, non-existent regulation and challenges around reaching the unplanned and disorganized peri-urban areas. These areas usually just mushroom with little city planning, and as such the usual roads and paths that WSPS use when laying pipes are not always available (Chepyegon & Kamiya, 2018). Research has also shown that among the urban poor, there is a higher incidence of vandalism and illegal connections, largely because of the lower literacy levels and higher levels of poverty. This poses a problem for water utilities because up to 231 million urban dwellers, that is 72% of the total urban population in developing countries live in low income communities, and they expect access to potable and the WSPs have a mandate to meet that expectation (Dovey & King, 2012). These people have started to realize that they have a right to access to potable water, various water sectors have made concerted efforts to respond to that demand by registering improvements in metering strategies and water provision in urban poor areas.

In Johannesburg, one of the first WSPs to pilot individual prepaid water meters in Phiri town, a peri-urban area, to try and improve demand was Johannesburg Water (Dovey & King, 2012). The project failed to gain ground and after some protests, came to an end, forcing the WSP to rethink its strategy.

In contrast, in Malawi, one of the WSPs, Lilongwe Water Board partnered with WaterAid and developed the Water User Association (WUA) approach (Baietti et al., 2006). In this strategy, the water board developed a deliberate pro-poor strategy within the WSP's, peri-urban areas (Collignon & Vezina, 2016).

The WSP in Uganda piloted a strategy in their peri-urban areas where they installed individual prepaid meters. This approach did not work because the residents could not afford the start-up cost as prepaid meters at roughly $200 per meter (World Bank, 2016).

On the other hand, in Ethiopia, they opted for water kiosks, where communal water points are metered, and individuals are trained to man these water points and sell water on behalf of the WSP. This was adopted from a model that had been developed in Kenya (Njoroge, 2011).

In Maputo, the water service provider failed to meet demand as the low-income communities mushroomed. As such, innovative businessmen have stepped in and started selling and providing piped water from private boreholes, though unregulated (Mbuvi et al., 2012).

In Tanzania, automated meters were used which relied on a global positioning system (GPS) to track each customer, monitor leakages, improve on billing, improve customer service. This was piloted in the peri-urban areas of Dar es Salaam (Gambe, 2015).

In Kenya, most low-income communities do not have well planned and organized water supply arrangements. The supply model consists of poorly managed and unsustainable standpipe or utility operated communal water points (WSTF, 2015).

The reform process in the water sector in Kenya started in 2002 with the aim of improving water service provision, but there are still issues around water quality, mismanagement, non-revenue water, illegal connections, aging infrastructure and effect staff in areas such as Nakuru and Kisumu (WASREB, 2011). On average the WSPs in these two cities were averaging high NRW at 52% and very low coverage at 69% (Saria, 2015).

The overarching aim of this study which was to develop innovative water metering strategies in Kisumu and Nakuru to facilitate improved water service provision to the urban poor was motivated by the aforementioned context.

1.1 PROBLEM STATEMENT

Kenyan Water Service Providers no longer effectively use conventional means to deliver water to low income areas. This is very true especially in the context of the United Nations sustainable development goal #6, "By 2030, achieve universal and equitable access to safe and affordable drinking water for all" will also not be met (Holt, 2015).

Most utilities in Kenya and in the region are quite capable when providing water in posh upper-class urban townships, cities and towns (these are differentiated by size, i.e. a group of townships make a town, and a group of towns make a city). Governments and Non-Government Organizations also are focused on providing water services to rural areas and villages. There is a critical mass, the residents of peri-urban areas, who miss out from focused and innovative water service provision. Research shows that, as of 2015, the peri-urban residents in sub-Sahara Africa account for 72% of the population, which is about 231 million people (UN, 2017). Further to that, 60% of sub-Sahara Africa comprises of peri-urban dwellers and these people do not access any water reticulation system and use water from unsafe sources (Holt, 2015).

The overarching context is that the water sector was unable to meet the Millennium Development Goal 2015 to "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation" (Chepyegon & Kamiya, 2018). There is an urgent need for innovative solutions to address the even more ambitious Sustainable Development Goal (SDG) number 6, to achieve universal and equitable access to safe and affordable drinking water for all by 2030. If solutions are not found, and implemented, SDG #6 will also not be met (Holt, 2015); utilities in Kenya have a real challenge to meet this new goal. The first thing that needs to be done is to realign their goals and vision statements so that they position themselves to be more challenged and more focused on achieving results in neglected peri-urban areas and not just maintaining the status quo. Next, utilities need to start to think through and develop strategies that will enable them to achieve those goals.

So, the problem is, water service providers will not be able to adequately contribute to the United Nations Sustainable Goal number 6, to achieve universal access for all by 2030. This is so because most potential customers for these water service providers are peri-urban area dwellers and the service providers are unable to adequately provide water to them. To address this problem, this study compared the two approaches, the Delegated Management Model (DMM), and the newly developed Communal Prepaid Meter (CPM), and provided solutions from these two approaches, which can be shared and replicated in Kenya and in the region, as a way of contributing knowledge by helping sub-Sahara water service providers to have specific options in the improved DMM and CPM when providing water to underserviced peri-urban areas and hence contributing towards the sustainable goal.

This study therefore was aimed at developing two innovations in Kisumu and Nakuru through two water utilities, Kisumu Water and Sewerage Corporation (KIWASCO) and Nakuru Water and Sanitation Services Corporation (NAWASSCO), and to develop a replicable model, which will help improve water service provision in Kisumu and Nakuru.

1.2 OBJECTIVES

The objective of this study was to develop innovative water metering technologies for improving the provision of water services among low income communities in Kisumu and Nakuru, sites which were selected as case studies.

Specifically, the study aimed:

1. to develop and install 93 communal prepaid metering in peri-urban areas in Nakuru within a period of one year;
2. to modify and improve delegated water service provision in 13 delegated management models in peri-urban areas in Kisumu within a period of one year;
3. to compare water service provision using communal prepaid metering in Nakuru and the delegated metering models in Kisumu in comparison with the same sites without the study models.

1.3 RESEARCH QUESTIONS

The study in response to the overall aim sought to establish if developing innovative water metering technologies have any potential influence these have on considerably improving the water services to low income communities in Kisumu and Nakuru. These technologies were developed for the study, with the CPM being newly designed and piloted in Nakuru while the DMM was modified and improved to enhance the study. The main research question is as follows:

Are innovative applicable engineering and financial interventions valid tools for performance enhancement for service provision to the urban poor, and are they helping the water sector take a significant step towards achieving the Sustainable Development Goal of 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all?'

The specific research questions were:

1. Can communal prepaid metering in peri-urban Nakuru improve water service provision?

2. What are the fundamental elements of the delegated management model that need to be improved or modified to enhance water services in Kisumu's peri-urban areas?
3. Is communal prepaid metering a more viable option for enhancing water service delivery in peri -urban areas when compared the delegated management model?

1.4 SCOPE OF THE STUDY

This gave emphasis on providing water services to peri-urban areas. In so doing, focus was given to the water provision element of utilities, without considering sanitation services (Acolor & Adams, 2013). Further to that, the study focused on only two cities in Kenya, Kisumu and Nakuru, and not in any other city in Kenya or indeed any other city within sub-Sahara Africa. The study also only examined issues in peri-urban areas but was not focused on suburban areas or rural communities, because water service provision in peri-urban areas are distinctly different to rural water provision and suburban water provision (Mbuvi et. al., 2012). The study focused on piped water metering as a model for improving water service provision. Priority was given to water service provision only. The study did not consider water development or unmetered water service provision. It also did not examine the different sources of water, like boreholes, shallow wells and rainwater harvesting.

1.5 RESEARCH LIMITATIONS

This research was limited in that it was not easily able to identify who should be engaged when doing the interviews and who should be invited for focus group discussions. The research used residents of the two towns that were the subject of research, as well as government agencies, water companies and other key stakeholders, but only in the two towns. Those in the case study countries were engaged through focus group discussions. When dealing with government officials in the regulatory agencies and the WSPS, the researcher engaged them and solicited their views on the low-income communities through key informant interviews on urban poor dwellers, provision of water to such residents, prepayment viability and delegated management, and how these innovations are improving water service delivery. The discussion could have been richer if consultations were done wider than the expected residents, and government officials.

CHAPTER TWO: LITERATURE REVIEW

2.0 INTRODUCTION

Relevant and current literature was reviewed in this chapter. The focus was on literature that discusses water service provision in low income communities. The review is structured in such a way that it starts with key issues around water service provision in these low income areas. Then the focus is on the extent to which the SDG 36 is achievable, considering that access to potable water in these low income areas is still considerably low.

The United Nations estimated in 2015 that 72% of the urban residents in sub-Sahara Africa dwell in peri-urban areas. This accounts for nearly 231 million people (UN, 2017). There was a lack of focus on peri-urban areas as evidenced in table 2-1, because 60% of sub-Sahara Africa comprised of unconnected urban poor dwellers. Further to that, sub-Sahara African water service providers had very high non-revenue water averaged at 55% (IBNET, 2017). A close analysis of the investment profiles of the WSPs showed that they were economically not viable, as demonstrated by poorly financed urban poor projects (Mbuvi et. al., 2012). It was observed that because of these concerns, the conventional way of service provision to the high-density areas could no longer be considered as effective (Berg and Mugisha, 2009).

Table 2-1 Percentage of Urban Dwellers with access to Metered Connection in sub-Sahara Africa

Country	No. of Urban Dwellers accessing improved Water	% of urban dwellers accessing improved water sources	% of urban dwellers with metered connections	% of urban national population accessing improved water sources	% of national population with metered connections
Malawi (1990)	1,031612	91	37	42	6
Malawi (2015)	2,658,662	96	33	90	8
South Africa (1990)	392,238	99	82	70	32
South Africa (2015)	1,101,755	98	69	91	51
Kenya (1990)	4,842,150	92	31	54	6
Kenya (2015)	12, 884, 502	77	28	56	13
Mozambique (1990)	3,033,980	100	98	79	33
Mozambique (2015)	4,670, 278	97	74	77	28

Source (IBNET, 2017)

The chapter attempts to review in Malawi, Mozambique, Zimbabwe, Ethiopia, Kenya and South Africa, what innovations have been developed and how they are addressing this concern. These innovations include private operators, water kiosks, individual prepaid meters and water user associations.

2.1 WATER SERVICE PROVISION

2.1.1 Service Provision in sub-Sahara Africa

WSPs face multiple challenges when serving their constituents, especially those that live in peri-urban areas, and these challenges include increasing populations and as a result a significant increase in the need for water supply (African Development Bank, 2017). These are utilities that need Government and donor intervention for them to invest in new facilities and can hardly meet their running costs (Mbuvi et. al., 2012). The reality is that while cities have grown and demand has mushroomed, the infrastructure for water supply has not grown (Franceys, 2011). In other words, Africa has a huge constraint when it comes to human resource and financial capacity needed to grow their water network systems and to provide potable water to its people (Estache & Kouassi, 2012). Further to this, the people who currently manage these utilities have underperformed (Saghir et. al., 2015; Palmer, 2013). Even though the wind of change swept across Africa in the late 50's and early 60's and with it came droves of donor funding to the water sector, there is very little to demonstrate progress as sub-Sahara Africa is still unable to meet what is required for the water sector to meet demand (Franceys, 2011; Mwanza, 2005).

Hindrances to improvements in the supply of water services cannot only be because of technical and financial inadequacies, but some blame must go to institutional and political challenges (Chepyegon, 2018). Most of the Government-owned utilities are found to be highly wasteful as they run non-revenue water figures higher than 50%. This can be due to old equipment, and poor technology, but this is also due to poor management leading to low billing collections (Foster et. al., 2014). The biggest culprits when it comes to collections is government institutions such as the hospitals, the army, the police, prisons, and schools who all take advantage of their 'sensitive' nature and hardly ever pay their bills on time or at all (Gambe, 2015). Further still, most utilities that are owned by the Government are neither accountable nor autonomous in their dealings. This quagmire creates an environment where investments towards improved service and expansion is almost non-existent and leaves the utilities vulnerable to a lack of cash flow and political meddling (African Development Bank, 2017).

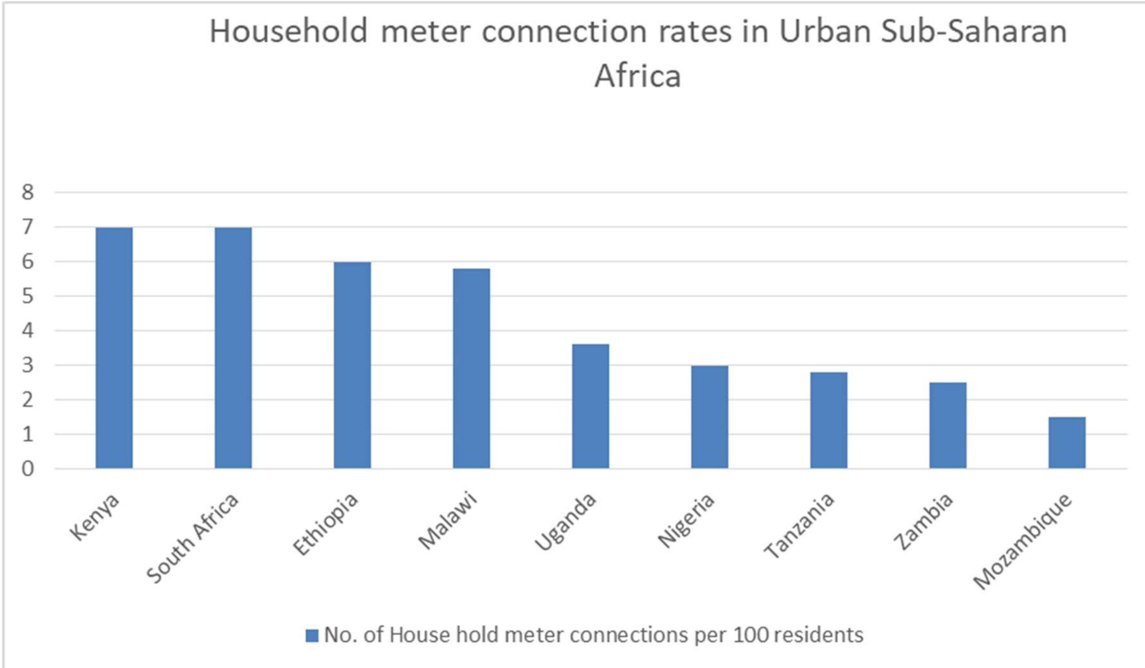

Figure 2-1: Household Meter Connections / 100 residents

Source (WSTF, 2015)

The poor are the biggest victim of these inefficiencies. Almost 60% of sub-Sahara Africa comprises of urban poor dwellers and they are mostly not connected to any water system (figure 2-1). This means that they get water from sources that are not regulated or legalized by Government and yet, they account for up to 50% of the water that these people consume, and these unregulated sources are usually up to two times as expensive as water supplied by the utility (Groom et. al, 2016). The reality is, while the main source for potable water is the WSP, much of this water is not provided through individual connections as only about 40% of the peri-urban areas in Sub- Saharan Africa is metered (Holt, 2015). This is further demonstrated in figure 2-2.

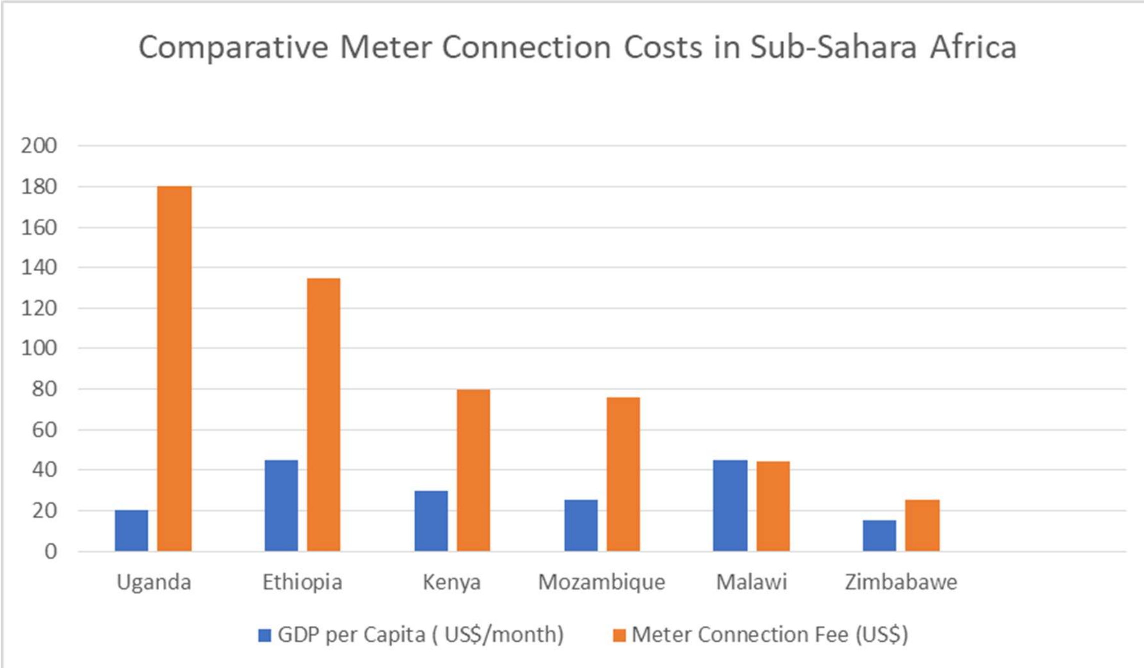

Figure 2-2: Comparative Meter Connections Costs

Source (ADB, 2017)

Apart from household connections, public stand posts are the most favoured means of providing water to the population by utilities. Almost 24% of the world urban poor populace is supplied by communal stand posts (Estache & Kouassi, 2012). Most people do not access WSP water primarily because they live far away from developed residential areas or they live-in low-income areas. Table 2-2 shows the number of urban town dwellers served by water companies in a selection of African Cities as of 2015. About 24% of the urban town dwellers in sub-Sahara Africa access water from sources such as unprotected shallow wells and boreholes.

Table 2-2: Percentage of city residents served by utility network

SERVICE LEVEL	Abidjan [Cote d ' Ivoire]	Nairobi city [Kenya]	Dakar [Senegal]	Kampala [Uganda]	Dares Salaam [Tanzania]	Conakry [Guinea]	Nouakchott [Mauritania]	Cotonou [Benin]	Ouagadougou [Burkina Faso]	Bamako [Mali]
Source of water to household use [percentage of households]										
In house connection	76	71	71	36	31	29	19	27	23	17
Standpipe water fetched by household	2	1	14	5	0	3	30	0	49	19
Independent providers/traditio nal sources	22	27	15	59	69	68	51	73	28	64

Source (Groom et. al., 2016)

In the face of very extreme climate changes, WSPs are also increasing finding it hard to find reliable water sources. According to Groom et al (2016), by 2020, more than 600 million humans will reside in areas that are water stressed. This estimate is also confirmed by (Tsitsifli et al., 2017) who also estimate that over half a billion people will be water stressed by 2020. The next challenge that water companies in Africa are facing is the inability to invest in new infrastructure to replace old colonial facilities. Africa lags all other continents in this aspect (Stoler, et. al 2012). The problem is that very little financial resource is raised by African countries and most funding comes from donor agencies and bilateral corporations. Innovations and improvements in coverage and quality of service will not be realized if there are inadequate investments. This is true for the majority of sub-Sahara Africa, because quite a substantial number of countries have reformed their water sectors and have commercialized their utilities, but very few have matched the reforms with investments (Chakava, 2013).

It was estimated in 2012 that the African continent needed US$ 6 Billion annually up to 2015 for the continent to realize the MDG on water (African Development Bank, 2017). Each country was given this challenge and governments did try to raise these resources from internal financing and external financing. While using public funds for water service delivery is common practice, engaging local private financiers to be part of the water supply equation proved to be challenging because most did not see water as a viable business to invest in. Most felt that the utilities would not be able to afford private money and true, lending rates in most African countries were high (above 20%). It is observed that the debate is less essential as many private sector agencies are refraining from financing large scale water related projects in Sub-Sahara Africa (Groom, 2016). As the debate for using private financing for water services rages on, utilities are still being forced, as a result, to depend heavily on the usual developing partners for the foreseeable future. Water utilities will have to look inward, become creative and introduce efficiencies and systems that will encourage financial viability and an increase in capital expenditure (Sansom, 2002). With this as the prevailing reality, governments in the continent will have to evaluate their resource base and see what technology, human resource, management skills and finances can be concocted together to move the sector forward using available private and public resources (Water Utility Partnership, 2001).

2.1.2 Water Service Provision in Kenya

Water is supplied in Kenya using basic treatments systems (African Development Bank, 2017). Water is extracted from the ground or from surface water, treated to acceptable standards using WHO or local standards. It is considered conventional to treat water which has been drawn from its natural habitat like ground water, lakes, rivers or streams. The water is treated via filtration, coagulation and chlorination (Mbuvi et. al., 2012). The treated water is usually pumped to elevated service tanks in the supply area and redistributed by gravity to the communities. The water is then served to the customers and the customers pay for the services when they are billed.

This simple model usually alienates the urban poor because utilities find it very expensive and taxing to go through this cycle just for the poorer communities who in the eyes of the utilities are both hard to reach and don't provide a significant return on any investments made (WASREB, 2011). As a result of this perception, most of these people are supplied with very poor-quality facilities, normally just an individual tap or a badly managed public water stand, which is usually in a state of neglect (Berg, 2009). Since government owns these utilities, the utilities will normally reserve a levy within their tariff to help cover for government capital investments, both future and past loans, and the utility will be expected that it will recover these costs through the regular billing cycle.

The billing cycle finds its life through a metering system that the utility will have in the areas supplied where the customer post-pays for the water consumed (Carter, 2012). This is the current preferred option because the systems are easy to maintain, and that the meters are affordable and easy to repair and replace. Also, Castro, (2009a) rightly observes that this method is so widespread that utilities can easily learn and share best practices amongst each other given the similarity in the mode of operations. In addition, this supply method is porous and easily subjected to vices such as billing mistakes, vandalism and illegal connections. These are the factors that account for high NRW, which affects the stability of the WSPs (Cross & Morel 2005). It is also quite expensive for low income earners to pay upfront for new connections, leading them to be segregated naturally and conversely, the utilities find it expensive to maintain a team of meter readers and billing assistants who go around the customer zones reading meters and delivering bills. Consequentially, most residents in these cities will not have access to water, because most of them dwell in peri-urban areas where utilities are facing challenges to provide water, as described. This all speaks to the fact that coverage will remain low because most residents in these African cities are low income earners and they don't get the service (Castro, 2009a).

Customers usually can either have a house connection with a standard meter or be served by a standpipe which is placed outside their yard. These are normally post-paid arrangements and they normally pay after a month of consumption (Kumar et. al., 2002). Peri-urban dwellers cannot afford the cost of a brand-new connection and consequentially, do not have any facilities on their properties. They instead opt to be served using communal Water Kiosks. These are usually placed in common places within the townships, where people can have ease of access. In this option, you pay upfront for what you buy, and you pay by volume (Mbuvi, et al 2012). The unfortunate reality is that, even though this is a model meant to help the poor, people end up paying a lot more than those in affluent areas because of the kiosk attendants who usually set a tariff higher than the utility tariff so that they can get a little profit. In those areas where people are extremely poor, one finds that the people are being served with hand pumps or shallow unprotected wells, giving poor quality water which, the people use but to their detriment (Karanja, 2008).

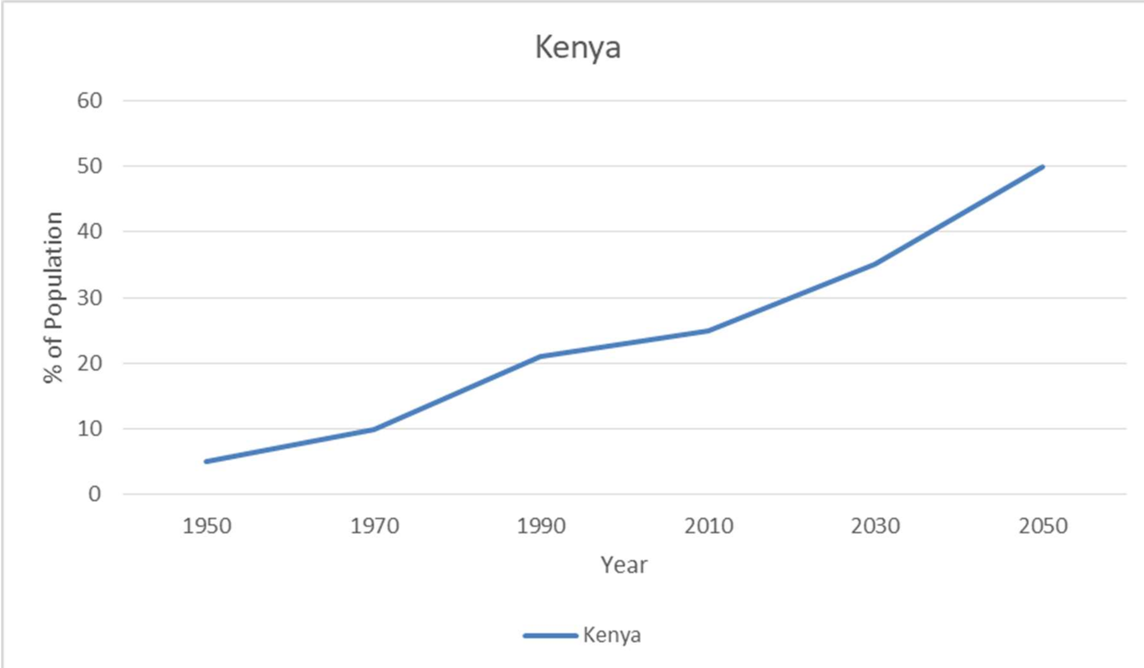

Figure 2-3: Projected Population Growth in Kenya

Source (Development Trust Fund, 2015)

As the population of Kenya has rapidly grown from the colonial days to date (figure 2-3), it has become necessary for water utilities to evolve, and as they have evolved, so has the equipment that is available for the complex process of water provision. In the meanwhile, the devolved Kenyan constitution (2010) impacts directly on the water sector in that it gives full responsibility of water and sanitation to the 47 counties, and it also clearly aligns itself to the reality that water is a universal human right (Acolor & Adams, 2013). The Water Act was further revised in 2016 and the revisions now give the Kenyan water sector the onus to tackle new opportunities and overcome existing obstacles in the sector. Water is essentially still the purview of National Government because water in its natural state is a Government resource, but water provision is the sole responsibility of the counties. The nature of water resources is such that water does not conform to county boundaries and as such, there will be conflicts, and there is a need for strong institutions at the national government that will preside over and regulate potential conflicts that will arise from these issues (Estache & Kouassi, 2012).Counties are at the moment uncomfortable with national government involvement in their affairs, as they see potential overlaps and conflicts, so this is an area that needs close attention and fine-tuning (Chepyegon & Kamiya, 2018).

Research has shown that each of the 47 counties has its own appreciation and interpretation of their mandate to serve. While some counties see water as a basic human right, others see differently. This might mean there is a need to harmonize county policies so that there is some consistency in how water is delivered in the various counties. (Tremolet & Hunt, 2016).

Sustained Water Service in the counties is in question, because while most counties are investing heavily in water facilities and new structures, there is less emphasis on maintenance and capacity building for the respective staff (UN, 2017). SDG #6 may not be achieved unless this concern is addressed.

While the transformation of the Kenyan political landscape and the devolution of resources and mandate to the counties within such a short time is commendable, it seems that the water sector will benefit the most from these transformational changes. Even though that may be the case, some of the larger counties like Nakuru and Kisumu have been exposed as the devolution continues. There is considerable investment and change in the urban centres, compliance to the new tenets, but water service delivery at a level of service that is acceptable is on the decline in the urban poor areas (Chepyegon & Kamiya, 2018).

2.1.3 Water Service Provision Innovations

2.1.3.1 Water Kiosks

These are in simple terms, sell points that have taps which are accessed by the customers and faucets which are accessed by the operator. They are operated by an attendant and the water source is usually the local water company. In places where supply is inconsistent, there can be a storage tank on the premise as part of the kiosk (Onyango, 2012). Water kiosks are managed under different models, like community management teams, or volunteers, or private individuals or indeed utility employees (Acolor & Adams, 2013). Usually, the kiosks also act as mini grocery shops and the operators use this to generate income which can be used for small maintenance issues and profit for the operator to supplement their incomes. Kiosks are designed depending on the country and community to serve between 500 and 3000 people at a time. The buyers normally buy the product using water pails or drums, usually 20 Litres per container (Skinner, 2009). Tariffs are set at a small percentage above that of the utility and can either be charged per pail or per household. Kiosks are a very key economic tool in the economy of water because when strategically placed, they serve a lot of people at once and change the livelihood and wellbeing of many people, especially in the high density areas, where the alternative sources, from shallow wells, rivers and the like are of lower quality and are not too appealing (Ali, 2010).

In Hawassa, Ethiopia, which has a population of over 300,000 and is subject to critical lack of adequate water services, the water utility was only able to satisfy 34% of water demand. However, with the recent completion of additional water sources, the utility's water production capacity has increased (SUWASA, 2011). With added revenue from the recent tariffs increases approved by the Hawassa Town Administration combined with technical Hawassa Town Water Supply and Sewerage Services Enterprise (HTWSSE), there is clear improvement in the way it operates and maintains water services, at the point supply and distribution. This improved situation has presented a good foundation for HTWSSE to expand water coverage to currently un-served peri-urban areas. Typically, in Hawassa, private water connection costs have been unaffordable for low income areas and public water taps (PWT). The poor have been obliged to get water from private water sellers, who use jerry cans mounted on donkey carts, at more than five times the minimum tariff rate charged by HTWSSSE (Mulenga & McGranahan, 2011).

To begin to address this situation, HTWSSSE borrowed a leaf from Kenya and piloted water kiosks as a way of water service provision in Hawassa. The new kiosk design and management model was derived from the experience of Kenya's Trust Fund, namely the Water Services Trust Fund (WSTF). A framework for the management of water kiosks by local private operators was developed which had not been previously tried in Ethiopia. The newly constructed kiosks connected three peri-urban areas in Hawassa to the HTWSSSE distribution network. The approach focused on piloting the use of private operators and ensuring sufficient incentives structures were established to yield effective management of public water taps. This pilot has the potential to be taken to scale in Ethiopia (SUWASA, 2011).

2.1.3.2 Water User Association Approach

WaterAid in Malawi collaborated with this WSP, Lilongwe Water Board (LWB) and a local NGO, the Centre for Community Organization and Development (CCODE) from August 2003 to December 2007 to enhance the delivery of water in the unplanned high-density communities of Lilongwe City (Water Aid, 2008). This was exemplified by an acute lack of focus by the service provider on community challenges, erratic billing and poor management of the communal water points by the local community leaders' own systems (Practical Action, 2012). The biggest bone of contention between LWB and the communities was a debt amounting to $ 16,000 that the residents were struggling to pay and had led the utility to disconnect their services to prompt the bill to be paid. WaterAid identified the key issue to be that the poor communities were paying double for their water. Water tariffs at communal water points in the poor areas, in spite of being subsidized, were still double as much or even more as in the low density. Private operators, hijacked the kiosks, used their financial muscle to pay the bills with LWB, then, they resold the water to the poor people at extremely high tariffs that were never agreed upon with the Board (Ardakanian et. al, 2011).

The communal water point management systems were subject to intense abuse by traditional community leaders, and local politicians who collected revenue from consumers, but pocketed the money instead of disbursing to the water service provider (WaterAid, 2008). The community leaders did not place the priorities of their constituents above their own, and they were not transparent and accountable in transactions. Sub sequentially, the communal water points were not properly maintained, and as long as the reticulation system was charged with water, the meters were subject to vandalism, worse still, they usually broke down again as soon as they had been repaired (WSSCC, 2011). LWB would normally be forced to charge average rates per water point when it discovered that a meter was vandalized, which was always to the disadvantage of the customers. LWB was not accustomed to carrying routine checks for pipe bursts and leaks in peri-urban areas. At times, reported faults remained unattended for up to a month (Jacobsen et. al., 2012). Illegal connections were common but never uncovered, let alone dealt with by the utility. The water board was not doing pressure management and as such, had no district meters to check how the hydraulics was performing and therefore had little grasp of the extent of what was happening in the network (Cross & Morel, 2005).

To adequately address these multiple concerns, it was felt that a dedicated pro-poor unit should be established within Lilongwe Water Board, which would have complete focus on these software issues and would help the board strategize on how to best serve the low income communities (WaterAid, 2008). The key factor that made LWB successful with their newly established pro-poor unit as a tool to better serve the peri-urban areas of Lilongwe is credited to the three-party partnership that existed between Lilongwe Water Board, WaterAid in Malawi and CCODE (Keener et. al., 2010). In this arrangement, the Water User Associations (WUA) have a secretariat, executive committee and a board of trustees a constitution and headed by a manager who runs a pool of water attendants and inspectors. In other words, the WUAs are run as business entities (WaterAid, 2008).

2.2 THE CONCEPT OF WATER METERING

A meter is a gadget used to read and gauge the amount of water used by a customer over a period of time. Kayaga, 2014 says that "In sub-Sahara Africa, water meters are the primary tool used by WSPs to gauge the volume of water that is used by its customers, who are usually metered separately and usually categorized as commercial, residential or institutional" (Kayaga, 2014). One advantage for service providers in using water meters is that users tend to conserve their water once they are aware that they are being metered. This has a positive effect on non-revenue water and helps service providers to manage demand and to redirect much needed water to the poor at a subsidy. (UNICEF, 2006).

Many meters are not fully functional in African cities because there is intermittent water supply, which means the meters can under register, and also because of the frequent changes in hydraulic pressure, the meters do tend to get damaged (Njoroge, 2011). Meters also tend to perform worse as they age, and usually this leads to under registering, a problem which means that the utility will get lower revenues, unless there is a clear meter replacement policy which is strictly adhered to (Practical Action, 2012). Meters are also known to measure air flow, which gives inflated bills, and this is usually an occurrence when systems fail to provide water 24 hours a day. When water is restarted in the reticulation, the water pushes air ahead of water through the meters (Kayaga, 2014). The cost of a meter in itself is quite manageable at $ 25/ meter. However, the real cost is in the maintenance and associated plumbing, which can get very high in complex high-density communities or in apartments and large buildings (Mwanza, 2005).

When deciding on which kind of meter to use, it important to consider the quality of the water, what environment the meter will be placed, how affordable it will be to the WSP and customer, ease of maintenance and other operational factors. (Ningbo, 2012). The positioning of the meter during installation is critical, it must be aligned to the direction of water flow and the reading screen and serial number must be easily accessed. The pipe network before and after the meter must be fully charged with water at all times in order for the meter to work effectively (Skinner, 2009). Meters should be installed within 25 meters of the delivery line and should be upstream of any main branches, diversions and regulatory valves that may be in the network (Mwanza, 2005). If a water meter is installed below ground, it should not go beyond 50 cm below ground level. Meters should be installed on the surface and where practical outside manholes and wells. Where this is not possible, the depth of the meter should not be any deeper than 500 mm. (Tag Meter, 2017)

Prepaid Water Meters

Prepaid meters are different from conventional meters in that they are operated electronically, and usually remotely. Also, credit is loaded into the meter in advance and the WSP's customer can only consume what has already been purchased. The meter is usually motorized by battery or in rare cases, electricity (Olivier and Fourie, 2007). These meters are fitted as separate house connections. Consumption is measured by tokens which are purchased at the local utility or at selected selling points (SUWASA, 2011).

Prepayment arrangements for services are commonplace in sub-Sahara Africa. The energy sector has been using prepaid meters for over 10 years now and there are many lessons that the water sector can draw from their experience in terms of the benefits and disadvantages of prepayment. (Olivier and Fourie, 2007). Electricity providing companies see these prepaid meters as a great tool for countering many of the difficulties that they face as they operate, such as peak load and demand, losses from under billing, high over heads and inadequate cash flow. (Schnitzler, 2008). The telecommunications sector has also been using prepayment for more than 10 years and comparatively, they seem to have done so with the most success. Water Service Providers are being encouraged to learn how communication service providers developed their pro-poor strategies and how their business now depends mostly on low income customers. (Kayaga, 2014; Gerlach & Franceys, 2009). Gerlach and Franceys (2010a) also derive ideas from the communications sector in recognizing the importance of designing a package that enhances cash flow by improving on revenue streams, by extending the services to the poorer customers by providing cheaper packages that are affordable but by default, more people access.

The inadequate financial resources usually encountered by WSPs are somewhat due to low revenue inflows, the price of equipment such as meters, inaccurate billing and collection, disconnections due to non-payment and non-responsiveness to customer complaints. This is one reason why WSPs are now in favour of prepaid meters, because they tend to deal with all these inefficiencies (Keener et. al., 2010). Studies have also shown that prepaid meters in general help customers to manage their own income better, as they are able to plan for how much of their income should go to utilities, and when utilities adjust their tariff, they are pre-warned and able to buffer those adjustments by changing their own consumption patterns. (Kayaga, 2014).

Conversely, the main disadvantage is that prepaid meters cost more than post-paid meters and that since the technology is new, there is need for advocacy and strategic information campaigns so that customers can widely accept the technology, and most importantly to develop technology that is adaptable to the various categories of customers. This is particularly vital in sub-Sahara Africa where most customers while being urban, are poor. (Trémolet and Hunt, 2016). Prepaid metering is now commonplace in the sub-Saharan energy and telecoms sectors but not as widespread in the water sector. There have been pilots with varying levels of success in Uganda and Kenya, Zimbabwe and South Africa, but the focus has been mostly for high income residents, with there being a huge untapped market opportunity for the low-income residents in the urban poor areas. (Trémolet and Hunt, 2016).

Pilot installations done in Kampala, Uganda show that prepaid metering is a welcome technology which makes water readily accessible to the general public without consumers having to deal with third party salespersons who can usually bloat the charge for their own profit (Ningbo, 2012). The typical prepaid meter cycle that this study is as demonstrated in figure 2-4.

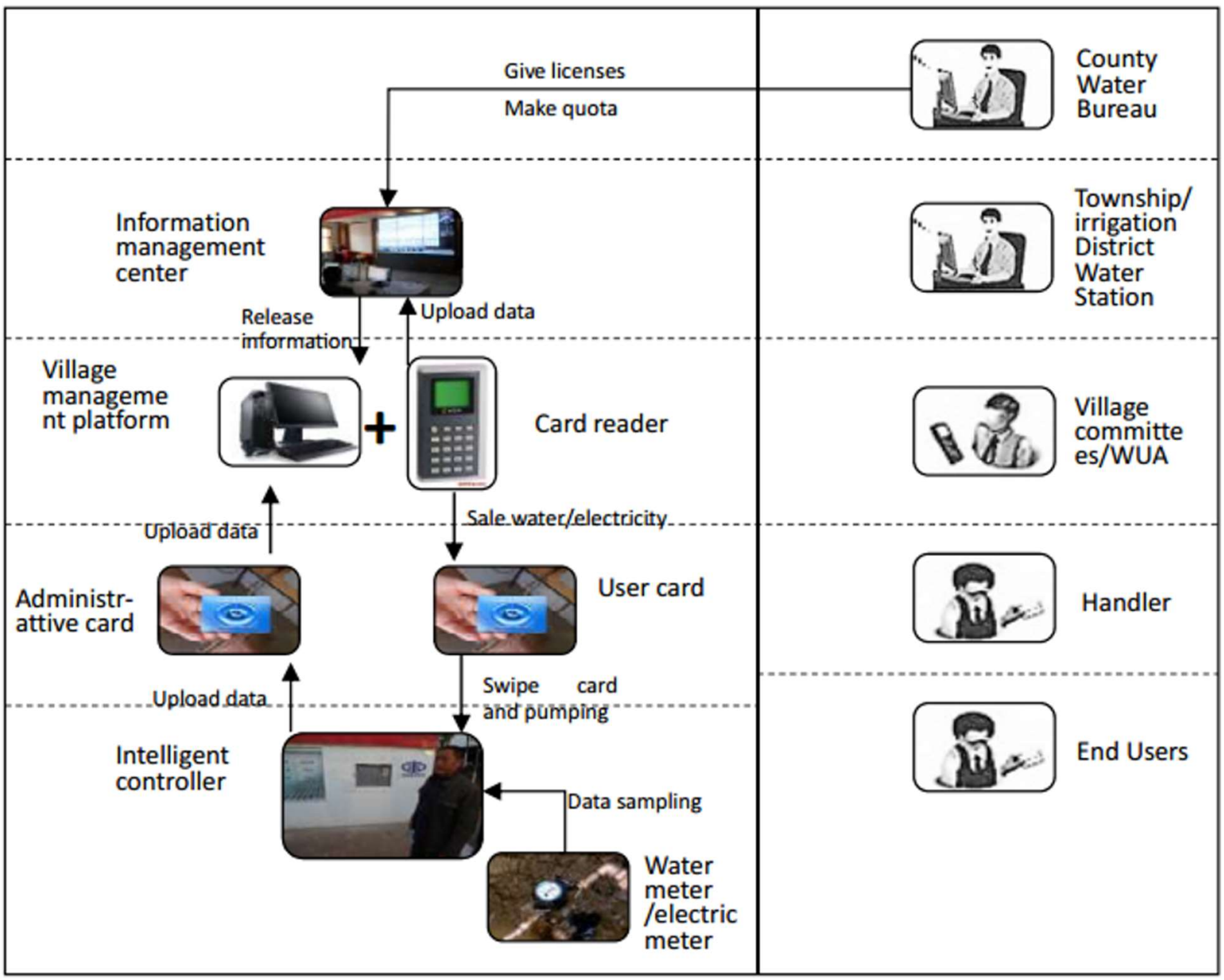

Figure 2-4 Prepaid Metering Cycle

Source (SUWASA, 2011)

From the success of other sectors, prepaid metering is now being viewed an option that can help deal with the issue of serving the urban poor (Njoroge, 2011). While this is now being piloted in Africa, the United Kingdom was one of the first countries to try prepaid metering, but progress was hampered when the meters were declared illegal when the utilities were taken to court in 1997 (Laporte-Vergnes & Franceys, 2010). In sub-Sahara Africa, the energy sector has been effective in using prepayment to curb corruption, to enhance revenue collection and to reduce on expenditure (Tag Meter, 2017). Pre-paid meters are deemed to be a useful way of helping utilities to clear bad debts, to cover the cost of meter installation by passing it to the customer) and to reduce operation costs that emanate from meter reading, disconnection campaigns and subsequent reconnections (Schnitzler, 2008; Berg & Mugisha, 2009). There is some hesitation within the water sector to endorse prepaid metering as the new frontier for water service delivery and the hesitation comes from the potential that prepayment has in abusing basic human rights (access to water for all).

The example of prepayment in Johannesburg is used where there was resistance to installing prepaid meters because residents would no longer access their free 6m3 of water every month and that residents couldn't afford the cost of the meter, and consequentially reverted to alternative sources of water. There was an outbreak of cholera at the same time in 2002 and the blame was place on the advent of prepaid meters. The residents of Phiri town reacted by demonstrating with support from the civil society, which prompted Government to retract and halt prepaid meters for a time (Heymans et. al., 2014). There were also concerns when the prepaid meters were initially launched as to the affordability of the meters due to high maintenance costs and non-availability of spare parts. (Schnitzler, 2008). Nevertheless, since the Phiri incident, better priced prepaid meters have been placed on the market with easier to find parts and more durable batteries, and South Africa now is the lead distributor of these meters in sub-Sahara Africa providing good technical back up and they also resolved the highly politically charged issue around the free 6m3 of water by factoring that in the meter data capture system. (Heymans et. al., 2014).

National Water and Sewerage Corporation (NWSC), Uganda was one of the first utilities to pilot prepayment after lessons were learnt in South Africa. The pilot was in Kampala (Kayaga, 2014). In contrast to the earlier South African experience, the residents, and stakeholders of Kampala welcomed the technology. The key things that appealed to them were the convenience proffered by the meters. There were still concerns as to whether or not the meters were sustainable, the relatively high cost of the meter at $200 compared to the $100 cost for the conventional meter, meaning that most people could not afford a meter upfront, and also that back up support was still not available in Kampala and technicians had to be flown in from South Africa whenever there was a need. (Berg & Mugisha, 2009; Laporte-Vergnes & Franceys, 2010). Quite a few prepaid metering projects were launched and piloted in the urban areas of Kampala. Most of the first batch installed in the Kampala peri-urban areas developed faults as they were not robust enough to function in the harsh Ugandan environment (Kayaga, 2014). The lifespan of these meters was estimated at about 10 years, but most failed within 1 year. "The mechanical defects are mostly due to the failure of the rubber isolation of the electromagnetic valve, which controls the outflow according to the accessible credit on the token, and a sensor problem, which releases only two litres" (Laporte-Vergnès, 2010). It was also found that it was more effective to go beyond just improving on the electromagnetic valves and other key features, but that it was important to engage the customers and provide them with education on the advantages to them on adapting this new technology, and how they can take care of their property. (Tag Meter, 2017).

In Zimbabwe, Harare Water Company first introduced prepayment in Mabvuku and Tafara. This was in 2012 and the project procured and targeted 10,000 individual connections (Ward, 2012). The pilot was registered as a success with challenges similar to those in Kampala. The residents needed advocacy in order for them to accept the technology, and there was need for the WSP to subsidize the cost of the meter so that the residents could afford it. Most of the success was around the WSP being able to reduce leakages, water losses and non-revenue water.

There were concerns around vandalism and inadequate knowledge in how prepayment would work. To address this, in Nakuru, Kenya, NAWASSCO found that by disassembling a meter in front of the potential users, and communities in general, and showing that there were no parts of value in the inside, they managed to distract potential vandals from trying to damage the meters or steal parts (SUWASA, 2011). In Kampala, Uganda, the need of more education meetings and literature was cited as a problem, and to address this, the WSP set up satellite offices within the low-income areas, so that customers could have a direct interface with the WSP. This was a step in the right direction, as the WSP improved its image among its customers, it was now considered as more customer friendly (Laporte-Vergnès & Franceys, 2010). NSWC gave more focus on customer care and did so by organizing community meetings where just like in Nakuru, the prepaid meters were disassembled while the community watched to show that the meters had no parts worth re-selling. Customers were also informed that if they tinkered with the meters, they would trigger an automatic shutdown, which would be to their disadvantage because they would not be able to access water. (Laporte-Vergnès & Franceys, 2010).

One setback for regular post-paid meters, which gives a strong case for prepaid meters is that while being tools of essence in water utilities, the reality is that customers are usually given bills were are estimated, because most WSPs try and avoid the meter reading cycle because of the need for diligence and close supervision (WSTF, 2015). That is where prepaid meters are at an advantage. There is an opportunity when using prepaid meters for WSPS, because the hassle of meter reading and billing is circumvented with a more reliable and plausible alternative. The prepaid meter is more reliable because human error is minimized considerably (WSSCC, 2011). Customers, when they have become familiar with the technology tend to be more satisfied as their consumption and expenditure collates and there is less queries to the WSP. This of course assumes that the WSP can supply water consistently, 24 hours a day (WSUP, 2011).

A good example is in Harare where residents accepted the prepaid meters relatively quickly and felt that they were done with bill over estimation from the WSP. Residents are cited as being weary of being cheated and believe that prepayment will bring to an end a long outstanding dispute between the WSP (which is the city council) and the residents. On this basis, Pre-paid meter technology is designed largely on the basis that it would provide residents with the opportunity to correctly budget for water usage (Berg and Mugisha 2009). This may be proven to be correct, because the uptake of prepaid meters that are being used by water consumers, to manage their water consumption and billing is on the increase (Franceys, 2011). Prepaid meters are considered by users to be more appropriate compared to other conventional service level options that are commonly found in peri-urban areas, standpipes and communal water points (WSTF, 2015). The point being water is now available 24 hours/day and people do not have the inconvenience of having to buy water through intermediaries such as water vendors or landlords who sell water at a premium (Chepyegon et. al., 2018).

Studies show that by introducing prepaid metering and by making billing and paying more convenient and customer friendly, the rate of the collection of revenue is very likely to improve (Chepyegon & Kamiya, 2018). Second, with more automation, and more efficiency, administrative costs will drop significantly for the water agencies. Third, with the addition of these prepaid meters on the network, the ability to accurately estimate and deal with NRW increases significantly (Gambe, 2015). This is so because now, those with illegal connections are being identified as more utilities do customer verification exercises as they introduce meters and illegal connectors are penalized and reconnected to the network legally (Skinner, 2009). As utilities pay more attention to their networks, they are able to trace leaks and repair them. This is reducing operation costs and is allowing water utilities to conserve more water and use it elsewhere." Certainly, prepaid meters are more cost effective because of the elimination of intermediary expenses such as meter reading and billing (Chepyegon & Kamiya, 2018).

These meters also move the collection efficiency to 100% because all water is paid for before it is distributed. This enables the water company to have a healthy cash flow. The utilities also now minimize on commercial losses, which usually happen on account of recurrent human error and also the temptation of staff to collude with customers to adjust bills for a bribe (Gambe, 2015). "For example, the City Council of Harare, which is the WSP responsible for collection, is yet to collect "$132 million from its customer base and they do not have a strategy to recoup this money. This kind of inefficiency is a huge opportunity for the prepaid meter as a solution" (IMF, 2012). "The Harare City Council indicated that the new prepaid meter technology will help deal with their high non-revenue water. Most of their customers never paid when presented with estimated bills from the WSP. That is why they register high non-revenue water at 31%, which is mostly from customers who bypass the WSP meters or indeed just vandalize the network to access water freely" (Gambe, 2015). However, by 2018, the situation had not improved, because the City Council now was owed $733 million and this was largely due to untraced customers and a slack in governance (Chepyegon & Kamiya, 2018). In Kampala, when prepaid metering was introduced, the revenue increment was surprisingly low at only about 3% from $1097/month to $1129/month (Kayaga, 2014). As utilities start to invest in prepaid meters, it is very important when developing a business case, to consider the pay-back period for the investment that the utility is undertaking. Depending on what literature one reads, the pay-back period for these smart meters and prepaid meters can range from 3 to 15 years (Laporte-Vergnès & Franceys, 2010, Easterly 2009); but in general, prepaid meters have a quicker return on investment than conventional meters.

In South Africa, particularly in the city of Johannesburg, a pilot prepaid meter project was commissioned in 2004 in the low-income areas of Phiri and Soweto, and the idea was to do individual prepaid household connections. The project was welcomed by the residents with violent and vocal protests which multiplied against this project. The protests were so intense and dramatic and when there was an outbreak of cholera, the WSP was blamed for creating a very bad health situation (Heymans et. al., 2014). While the reaction of the Sowetans was exaggerated and grossly based on a misunderstanding of the system, these protests were eventually used as evidence by those who oppose prepayment for the gruesomeness of the system (Cross, 2005). Residents in Phiri and Soweto complained against the high cost of water, blaming the prepaid meter for the adjusted tariff, and they further complained when they learnt of the involvement of a private corporation, Suez (France), who was under a management contract with Johannesburg Water (Heymans et. al., 2014).

They felt that the interest of Suez was to make money and not serve the poor. The prepaid meters had only been installed in the peri-urban areas and service in these areas was disruptive and inconsistent, so there was a sense of victimization and the residents of the peri-urban areas rejected the meters. (Ali, 2010). Moreover, a simple study of the culture and social dynamics of South Africa suggested that protesting was in the cultural nature of South Africans at that time, especially as the country was in the post-apartheid era (ADB, 2017). The commotion was nonetheless quite substantial, and as a result, prepaid water meters were declared unconstitutional in 2008. After a year of consultations and discussions, the meters were legalized in 2009 and are now commonplace in South Africa (Heymans et. al., 2014).

On the other hand, in other countries the concept of prepaid metering has been appreciated and adopted with very little fuss. For example, in North Africa, the prepaid meters installed by Veolia in the peri-urban areas Rabat are very well accepted. The distinct feature in these communities as that the users were engaged and informed of the benefits from the design phase right through the installation and as a result, they demonstrated a high sense of ownership, and were vigilant in curbing vandalism and misuse of the meters (Bakker & Kooy, 2008).

Evaluation of Water Metering and Service Provision

WSP Managers are keen on integrating these meters into their operations and strategy, but they need high quality and detailed information and evidence that would help them evaluate the performance of the meters. To that effect, it is critical that there is a collation of performance indicators that measure cost, efficiency, effectiveness as a minimum and help inform the managers of usefulness of such technology. Most sub-Sahara utilities use data which collected and collated by IBNET, the Water and Sanitation data agency managed by the World Bank. Their strategy is to work with utility Monitoring and Evaluation Specialists to collect data against standard indicators on a regular basis, either annually or biannually (Heymans et. al., 2014). The international Benchmarking Network for Water and Sanitation Utilities (IBNET) has put together the indicators in table 2-3 below and these are considered to be the minimum set to be used by utilities and were developed after discussions with a wide range of water professionals (Heymans et. al., 2014) and put together by the International Benchmarking Network for Water and Sanitation Utilities (IBNET).

Table 2-3: Core Water Service Indicator Categories

Core Water Supply Indicator Categories	
– Service coverage	– Quality of service
– Water consumption and production	– Billing and collections
– Non-Revenue water	– Financial performance
– Metering practices	– Assets
– Pipe network performance	– Affordability of service
– Cost and staffing	– Process indicators

Source (IBNET, 2017)

This set is not meant to be a one size fit all. Each country and each water sector will be able to tweak these indicators to address and respond to the specific needs and requirements of each different context. Each WSP will add or subtract indicators to suit their requirements (IBNET, 2017). The indictors in general are expected to cover areas around cost recovery, labor, quality of service and pro-poor initiatives. As the WSPs get used to collecting data around these areas, the quality of the data and the usefulness of the core indicators will become more pronounced. This may not be the case when they start engaging in this practice (WASREB, 2013).

The Kenyan Government in 2010 signed into law a Bill that provides for the right to clean and safe water in adequate quantities for each resident (WSTF, 2015). The law devolved responsibility of water service provision from national to county governments, the counties now face the uphill task of adapting to the new law and environment and being responsive to the water and sanitation requirements of their constituents. In the new law, national government is responsible for policy, regulation and technical assistance. Other agencies have other responsibilities. For example, WASREB is the National Regulator. WSTF is mandated to source and disburse grants and other sources of finance to the WSPs and to ensure that their development projects have a focus on pro-poor activities. WSPs in general already are providing decent service to their communities and county governments should adopt strategies that enhance this momentum and that do not disrupt what is already succeeding. The promulgation new law however is a demonstration of the commitment of the Kenyan Government to ensure that Kenya has clean safe and accessible water. (Njoroge, 2011). Based on the guidance from IBNET, this commitment is demonstrated through the Government's service criteria related to access to safe drinking water and is summarized in Table 2-4. Ranking of WSPs is a key government strategy to enhance healthy competition from which the customers are the main beneficiaries (SUWASA, 2011). WSPs in Kenya are ranked and evaluated on the basis of nine Key Performance Indicators (KPIs). These are, Metering Ratio, Water Coverage, Non-Revenue Water, O+M Cost Coverage, Personnel Expenditure as a Percentage of O+M Costs Hours of Supply, Drinking Water Quality, Revenue Collection Efficiency and Staff Productivity (WASREB, 2013). The Water Act of 2016 further strengthened that commitment in that there is now more emphasis in the devolved states to ensure that services are well regulated, new water sources are developed, and that water services are managed and delivered to constituents efficiently. The nine KPIs are as in Table 2-4 below.

Table 2-4 Key Performance Indicators for Kenyan Water Meters & Service Provision

Key Performance Indicators	**Threshold**	**2014/15**	**2015/16**	**2016/17**	**Trend Analysis**
Water Coverage %	Above 80%	55	55	55	Constant
Drinking Water Quality %	95% Compliance with KEBS and/or WHO Standards	92	94	94	Constant
Hours of Supply/day	22 hours/day	18	17	14	Declining
Non-Revenue Water %	Less than 25%	43	43	42	Constant
Metering Ratio	99%	90	91	93	Increasing
Staff Productivity, Staff/1000 connections	Less than 11%	7	7	7	Constant
Revenue Collection Efficiency	99%	96	96	100	Increasing

Source (IBNET, 2017)

When evaluating the performance of the WSPs, apart from the KPIs, it is realized and taken under consideration that each county is different and that each WSP has to consider its own assumptions and parameters, which may not necessarily be the same as the rest (WASREB, 2013). As such, WSPs normally evaluate themselves against their previous year's performance to see how they are doing as opposed to comparing only with other service providers. Table 2-5 provides an example of the evaluation process in Kenya, exemplified by NAWASSCO and KIWASCO, service providers in Nakuru and Kisumu respectively. This ranking was done in 2015.

Table 2-5 Overall Ranking and Ranking by Category for Publicly Owned utilities

	DWQ %[1]	NRW %[2]	Coverage %	HS/day[3]	S/Conn[4]	P/OM %[5]	RCE (%)[6]	O & M CC[7]	MC[8]	Total Score	Ranking
NAWASSCO	92	31	90	17	5	30	99	104	96	132	3
KIWASCO	91	41	66	24	6	32	97	105	88	88	7

Source (Development Trust Fund, 2015)

[1] Drinking Water Quality
[2] Non-Revenue Water
[3] Hours of Supply/Day
[4] Staff/Metered Connections
[5] Staff Expenditures as % of O& M (Operation and Maintenance) Costs
[6] Revenue Collection Efficiency
[7] O & M Cost Coverage
[8] Meter Coverage

2.3 WATER SERVICE PROVISION IN NAKURU AND KISUMU

2.3.1 Nakuru County

Nakuru town, which as a population of 473,228 (2009), is 270 Km^2 in service area, 50 Km^2 of which is in low income areas, is one of the largest (4^{th}) city in Kenya and grows at an annual rate of 4.5% due to high rural-urban migration (see figure 2-5) (Mbuvi et. al., 2012) Approximately 207,843 people dwell in low income areas, (Ward, 2012); accounting for 40% of the urban population.

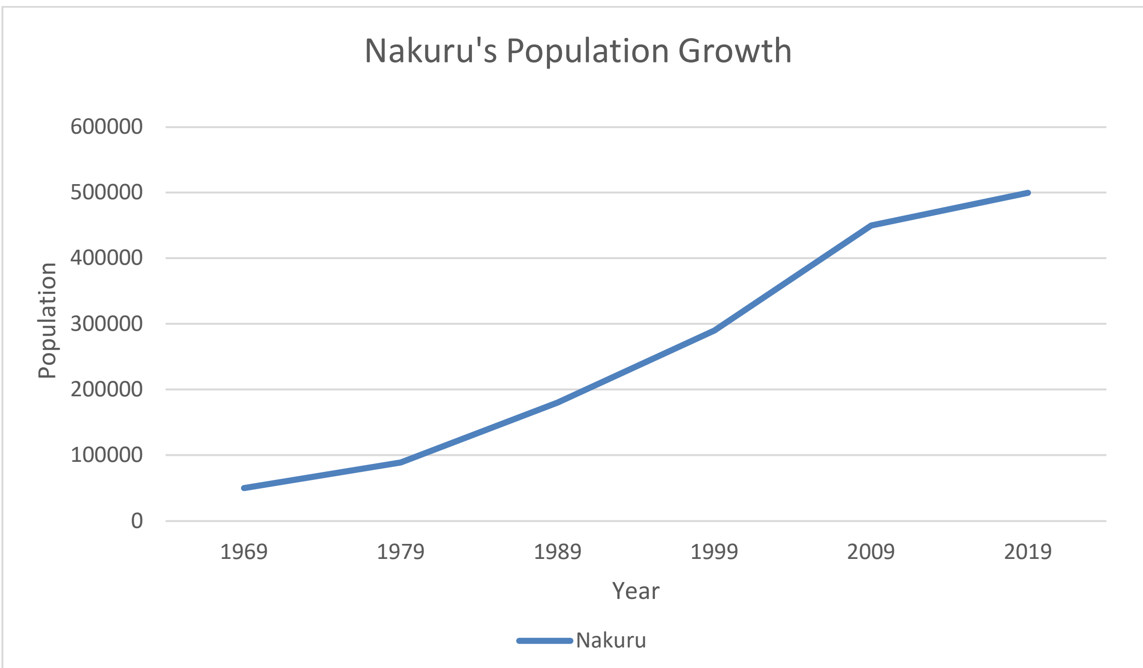

Figure 2-5 Projected Population Growth (Nakuru)

Source (Development Trust Fund, 2015)

Most of the residents in the peri-urban areas have access to Water Board, but there is a variation in the level of service. It is estimated that 6 % percent of all dwellers in these areas have an individual connection, 66% use a basic standpipe, 16% access water through utility kiosks, while 10% buy water from vendors, or from kiosks which are managed by communities. Vendors at kiosks peddle through 20-litre jerry cans at KSh2.00 while street vendors re-sell water to their customers for between KSh10.00 and KSh20.00 per 20 litres (Mbuvi et. al., 2012).

The majority of Nakuru's urban residents are the urban poor and they are also the ones who pay the most for water, per cubic meter and this is a higher cut on their monthly income (Dovey & King, 2012). Just like most African countries, this high expenditure is a factor that contributes to the poverty levels in Nakuru. The spiral effect is that vandalism, illegal connections, mushrooming of unregulated water vendors is a direct result of this inequality (UNHABITAT, 2011). The Water Service provider, NAWASSCO is impacted by these factors, because water theft has an impact on NRW, which has a knock-on effect on the WSPs ability to ring fence revenues for investments and improvements (SUWASA, 2011).

The WSP also has operational challenges is it does not ably manage its sewerage systems, leading to bad smelling environment and even water. Further to that, water supply is intermittent in some areas, and comes at a low pressure. The start-up cost is high and prohibitive to those in the peri-urban areas, and a study in 2013 magnified this because there were only 3,116 households without individual connections serving 24,928 people, because most could not afford the start-up fee of Ksh.2,700/=, accounting for the low coverage. There were only 2,069 yard taps serving 107,650 persons but water supply controlled by landlords who rationed water.

There are 34 water kiosks serving 17,000 people but these kiosks were not strategically located, leading to users having to walk long distances and had to ending long queues, especially in the morning and this increased the time spent in fetching water. (Chakava, 2013). There was a need for a solution to these challenges that would enable the WSP to improve service delivery to these urban poor customers.

2.3.2 Kisumu County

Kisumu has a population of 480,000 in 2017 (table 2-6) and is one of the major cities in Kenya. KIWASSCO, the local WSP operates under license from the Lake Victoria South Water and Sanitation Board, with the Board operating as the regulator, and monitoring performance (WASREB, 2013).

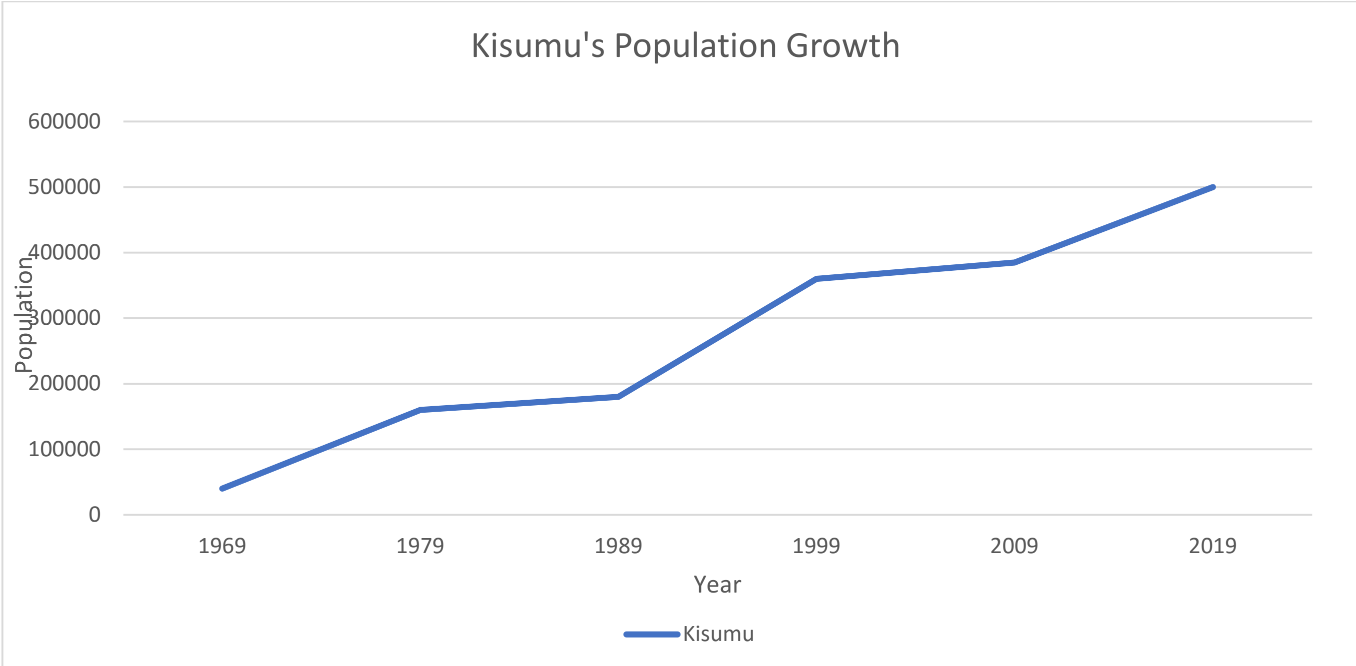

Figure 2-6 Projected Population Growth (Kisumu)

Source (Development Trust Fund, 2015)

By 2005, a mere 40% of Kisumu has access to clean piped water. The USAID program, Sustainable Water and Sanitation in Africa (SUWASA) carried out a baseline study and found that 83% used piped water either communal water points or vendor's tankers for drinking 55% used spring water and unprotected shallow wells for other domestic uses like washing and even cooking. There were consistent water outages, with 62% of the customers interviewed saying that their taps ran dry daily (SUWASA, 2011). Pipes burst frequently and there were concerns about water being contaminated. These inconsistencies led to vandalism, leakages and non-payment of bills. The water utility in 2007 had high non-revenue water at 66% (Kamani et. al, 2012).

KIWASCO was concerned with the increasing rate of non-revenue water and the challenges in the peri-urban areas and as such, piloted a concept, where they delegated the management of services to a master operator to manage water supply, billing, revenue collection and basic maintenance within a specified area. This was a spin-off of the Water User Association Model in Malawi, only that in this case, instead of running the area through a committee, an individual was responsible (Onyango, 2012). In this arrangement, which was called the Delegated Management Model (DMM), these Master Operators come from the community, to ensure that all decisions and issues around the DMM are responsive to the concerns of the communities, who are considered as the principle stakeholder. (Gerlach and Franceys, 2010a). The division of responsibilities is as follows: KIWASCO is responsible for installing and reading the master meter, technical piping work, and ensuring pipes are provided to high demand areas (O'Regan, 2012). The Master Operator is responsible for delivering water to residents, receiving money from customers and paying bills to KIWASCO, reporting problems to KIWASCO, and reading the meters accurately (Mbuvi et. al., 2012).

The aims of the delegated management model therefore, is to register savings by reducing non-revenue water; to make sure that there is consistent service delivery and managed at the lowest level; to create employment opportunities while drawing from the vast knowledge, expertise and experience of local tradesmen and to significantly increase the peri-urban areas access to high quality water services (Onyango, 2012). However, the Delegated Management Model which had been piloted was not being taken to scale and the issues and concerns were that there was low connectivity; only 14,210 connections for a population of 379,000 had connected to KIWASCO's network (SUWASA, 2011). As indicated in table 2-6, this represents 20.4 %-meter coverage (assuming each household has 5 residents (DTF, 2015) Residents of the low-income areas did not have access to potable water. KIWASCO had a new treatment plant, commissioned in 2011, and an abundance of water supply and needed to match that development with new connections but residents were not connecting to the KIWASCO network (Jacobsen et. al., 2012). Studies to find why there were challenges of low connectivity showed that that the high start-up fees for new water connections for the poor was restrictive (SUWASA, 2011; Kamani et. al., 2012). This suggests that the DMM in its current state needed to be improved on and modified to enable water utilities to achieve better service in the peri-urban areas.

Table 2-6 Key Metering Statistics in Nakuru and Kisumu

Nakuru	
Meters Connected	34,500
Meter Coverage	89.62%
Meter Water loss (NRW)	31.46%
Meters coverage in residential areas	69.24%
Kisumu	
Meters Connected	14,210
Meter Coverage	20.4%
Meter Water loss (NRW)	41.22%
Meters coverage in residential areas	41.09%

Source (IBNET, 2017)

2.4 PERFORMANCE COMPARISON METHODS

In choosing which method to use when coming up with a comparison method, a decision was made based on the type of data being compared and what the research questions were interrogating through the research. Thought was also given on the data analysis techniques that would apply to the data when it is collected. The statistical test that is appropriate for this study was chosen from these five options:

2.4.1 The Wilcoxon Signed-Rank Test

The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used to compare two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks (the arithmetic average) differ (IBNET, 2017). Normally used as a nonparametric test that can be used to determine whether two dependent samples were selected from populations having the same distribution (Shuttleworth, 2008).

2.4.2 The Dependent T-Test

The dependent t-test (also called the paired t-test or paired-samples t-test) compares the mean ranks of two related groups to determine whether there is a statistically significant difference between these means (Yin, 2009).

2.4.3 One-Way Analysis of Variance

The one-way analysis of variance (ANOVA) is a technique that can be used to compare means of two or more samples using the F-distribution. The ANOVA tests the null hypothesis that samples in all groups are drawn from populations with the same mean values. To do this, two estimates are made of the population variance (Shuttleworth, 2008). These estimates rely on various assumptions. The ANOVA produces an F-statistic, the ratio of the variance calculated among the means to the variance within the samples. If the group means are drawn from populations with the same mean values, the variance between the group means should be lower than the variance of the samples, following the central limit theorem (Yin, 2009).

2.4.4 Chi -Squared Test

A chi-squared test, also written as $\chi 2$ test, is any statistical hypothesis test where the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true. The chi-squared test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories (Shuttleworth, 2008).The purpose of the test is to evaluate how likely the observations that are made would be, assuming the null hypothesis is true.

2.4.5 The Odds Ratio

The Odds Ratio (OR) measures the association between an outcome and a treatment/exposure, or in other words, a comparison of an outcome given two different groups (IBNET, 2017). The OR is a comparison of two odds: the odds of an outcome occurring given a treatment compared to the odds of the outcome occurring without the treatment. Odds represent the probability of an event occurring divided by the probability of an event not occurring. An OR value of 1 indicates no effect on the odds from the exposure to the outcome; of OR values less than 1 indicate that lower odds of the outcome are attributed by the exposure; and of OR values greater than 1 indicated that higher odds of the outcome are attributed by the exposure (Shuttleworth, 2008). To calculate OR, the frequencies of two dichotomous variables are required.

The ANOVA and the Odds Ratio were chosen as the most appropriate methods. The ANOVA tests more than one sample area, which would be useful in the dual cited study in Nakuru and Kisumu. When using ANOVA, the basic assumption is when taking samples from a population, the samples must have equal variance, the population sample should be normal, and the observations should be independent of each other. Also, because the dependent variable in this study, improved service delivery in the urban poor areas, has a binary outcome.

The Odds Ratio was also preferred because is a relative measure of effect, which allowed the comparison of the Communal Prepaid Meter (CPM) and the Delegated Management Model (DMM) but also relative to the comparison of conventional metering models in the two study areas. If the outcome is the same in both groups the ratio will be 1, which will imply there is no difference between the two. It was assumed that a sound conclusion could be arrived at if the two statistical tests interpreted the data and gave similar outcomes.

2.5 DEVELOPING AND INSTALLING METERING MODELS

In developing a good metering strategy, it is important to pay attention to the many influencing factors that need to be tied together in the development process, so that the design is responsive to the needs, desired level of service, topographical and geographical considerations and the financing needed to implement and install the meters. Then, with these issues in consideration, step by step strategies can be developed, with clear priorities to tackle each of the components (Chepyegon & Kamiya, 2018). This was the analytical approach that was applied to develop the two metering models. Firstly, when setting to design a metering model is to understand the distribution network, the characteristics of the network, how many people are connected to the network, the pressure dynamics, the flow rate, the pipe sizes, the spread of the area and the topography? These parameters help in developing tools and strategy (Holt, 2015). The components of NRW, and the priority areas of the network for investigation, can be determined by conducting a water balance.

Further to these physical characteristics, there is a need for the WSP to understand how NRW is determined in the area, how of it is ascribed to real losses and how much is ascribed to apparent losses. A key step also before meter installation is to ensure that the hydraulics have been fully addressed, with the area set up in appropriate pressure zones, which are in tandem with the geographic zones using boundary valves and district metering.

Once the technical assessment has been done, the network can be assessed to determine how much of it needs to be upgraded to help reduce losses, manage pressure, and keep NRW as low as possible (Collignon & Vezina, 2016). In both the study areas, the WSPs are running networks in the low-income areas that are dilapidated, requiring major upgrades. The WSPs have poor data management and record keeping, and there is a need to improve the capacity of their staff to handle any upgrades. The tariff structure is not based on cost recovery, and the operation and maintenance policy are lacking. The WSPs also need to ensure that they are paying attention to the fundamentals such as zoning. The concept of zoning is basically to break up a large network into smaller manageable areas which are called zones, which can be analysed, observed and maintained with more ease. This allows for better monitoring, more accurate pressure management and control of flow. Zones are also only effective if a good metering strategy is in place because all measurements are through the installed meters. Measurements are there essentially to generate data for the water balance calculation (Collignon & Vezina, 2016). Monitoring the flow of water consistently is a step towards managing the reticulation effectively. This collates with a good customer enumeration exercise which is essential in helping the WSP in being able to forecast demand growth and also to monitor activities around non-revenue water.

2.6 SUMMARY OF LITERATURE REVIEW

This review reviewed literature that closely focuses on providing services to the urban poor communities in sub-Sahara Africa with the aim of finding applicable solutions that could be used in Kenya, and replicated in the region, with an overarching aim of achieving the sustainable goal number 6 of universal access to water by 2030. The real challenge being that sub-Saharan water utilities are good at providing water in developed urban areas while Governments and non-Governmental organizations tend to focus on water supply in rural areas. The literature review reveals that 70% of urban dwellers in the region live in these peri-urban areas (231 million in 2015), but up to 60% of these do not have access to decent water. The devolution process in Kenya, as reflected in the water sector while having been effected from 2016, has uncovered numerous problems, mostly due to poor governance, that need to be addressed in order for the transition to be smooth and for there to be sustained access to clean water in the urban poor areas. The overarching drive being that the United Nations has set a

Sustainable Development goal that there should be access to all by 2030. This study hopes to contribute to this quest by introducing innovations that if successful, can be taken to scale and help to increase coverage significantly.

This is however a knowledge gap when it comes to water provision, and there are inadequate engineering tools when it comes dealing with high density peri-urban areas. To address that gap specifically, the review focused on prepaid metering and the delegated management model, which are applied in Nakuru and Kisumu, and examining their suitability specifically in two designated peri-urban areas. The two tools are not mathematical models but practical models which were developed to help provide clean water in the urban poor areas. As has been discussed at length so far, the implementation of prepaid meters seems to have positive impact on customers' way of managing their households. The review suggests that there is some scholarly discussion on various service provision options that are available within sub-Sahara Africa, most which have had varying levels of success, but the literature suggests that metering options are tools that water service providers are most akin to and which will help them to increase coverage, especially in the low income communities which are underserved in most cities. Of the metering options available, the prepaid metering and delegated management models are the tools that have been piloted in Kenya are capable of addressing the main research objective of this study, i.e. to develop innovative water metering technologies for improving the water supply among the urban poor in Kisumu and Nakuru. Literature suggests that there are challenges with individual prepaid meters, especially in low income communities. Literature also shows that the delegated management model while having been piloted in Kisumu with some success will need modifications and improvements to ensure that the model remains sustainable.

CHAPTER THREE: MATERIALS AND METHODS

3.0 INTRODUCTION

In the literature review, it is clear that in sub-Sahara Africa there is a growing recognition of the fact that while the water sector continues to grow and improve, there is a clear challenge and lack of strategic focus on service to the urban poor who dwell in peri-urban areas. There is a lack of a systematic and deliberate focus on metering strategies that can help address this growing concern. This chapter therefore describes two approaches for evaluating the performance of metering models and how they help address the water demand and specific requirements and needed level of service for the low-income communities.

3.1 AREA OF STUDY

This study could have been done almost anywhere in sub-Sahara Africa, but was focused in Kisumu, which is the third largest city in Kenya and Nakuru, which is the fourth largest city in Kenya. It was projected that by the end of 2017, Kisumu would have grown to 800,000 and Nakuru would have grown to 760,000. Most of the residents of these two cities however live below the poverty line, with figures estimating up to 80% living below the poverty line (UN-DESA, 2017).

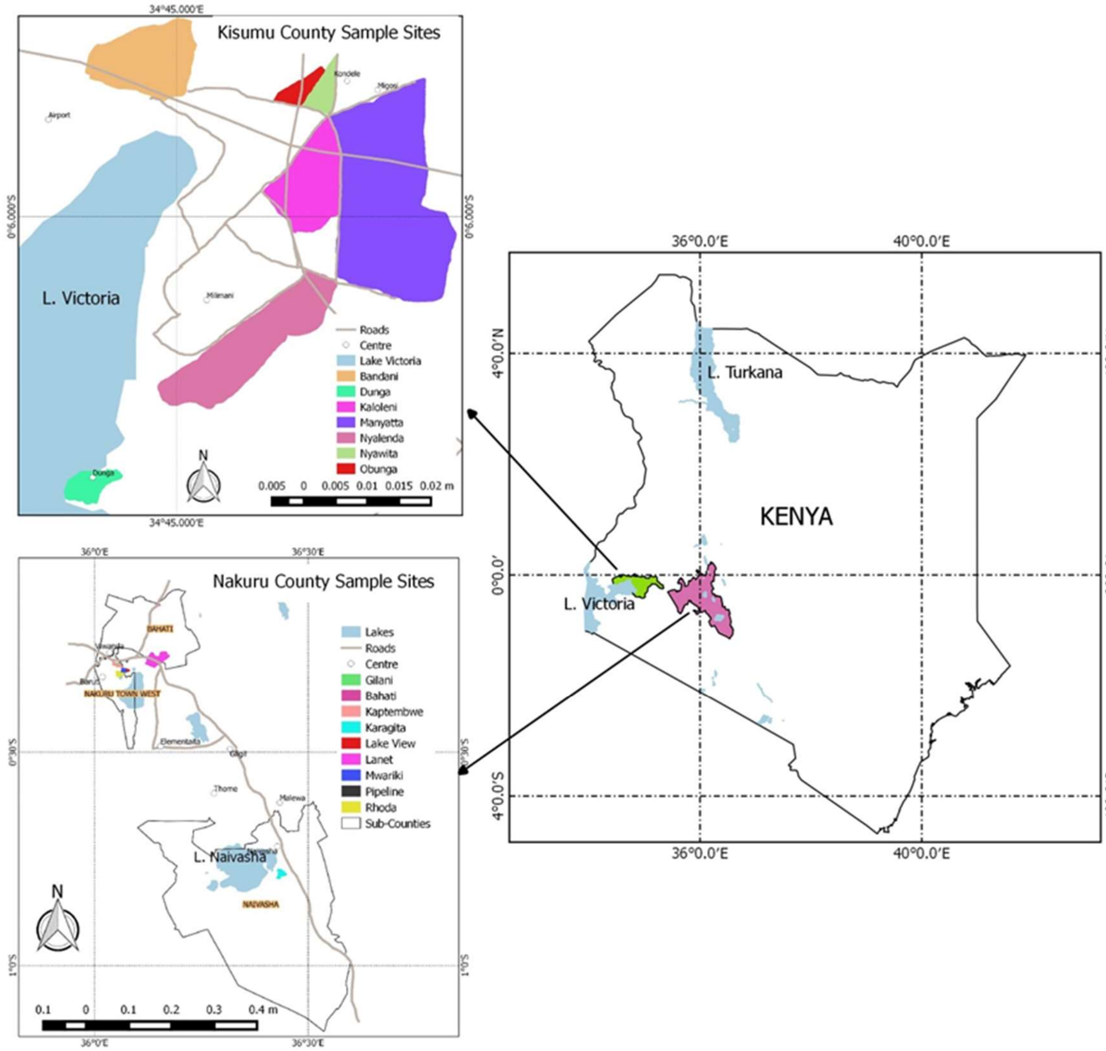

Figure 3-1 Location of the Study Area

Source (Author)

Nakuru is served by the Nakuru Water and Sanitation Services Company (NAWASSCO) serves 70% of the population, through 40,900 customers who are metered (WASREB, 2011). In contrast, only 29% of the Kisumu population (table 3-1) is served by Kisumu Water and Sewerage Corporation (KIWASCO) through 14,000 customers who are metered (WASREB, 2011). This low coverage in Kisumu is due to the fact that most of the low income areas are not yet provided with potable water, hence the need for innovative interventions.

Table 3-1 Key Parameters in the two Study Areas

Parameter	Nakuru Town	Kisumu Town
Total population in service area	674,789	525,313
Population served	472,352	153,083
Percentage of population served	70.0%	29.1%
Number of metered connections	34,500	14,210
Non-Revenue Water (NRW)	31.46%	41.2%
Drinking water quality compliance (KEBS*& WHO standards)	64%	91%
Average time to fetch water from nearest water point	1 hour	1 hour

Source (WASREB, 2011)

3.2 CONCEPTUAL FRAMEWORK

By developing and installing metering solutions in Nakuru and Kisumu, this research was conceptualized to ask the question: 'Are innovative applicable engineering and financial interventions valid tools for performance enhancement for water provision to low income communities, and are they helping the water sector take a significant step towards achieving the Sustainable Development Goal of 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all?' Below are issues extrapolated from the literature, and a brief demonstration of how this research contributes to knowledge?

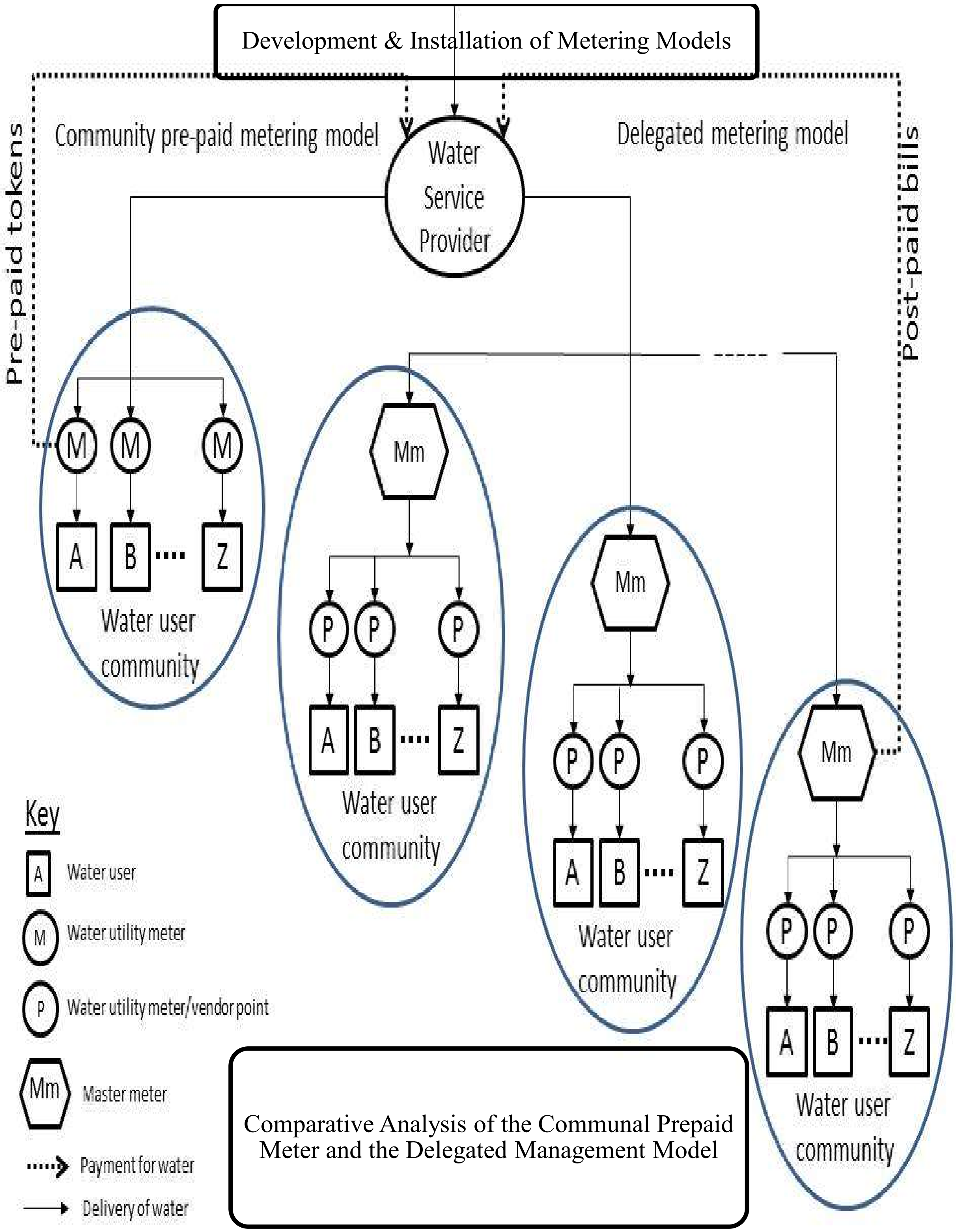

Figure 3-2 Conceptual Framework

Source (Author)

The data lent emphasis on the design of the CPM system in Nakuru and the delegated management model in Kisumu. Data loggers were used to monitor the performance of the meters installed in the two sites, and district metering (this is when meters are used to create hydraulic boundaries), using zonal meters was adopted in Kisumu as well to enhance the performance of the delegated management model zones that were selected. With reference to figure 3-2, meters were installed at Mm for the DMM and at M for the CPM. Data, using the data loggers, was collected at point Mm and (A, B…Z) for the delegated metering model and at (A, B…Z) for the communal prepaid metering model. The data generated, was analyzed using the tool, analysis of variance (ANOVA). The conceptual framework was the backbone from which results were interrogated of the performance of the DMM and CPM under a select list of performance indicators. The conceptual framework was setup to detail the data collection methods, research questions, and evidence needed when addressing the questions, to provide guidance for the field work and to help formulate an analysis strategy. The framework is shown in figure 3-2.

3.3 WATER METER INOVATIONS

3.3.1 Communal Prepaid Water Metering

In this study, the communal prepaid meters system has been designed using the microcontroller IC 89C51 with the help of serial data transfer Inter-Integrated Circuit (I2C) protocol. The Microcontroller IC acts as a main controlling element for the overall functioning of the system. It is designed such that the memory IC acts as a smart card on which the prepaid amount has been loaded by the user and then he put that IC in the system. After that, the system turns on and makes the water supply on by detecting the credit loaded on with the help of solenoid valve. After turning on, the supply of water is continued till credit on the smart card reaches zero value. As soon as the unit value reaches zero, the water supply is break through the solenoid valve. The block diagram of the Prepaid Smart Card System for Water Supply has been shown in the Figure 3-3. Flow meter senses continuously the flow of water from the pipe. As the water flows, it is measured in litres and this is done continuously until the credit runs out. When the credit is finished, the solenoid valve switches off and that in turn triggers the water supply to shut down. The four Light Emitting Diodes (LED's) has been connected to indicate the status of the system. There is a requirement of the smart card programmer so that the smart card can be recharged easily. This has been shown in the Figure 3-3. This system consists of microcontroller IC 89C51, smart card slot where the smart card to be inserted, different switches for recharging the smart card and Liquid Crystal Display (LCD) for display of recharge status. The LED has been connected to show the status of the overall system.

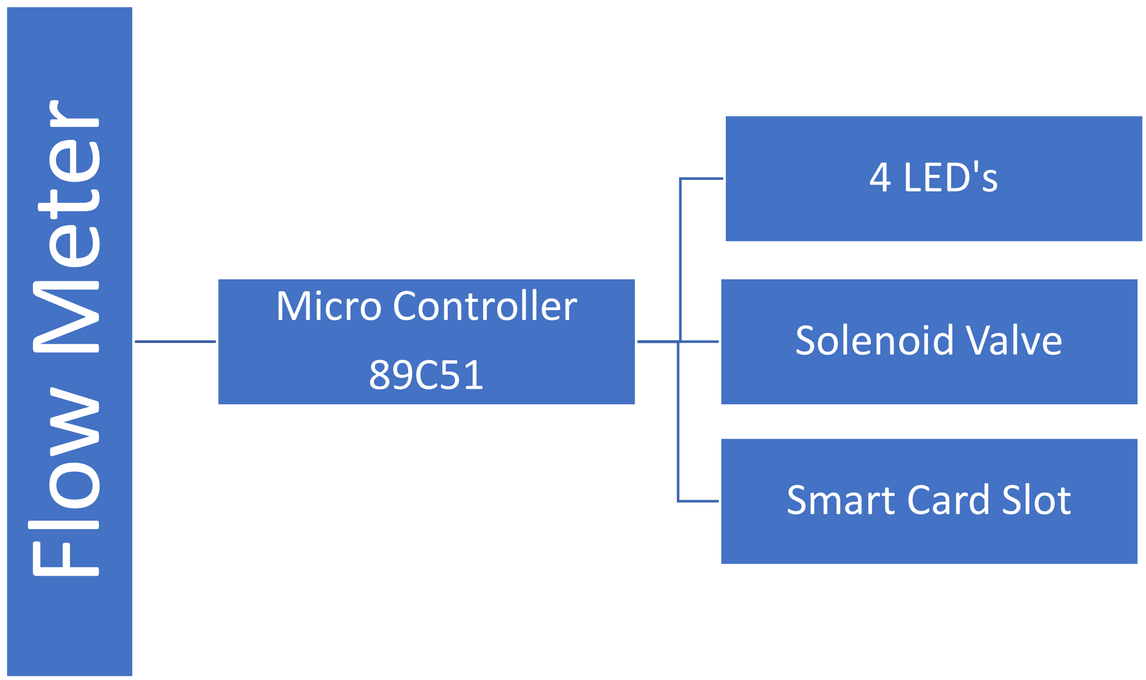

Figure 3-3 Block Diagram for the Communal Prepaid System

Source (Author)

Algorithm for the prepaid system:

1. Insert the smart card in the smart card slot.
2. Read the value on smart card.
3. Turn on the water supply with the help of solenoid valve.
4. As water passes through the pipe, count the units of water passed and continuously decrease the units on the smart card. This assumes no leakage between the meter and the point of water drawn by the consumer. (This is a safe assumption, if the CPM is properly designed and installed, and usually the distance between the meter and the draw point is less than a foot.)
5. When the units on smart card reaches zero, turn off water supply by closing the solenoid valve.

Algorithm for the smart card recharges system:

1. Insert smart card in the slot.
2. Display the current status of smart card on the display.
3. Enter the units on smart card with the help of switches.
4. Display the status of smart card on the display.
5. Remove the smart card

3.3.2 The Delegated Management Model

The delegated management model was designed so that water utilities sell bulk water to agents contracted to operate and manage to a master operator who is under contract to run a section of the reticulation, especially in peri-urban areas. The WSP will select master operators through a public competitive selection progress. These are residents of the communities that they will be serving. The master operator in an arrangement similar to a public-private partnership will be under contract with the WSP to operate the given area through billing, revenue collection, operation and maintenance. A master meter which measures water flowing into the area will be the basis from which the master operator pays the WSP and any surplus from his collected revenue is used for operation and maintenance and his marginal profit. Through delegating in this way, the utility is expected to reduce administrative costs and allow customers to have a nearer point of interface in comparison to the WSP which can seem distant at times. The model offers consumers a few options to select their level of service: private connections (with the option of paying the start-up fee in instalments via an arrangement with a microfinance agent), shared standpipes, and commercial kiosks. The microfinance agent recovers his money from the utility directly. Tariffs are negotiated between the master operator and the WSP but are kept at a rate that is pro-poor.

3.4 DATA REQUIREMENTS AND COLLECTION STRATEGIES

3.4.1 Data Types

Table 3-2 below provides a summary of performance indicators and data types that guided this research.

Table 3-2 Performance Indicators and Data Types

Performance Indicators	Data Types
Existing Metering Strategy 1. Coverage in peri-urban areas	1. Population Density, number of connected meters, illegal connections
Water Metering Types 2. Coverage in peri-urban areas 3. Customer satisfaction	2. Population density, Demand (Litres per Capita), number of individual connections, number of standpipes (customers served per standpipe), areas unserved, number of meters 3. Market Survey, Customer Enumeration
Performance Indicators 4. Levels of non-revenue water 5. Cost of Water 6. Water Borne Disease Incidence 7. Time taken to fetch water 8. Potable Water	4. (Water Produced, Water Billed, Water Sales) 5. Cost of production, treatment and distribution, Energy Costs, Staff and administration 6. Record of water related illnesses in hospital 7. Survey, Questionnaires, Observation 8. Utility Lab Tests, KBS Verification Tests

Source (Author)

3.4.2 Sampling and Data Collection

Data collection was guided by the following parameters: coverage in peri-urban areas, customer satisfaction, incidence of water-borne disease, non-revenue water, cost of water, time taken to fetch water and potable water. WASREB also uses these parameters in evaluating the performance of water boards in Kenya (WASREB, 2010).

The study was designed such that samples were collected from the two study areas in sets of two, i.e. each sampled from sites with and without the study metering models in equal amounts. Data collection was deliberate, and through focus group discussions, field visits and interviews. Interviews targeted water-user households, water vendors/meter operators, and staff members of the WSPs Collection were done through a deliberate process of interviews, focus group discussions through field visits. The FGDs targeted members of the community, members of the WSP, water user associations, water vendors and landlords. The primary data collection was through the methodology; focus group discussions (as stated above), questionnaires, surveys, interviews and surveys.

The questionnaires were categorized. The household sessions focused on issues around cost of water, satisfaction, waterborne disease incidence and time/distance taken to fetch water. The WSP interviews focused on water quality, non-revenue water and coverage. During the field visits, the investigation was focused on getting data on the frequency of leakages and the number of times the WSP experienced outages.

The study design was conceptualized so that for each city, Kisumu and Nakuru, there would be study areas with the metering models, i.e. the CPM for Nakuru and the DMM for Kisumu and areas without the models, (which in their case would have the old kind of conventional meters) but the constant would be that each area studied would be served by the same water board. The normal conventional metering model consists of a post-read meter which measures flow on a monthly basis and readings are taken manually by a meter reader and the readings generate a bill from which the customer is expected to pay on a regular frequency.

In response to the rainfall patterns of Kenya, primary data was collected during the dry season (January – March 2012) followed by more data during the second dry season (July 2012). To have a clear appraisal of extent the DMM and the CPM impacted on the key parameters, the dry season was chosen as the best time for the investigations, because studies has shown that during the dry season, water demand is high in households (WASREB, 2010).

532 households (288 in Kisumu and 243 in Nakuru) and 133 employees of the service providers (49 in KIWASCO and 84 in NAWASSCO) were selected randomly for interviews. While being randomly selected, there was a uniform spread across the target low income communities, (6 in Kisumu and 9 in Nakuru). Using questionnaires which were designed in advance, interviews were conducted, and key questions explored how the DMM and the CPM can help to enhance water provision in the urban poor communities. The interviews were both structured and unstructured and open ended. Nominal and ordinal data was used in analyzing the findings, to ease the process. Ordinal variables were used inform on the customers options, while nominal variables informed on values such as the demographics of the two study areas. The collection methodology can be described as being by primary means, through focus group discussions, observation, and key informant interviews (as described above) and surveys through interviews. FGDs were used to engage the communities to get their opinion on the WSP performance, as defined by the study parameters. There were four FGDs in Kisumu and six in Nakuru, while in totality, there were seven field visits carried out in Kisumu and similarly, seven field visits carried out in Nakuru.

3.5 DATA ANALYSIS

To explore the relationship between DMM and CPM, and the impact the meters had in the study areas, through independent interviews and questionnaires, this was asked "in general, is there a sense of satisfaction with how the DMM is delivering services to your household DMM (in Kisumu) and CPM (in Nakuru)?" The independent variables consisted of the key indicators which have been listed above.

To explore the positive (and negative) impact that CPM and DMM has in helping peri-urban areas to access clean and safe water, the study operationalized these two indictors, Incidence of Water Borne Disease and water quality (Potable Water).

The outcomes helped to establish to what extent DMM, and CPM have an impact, as these are key performance indicators for effective water service provision for any water utility that is providing water in low income communities. The analysis was carried out at 5% level of significance.

Data that was generated from interviews was captured through written notes and meetings were recorded using voice recorders. This was to ensure data accuracy, especially when doing focus group discussions and key informant interviews. Using a laptop that was dedicated to this study, the transcripts from the FGDs were saved in separate files. The reports from the focus group discussions were also saved separately, but in the same laptop. Answers to the open-ended questions in the questionnaire were looked over, with the aim of making edits to ensure that everything logical and consistent and the answers were kept on a spread sheet. With this, it was easy to group all the responses and align them against similar themes and patterns. The themes were then triangulated with other data sources to harmonize the information. Where an interviewee had a unique but very valid viewpoint, he and his contribution were duly noted as well. All the data collected, the literature written, the tables and analysis were all saved and were used for verification.

Having gone through this stage, the last phase was to interpret the data and have an-depth understanding of what the data collected means. This thought process is what led us to the research conclusions. On the other hand, answers generated from the closed ended questions produced quantitative data. This data was cleaned and verified before it was given appropriate codes before being analysed. Checks were done as well, for some instances where there was a distinct difference between the viewpoint of the various kinds of interviewees such as water companies, local government, the private sector and NGOs.

3.5.1 Performance Evaluation

The CPM and the DMM were implemented and assessed in the two study areas, i.e. the CPM in Nakuru and the DMM in Kisumu between January 2011 and January 2012 (Figure

3-2). The CPM is a model that was tested in Nakuru where instead of the normal water point, you have an automated prepaid meter which is activated by tokens which customers can access at the WSP and get credit. 91 CPMs were installed. The DMM is a metering model where the WSP delegates the management of predefined areas to mater operators. The master operators are responsible for operation, maintenance, billing and revenue collection in these areas and they remit collected revenue to the WSP on a monthly basis, in tandem to a reading that is taken at a master meter. This was piloted in Kisumu with 6 master operators.

Government of Kenya guidelines (WASPA, 2018) were used in developing and deciding where and how these water meters should be installed. The CPM had the aim of targeting 15,000 people in Nakuru by improving the quality of service delivery and water, in six urban poor areas (Figure 3-1). The DMM in Kisumu covered 1539 household connections (individual) and 1557 connections through the following: water kiosks, hospitals, clinics and schools (Figure 3-1).

Each performance indicator has a threshold defined that helped in this study to show how it is behaving relative to expectation. In this instance, static thresholds were set, and they are as in table 3-3. These were developed, with reference to performance indicator guidelines that were developed by the International Benchmarking Network for Water and Sanitation (IBNET) to guide water utilities in service provision. As indicated by IBNET, utilities which are strong in cost of water, coverage and non-revenue water and usually tend to be utilities which are focused on commercialization, growth and business models. On the other hand, utilities which are strong in customer satisfaction, time to fetch water, potable water and water borne disease tend to be focused more on customer service, levels of service for customers and customer satisfaction.

3.5.2 Qualifications in an area for a Metering Strategy

When designing a metering strategy, focus is on finding gaps between water demand and factors to consider when designing a metering system in peri-urban areas include first target area's population for purposes of determining whether there is adequate demand to justify the investment. In understanding the demand for water, it was clear that the economic, social and political conditions, both within and outside the study areas also had an impact water supply and demand. This analysis was closely followed by assuring that in the study areas, there was adequate and consistent supply to meet and address that supply. An appreciation of the topographical lay out and the environmental condition of the study area helped in determining the appropriate technology, i.e. the pipe sizes, need for pressure management valves, gauges and other appropriate technology to support the installation of the meters. Failure to employ appropriate technology could have led to water stress, expensive high-pressure meters and a general higher cost of water. Once the larger picture was clear, an understanding of the requirements of the urban dwellers was critical. There are several levels of service options available, like the standpipe, the communal water point, individual household connections and the water kiosk. Each level of service has its own metering strategy and by understanding the level of service required in the study areas, it was a good guide as to what metering strategy would be appropriate in the areas.

Table 3-3 Performance Indicator Thresholds

Performance Indicator	Threshold	
	With study model	Without study model
Coverage	85% (± 4%)	61%
Customer Satisfaction	95% (± 2)	75%
Non-revenue water	27% (± 3)	49 %
Cost of Water	Tariff within 98% (± 2) of actual cost of water	Tariff within 85% of actual cost of water
Water Borne Disease Incidence	1/1000 persons/year	5/1000 persons/year
Time taken to fetch water	15Mins	30Mins
Potable Water	100% compliant to WHO & KEBS Standards	90% compliant to WHO & KEBS Standards

(Source: adapted from IBNET, 2017)

3.5.3 Performance Evaluation

The Wilcoxon signed-rank test and the dependent T-test were considered but not preferred for this study because the parameters of the two study areas, Kisumu and Nakuru, were not dependent of each other, and the study models, the CPM and DMM were also not dependent of each other during the study. The chi-squared test was also considered, but because it was anticipated that there would not be a noticeable discrepancy between the expected and observed frequencies in the CPM and the DMM.

The ANOVA and the Odds Ratio were chosen as the most appropriate methods. This was so, because the ANOVA tests more than one sample area, which would be useful in the dual cited study in Nakuru and Kisumu. ANOVA assumes three things, that the population sample must have equal variance, observations should be normal, and the observations should be independent. Also, because the dependent variable in this study, improved service delivery in the urban poor areas, has a binary outcome.

The Odds Ratio was preferred because is a comparative measure of cause and effect, which allowed the comparison of the CPM and the DMM but also relative to the comparison of conventional metering models in the two study areas. If the outcome is the same in both groups the ratio will be 1, which will imply there is no difference between the two.

The objective of analysing data is fusing both qualitative and quantitative evidence research question by probing, classifying, organizing and testing the data (Yin, 2009). As previously stated, both qualitative and quantitative data types were collected for this study. The questionnaires generated quantitative data while qualitative data mostly came from participatory observations, documents, key informant interviews, questionnaires, and the FGDs.

The study parameters (7 data types and 8 indicators as in table 3-2) went through a comparative statistical analysis with the installed study metering models and without installed study metering models which was done between cases. It was necessary to assess the impact of the DMM and the CPM in the study areas on each study parameter and One-way analysis of variance (ANOVA) was the preferred means for achieving that. This was necessary in order to determine the extent to which there are any statistically significant differences between the 7 independent data types; levels of non-revenue water, coverage in peri-urban areas, customer satisfaction, cost of water, incidence of water borne disease, time taken to fetch water and potable water. Data analysis was two-fold, (a), to learn how the DMM and CPM has impacted in the two study areas, and (b) to investigate the positive and negative contribution metering has made in the key indicators i.e. Levels of non-revenue water, Coverage in peri-urban areas, Customer satisfaction, Cost of Water, Incidence of Water Borne Disease, Time taken to fetch water and water quality (potable water). ANOVA was used to determine the association the dependent variable (DV) and independent variables (IV) using primary data from the study.

As stated earlier, ANOVA was appropriate because for this study, service delivery in urban poor areas which is the dependant variable, had a binary outcome. Further to the ANOVA, the Odds Ratio (OR) was used to also verify if there was coloration the independent variables and dependent variables. An Odds Ratio is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. For this study, the 95% confidence interval was used to determine the accuracy of the OR. A large confidence interval would indicate a low level of accuracy of the OR, whereas a small confidence interval would indicate a higher level of accuracy of the OR.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0 INTRODUCTION

Prior to installing the metering models, 15% of the people who dwell in the Nakuru study area and 39% of those who dwell in the Kisumu study area Nakuru did not have access to safe and potable water. In the low-income urban communities' residents sourced their water from communal water points, standpipes, unprotected sources or private water sellers (Hanjahanja and Omuto, 2018). They would have to walk up to a kilometre to draw water from unsafe wells draw water from rivers, or paid water sellers for highly priced water nearer their dwellings (Abrams, 1999). Purchasing water from standpipes normally involved conflict over sharing and paying for the revenue, and at the same time, the standpipes were rendered useless when the water company has disconnected the service because of non-payment (Mbuvi et. al., 2012).

The installation of the DMM and the CPM respectively was designed to counter these challenges and to help the two water utilities, KIWASCO and NAWASSCO to improve on water service provision in the peri-urban areas against the key indicators coverage, non-revenue water, customer satisfaction, cost of water, time taken to fetch water, water borne disease incidence, and potable water. The findings show that the DMM and CPM are sustainable models. They are sustainable because the technology adopted is user friendly, easy to maintain and easy for both the utility and the users to handle (in the case of the CPM) and is easy to adopt, apply and take to scale in the case of the DMM. As such, the utilities will now be able to cope with growing low-income communities, and as such, there is an opportunity to meet unsatisfied demand for potable water in these areas. This is so because the DMM and the CPM are models that able to address this concern (Hanjahanja and Omuto, 2018).

4.1 INSTALLATION OF METERS

The DMM is a viable tool for water provision in the urban poor communities. It is appropriate in that it removes the water utility from being the interface with the customers, as the role is delegated to master operators. The MO's are people from within the community, known leaders and entrepreneurs and the study found that customers were comfortable with dealing with the

MO's as compared to KIWASCO directly. It is also appropriate because the MO's are motivated to install meters, collect issue bills, collect revenue and handle faults in a more efficient manner, as the cost of inefficiency has a direct bearing on their business model. In the DMM, meters are installed by the MO, but only within the delegated hydraulic area that has been assigned to them by the utility. The advantages of this model are that customer service and satisfaction is high, and the utility is assured of its revenue in the delegated areas, but the model is limited in that, there are a few DMMs and the concept needs to spread, the MO is unable to directly influence the consistency of water flow from KIWASCO and the MO is also unable to affect the water quality. The is because the MO is not an employee of the Water Company, he just buys water in bulk from the company so he has no influence on the water flows or water quality. There have been incidents where a meter has been installed in a neighbouring DMM because the hydraulic boundaries were not clearly defined. In this study, one key input was the introduction of district metering and boundary valves to ensure that boundaries are clearly defined and that there are no such overlap. Vandalism is reduced in the model because the Mo is highly motivated to protect his investment and as such, he conducts regular inspections and monitors his network more frequently than KIWASCO was able to.

The communal prepaid metering model was found to be very useful in Nakuru. The fact that residents can access water at any time of their convenience without having to wait for an operator was a big value addition. They were effectively already buying water 'prepaid' before the study because they would buy water in pails using KES. The local leaders were the ones responsible for ensuring safety and doing minor repairs on the CPM, but NAWASSCO does do routine visits to ensure that the technical side of things is up to date. During the study, only 93 meters were installed, and this presents an opportunity for growth as these meters are only serving up to 18,000 residents. The location of the meters was also seen as a welcome development as the CPMs are assisted such that residents do not have to walk more than 300 meters to the nearest point and they no longer spend long periods fetching water. NAWASSCO worked with the local leadership to determine appropriate locations for the meters, which met the social concerns, while being responsive to the hydraulic considerations. Being fully automated, there was a huge potential for vandalism, but the CPM sites were carefully chosen to be well secured and within compounds to prevent vandals from damaging the meters.

It was observed that the percentage of non-revenue water was higher in areas where the metering models were not installed compared to where they were installed (Table 4-1). In Kisumu, NRW (the volume of water produced but not accounted for caused by factors such as water losses from pipe leakage, faulty meters, vandalism and illegal connections (Liemberger & Wyatt, 2018) was higher in the communities that had not installed the CPM or the DMM; leading to the assumption that the study metering models did have an impact on NRW. Coverage is measured as the percentage of an area that has been provided with clean and potable water over 20 hours/day. If an area has a coverage of 75% or more, the WSP serving in that the area is assumed to be a well performing utility (Collignon & Vezina, 2016). The study areas that had the CPM and the DMM achieved coverage above 75%, making the models tools for high performance. However, the study areas without study meters in Kisumu indicated low water coverage (Table 4-1).

It was observed that NRW was lower by 70% in areas in Nakuru without CPM installed than areas where the CPM was not installed. It was also observed that the cost of water/ 20 litres was also lower by 80% than areas where the CPM was not installed. This suggests that there is better improved water service delivery and management by comparison in areas with the CPM installed. Consumers were observed to manage water as a resource and the reticulation network better because they had more stakes through prepayment. This was a contributing factor to the low NRW and improvement in managing of the reticulation in the CPM. There was also an improvement by 75% in the time taken to fetch water in these areas with CPM, (Table 4-1), and hence, the improvements in NRW and the rime to collect water suggest that CPM improves water service delivery and coverage in low income communities.

NRW was lower in areas by 92% in Kisumu in the study areas that had the DMM in comparison to those areas without the DMM. It was also observed that the time taken to fetch water in those areas with the DMM was reduced by 50%, in comparison to areas that did not have the DMM (Table 4-1). These improvements directly impacted coverage because there was an increase in coverage by 90%. The DMM has led to improved water service delivery and there is an improvement from consumers in being more responsible for water resources as well as the reticulation network, just like in the Nakuru case.

ANOVA when testing the with and without metering models, showed that DMM and CPM significant positive difference at 5% level of significance on the key indicators when performance was compared to the areas that did not have these two study models.

4.1.1 PERFORMANCE EVALUATION

A critical look shows that the Delegated Management Model impacts more on these parameters, NRW, coverage and incidence of water borne disease while the Communal Prepaid Metering Model has more positive impact on time to fetch water, the cost of water and water quality (potable water). It was also observed that the DMM impacts positively on these indicators, NRW and incidences of water borne disease (Table 4-1).

Table 4-1 Comparative Analysis of DMM, CPM and Conventional Metering Models

Delegated Management Model (Kisumu)	**With Study Model**
Performance Indicator	From 2013 to 2016
Coverage	61- 85%
Customer Satisfaction	76 - 95%
Non-revenue water	48 -27%
Cost of Water	85 -98%
Water Borne Disease Incidence	5 – 1 /1000/ persons/ year
Time taken to fetch water	30 -15 mins
Potable Water	87 - 100% compliant to WHO & KEBS Standards
Conventional Communal Water Points (Kisumu)	
Performance Indicator	From 2013 to 2016
Coverage	61 -60%
Customer Satisfaction	73 -71%
Non-revenue water	48 -57%
Cost of Water	85 -82%
Water Borne Disease Incidence	5 - 7/1000/ persons/ year
Time taken to fetch water	30- 37 mins
Potable Water	85 – 84 % compliant to WHO & KEBS Standards
Communal Prepaid Meters (Nakuru)	**With Study Model**
Performance Indicator	From 2013 to 2016
Coverage	85 - 92%
Customer Satisfaction	45 – 65%
Non-revenue water	60-32%
Cost of Water	55-65%
Water Borne Disease Incidence	7-4/1000/ persons/ year
Time taken to fetch water	30-15 mins
Potable Water	87-100% compliant to WHO & KEBS Standards
Conventional Communal Water Points (Nakuru)	
Performance Indicator	From 2013 to 2016
Coverage	85 -82%
Customer Satisfaction	45 -46%
Non-revenue water	65 -64%
Cost of Water	55 -61%
Water Borne Disease Incidence	7 - 8/1000/ persons/ year
Time taken to fetch water	30 mins
Potable Water	87-82% compliant to WHO & KEBS Standards

4.2 COMMUNAL PREPAID METERING MODEL

The installation of the CPM was done with some thoroughness, so much that it revealed that the reticulation had several issues including burst, leaks, and illegal connections, issues which needed to be addressed urgently. However, for the most part, urban poor dwellers observed better service when the CPM was introduced.

Prior to the installation of the CPM, 51 % of those who were interviewed confirmed that they normally walk up to 30 meters per trip, on account of endless water outages and in the process of fetching water; they wait long periods due to the outages. This process takes up to an hour. When all is factored in, consumers are paying up to twice the actual cost of water, as vendors usually put a hefty mark up on their tariff. After the meters were installed, respondents informed that they no longer used vendors who peddled water in their communities, so it was observed that the CPM had induced a noteworthy improvement in the use of the NAWASSCO's supply for at least 73 % of the respondents. Socially, this meant that there was a drop in the time spent on water fetching. 92 % of respondents interviewed confirmed that they spent less than 15 minutes a daily in water fetching from the baseline, where up to 64% had indicated that it took up to 2 hours daily just to fetch water.

4.2.1 INCREASED QUANTITY OF WATER

The Baseline survey revealed that before the meters were installed, households consumed 20 litres per person, per day, with 4 people per homestead used on average 4 jerry cans per day for domestic use. Over the monitoring period, which was after the prepaid meters were installed, 73% of respondents confirmed that they were using more NAWASSCO water for their personal domestic use, up to three additional jerry cans per day. As they were being interviewed, the consumers said since the advent of the prepaid meters, they no longer had to wait until their free time during weekends to wash cloths which was the time they could go out and get more water from other sources. 23 % specifically indicated that their personal hygiene had improved because of the intervention, suggesting that increased availability of potable water directly collates with improved hygiene practice. When interviewed, landlords also confirmed that there was a reduction in water use and wastage as their tenants were more aware of water use, on account of the CPM.

92 communal prepaid meters were installed and fully functional by August 2013, with slightly over 4,000 tokens being used. Since it was difficult to enumerate the exact number of beneficiaries, it was assumed that each token serves 4 people, so up to 16,000 could have had direct benefit from the intervention. For the most part, each communal water point can serve up to 50 households. Each home will have their own token, or in some cases a card which is used to draw water from a dispenser. The token only works if it has been loaded with credit at the nearest vending point.

4.2.2 COST OF WATER

Landlords informed this study during informant interviews that before the advent of the metering models, water tariff would be combined with the monthly rent, and as such, residents were not paying directly for their water and they were wasteful. The wastage usually meant that NAWASSCO would come and disconnect the water forcing the landlord to pay hefty water bills ranging from $ 188 to as high as $ 325 per month. Tenants would become creative, and then resort to other sources outside the compound and they were reportedly paying on average KES 5 per jerry can, to meet their requirements. With the communal pre-paid meters in place, the landlord now is just responsible for paying for actual consumption. A landlady informed the researcher that her water bill is now on average 95% less than before at just $ 11per month. On the other hand, the tenants confirmed that the token was properly calibrated and that they were now using a flat rate of KES 1.2/ jerry can, which the tenants considered to be fair, and that it was a realistic tariff. A survey conducted with the tenants revealed and confirmed that the token recharge was now at $ 1.78, which is 1/3 lower than the initial amount required. With this reduction, customers are saving $ 0.75/m3, which represents a 75 % drop in the cost of water. The new tariff was considered to be reasonable for the dwellers, which no longer had any fear of being disconnected from the network by NAWASSCO and neither do they are afraid of the inconvenience of a disconnection and expensive reconnection procedure. On account of this development, 40% of the customers who were interviewed felt there was a significant improvement in their cash flow on account of the prepaid meters. The reduced cost of water at $ 0.75/m3 is approximately 12% of the average rent per month. This was calculated on the assumption that water consumption had increased to 6 jerry cans per day. (Each jerry can represents 20 litres and a standard household in peri-urban Kenya is assumed to consume 120 litres per day (WASREB, 2017)).

4.2.3 ACCEPTABILITY OF THE TECHNOLOGY

The figure below (figure 4-1) demonstrates the key benefits derived from installing the communal prepaid meters as derived from responses from respondents interviewed. Overall the user approval ratings increased significantly, with 94 % expressing their satisfaction with the metering model.

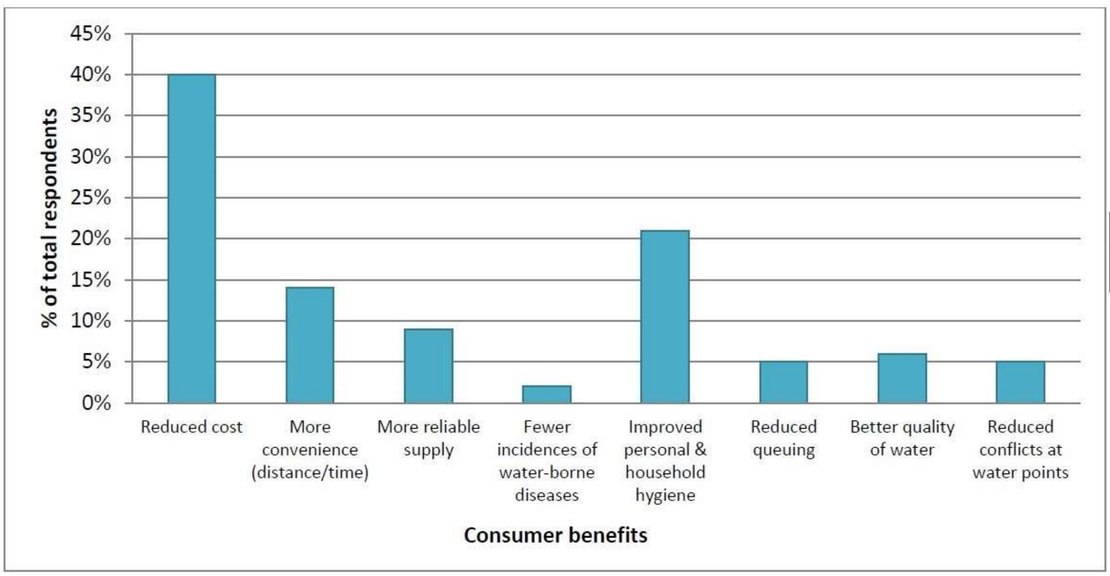

Figure 4-1: Prepaid Meter Benefits

(Source: Author)

4.3 DELEGATED MANAGEMENT MODEL

The installation of the DMM also revealed that the reticulation in the study area had several issues including burst, leaks, and illegal connections, issues which needed to be addressed urgently. In the areas where DMM was installed, the residents registered improved quality and level of service when prepayment is introduced. The purpose of the DMM is to help the utility improve on how it provides potable water in a customer focused manner to urban poor dwellers (Schwartz et al 2010; Onyango, 2012; Practical Action, 2012). Customers, who now get potable water, after the installation of the DMM, are now focusing on ensuring that their well-being is assured, the water is not affecting their personal economy, or their personal lives, while having continuous supply. The focus group discussions revealed that both the residents in the high-density areas and the Master Operator see the DMM as a real opportunity for generating much needed revenue and cash.

4.3.1 COST OF WATER

With the advent of the modified DMM, water has become much more affordable, for example, before the DMM; people would buy water from peddlers at 20 KSh per jerry can to 3 KSh for the same volume of water bought from the DMM. This was acknowledged as fact by residents in the community during the FGD's.

Consumers that were interviewed made the point that water was a significant part of their family budgeting, and the reduction in prices that came with DMM's was a very welcome relief. However, since most of these are extremely poor, the impact of the cost of living, which rises continuously due to other factors beyond water, it still meant that at times, they had to make financial decisions based on their cash flow to avoid DMM water and go for unprotected sources, mostly for washing clothes.

4.3.2 TIME TO FETCH WATER

Water service has improved significantly with the advent of the DMM, and women and children no longer spend so much time drawing water, as the reliable DMM have improved water availability. The time has been reduced from 30 minutes to 15 minutes. The installation of DMM's means that residents do not have to worry about long distances, neither do they worry about having to send children or even women to draw water odd late hours because there was no access during the day. Whereas in areas without the study model, women and children can walk up to 1 kilometre to fetch water, in the DMM design, distances are kept to within 150 metres to the nearest water point. The improved access also means to the residents that they no longer must endure long hours on queues, because there is better efficiency at the various water points. This gain in time is valuable and highly appreciated by the residents. When discussing this in the FGDs, they did emphasize that they felt it was easier to access water at water points that are manned by MOs, because they are situated right in the neighbourhood, where there are many houses, so they feel protected and comfortable when they are drawing water. They are now spending less than 15 minutes in collecting water in comparison to the 1 hour it took prior to the intervention.

4.3.3 POTABLE WATER

Residents who access water through DMMs are very confident with both the water quality and the water adequacy (quantity) they are getting from DMMs. In the FDGs, participants indicated that since they can see how the MOs operate, that gives them the confidence required for well treated water, which is good for human consumption. It was also noted in FDG's that the water points are open longer times (up to 20 hours a day) to the convenience of the residents. The women residents were particularly impressed and happy that this has helped them to manage their lives better, and that the quality of water means that their health and quality of life has improved as well. Some of the people interviewed indicated that there were some interruptions in supply, from time to time, but this is due mostly to maintenance and this was also more prevalent in the dry season when the water sources dry up.

4.4 PERFORMANCE COMPARISON

A comparative statistical analysis of key meter performance indicators was conducted for KIWASCO and NAWASSCO with the meters installed from 2014 and without the meters installed in 2013, as analysed (in table 4-2 and 4-3). The ANOVA and the Odds Ratio were both opted to be applied as tools to do a comparative analysis at 5% level of significance for each study indicator to assess and determine to what extent the DMM and CPM impact had in the respective study areas. The P values suggest that the data failed to reject the null hypothesis, indicating that each parameter is independently impacted by the DMM and

CPM. However, the mean values, as analysed in table 4-2 show that the two models, impacted the study areas and improved operations, and service to the communities because there are improvements in the key study areas, metering levels, coverage and non-revenue water.

4.4.1 RESULTS OF ONE-WAY ANOVA

H_0: $\mu_1 = \mu_2 = \mu_3 = ... = \mu_k$

H_1: At least one μ_i different

where

- μ_i is the percentage mean of the i^{th} group ($i = 1, 2, ..., k$)

Table 4-2 Descriptive Statistics

performance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
delegated management	50	77.3600	22.39238	3.16676	70.9962	83.7238	27.00	100.00
communal prepaid	50	69.7600	20.48151	2.89652	63.9392	75.5808	32.00	100.00
Total	100	73.5600	21.68848	2.16885	69.2565	77.8635	27.00	100.00

(Source: Author)

Table 4-3 ANOVA table

ANOVA

Performance

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1444.000	1	1444.000	3.136	.080
Within Groups	45124.640	98	460.456		
Total	46568.640	99			

(Source: Author)

From table 4-3 we can see that our P-value 0.080 is greater than 0.05 (95% confidence). Therefore, the null hypothesis cannot be rejected. We can see that our P-value 0.080 is greater than 0.05 (95% confidence). It is therefore clear the null hypothesis cannot be rejected and the conclusion would be that there is no statistically significant difference between CPM and DMM. This means that practically, the DMM is just as effective as the CPM when responding to the six selected performance indicators as a way of determining if they are helping the respective WSPs to be of service to the peri-urban areas. In other words, each model, in comparison can be used to serve peri-urban areas, assuming that the areas have conditions similar (peri-urban communities, low income dwellers, high density areas, sparse access to water, interment water supply, relative high cost of water) to the study areas and that the water utilities have the ability to develop and sustain the DMM or the CPM.

4.4.2 RESULTS OF ODDS RATIO

Using logistic regression, the CPM model was coded as 0 and DMM as 1. Then a binary logistic regression in Stata 12 was run to obtain the odds ratios to compare the 2 models when it comes to independent variables, potable water, time taken to fetch water, coverage, customer satisfaction, Water Borne diseases incidence, Non-revenue Water and Cost of Water. Table 4-4 below gives the odds ratio results.

Table 4-4 Odds Ratio Results

```
. logistic Model Coverage CustomerSatisfaction CostofWater NonRevenueWater Water
> BorneDiseaseIncidence TimeTaken PortableWater, asis

Logistic regression                             Number of obs   =         18
                                                LR chi2(-1)     =      24.95
                                                Prob > chi2     =          .
Log likelihood =          0                     Pseudo R2       =     1.0000

------------------------------------------------------------------------------
       Model | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Coverage |   .6408019          .       .       .            .           .
CustomerSat~n |   1.419539          .       .       .            .           .
 CostofWater |   4.944326          .       .       .            .           .
NonRevenueW~r |   1.331232          .       .       .            .           .
WaterBorneD~e |   .3300028          .       .       .            .           .
   TimeTaken |   .6106204          .       .       .            .           .
PortableWater |   .1879257          .       .       .            .           .
       _cons |   1.22e+22          .       .       .            .           .
------------------------------------------------------------------------------
Note: 9 failures and 9 successes completely determined.
```

(Source: Author)

From the results the following are the interpretations. Each explanatory variable is considered independently as summarized in table 4-5.

Table 4-5 Odds Ratio Results Interpretation

Explanatory Variable	Odds Ratio	Interpretation of Odds Ratios
Coverage	0.6408019	The CPM is 36% better than the DMM when it comes to Coverage. (which means CPM covers 36% more people than those which are covered under DMM)
Customer Satisfaction	1.419539	The DMM is 40% better model than the CPM for this variable. (which means DMM satisfies 40% more customers than those which are satisfied under the CPM model)
Cost of Water	4.944326	The DMM is 4.9 times better than the CPM when it comes to this parameter. (which means the cost of water for the DMM was 4.9 times more than the cost of water for the CPM)
Non-Revenue Water	1.331232	The DMM is 33% better model that the CPM for this variable. (which means the non-revenue water for the DMM is 33% less than the non-revenue water for the CPM.)
Water Borne Disease Incidence	0.3300028	The CPM is 67% better model than the DMM for this variable. (which means CPM had about 67% more water borne diseases than the DMM)
Time Taken to fetch Water	0.6106204	The CPM is 39% better model than the DMM for this variable. (which means the time to fetch water was reduced by 39% under the CPM when compared to the time under the DMM
Potable Water	0.1879257	The CPM is 81% better model than the DMM for this variable. (This means 81% more water samples complied with the standards under the CPM when compared with the water samples under the DMM).

(Source: Author)

The parameters used are described in table 4-6.

Table 4-6 Odds Ratio Parameters

```
. logistic Model Coverage CustomerSatisfaction CostofWater NonRevenueWater WaterBorneDiseaseIncidence TimeTaken PortableWater, asi
> s coef

Logistic regression                             Number of obs   =         18
                                                LR chi2(-1)     =      24.95
                                                Prob > chi2     =          .
Log likelihood =          0                     Pseudo R2       =     1.0000
```

Model	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Coverage	-.445035	.	.	.	.	.
CustomerSatisfaction	.3503324	.	.	.	.	.
CostofWater	1.598241	.	.	.	.	.
NonRevenueWater	.2861048	.	.	.	.	.
WaterBorneDiseaseIncidence	-1.108654	.	.	.	.	.
TimeTaken	-.4932797	.	.	.	.	.
PortableWater	-1.671709	.	.	.	.	.
_cons	50.85489	.	.	.	.	.

Note: 9 failures and 9 successes completely determined.

(Source: Author)

From the results table, we can see that the Odds ratio for the two models seem to give similar results in that they performed positively for each indicator. Furthermore, we can see that the 95% Confidence Interval (CI) contains a value one which means that the association is insignificant at alpha = 0.05. The CPM and the DMM however while performing positively for each indicator, when compared, have varied in the extent to which they have responded. The CPM has performed better than the DMM in coverage, time spent to collect water, water borne disease and clean potable water while the DMM has outperformed the CPM in cost of water, customer satisfaction and non-revenue water. The cost of water, non-revenue water and customer satisfaction are indicators that are used to assess whether performing WSPs that are focused on service level improvements while incidence of water borne diseases, time to fetch water and coverage are used to measure the utilities strength in customer orientation.

The positive performance in all the indicators however also confirms the results found in the one-way ANOVA above.

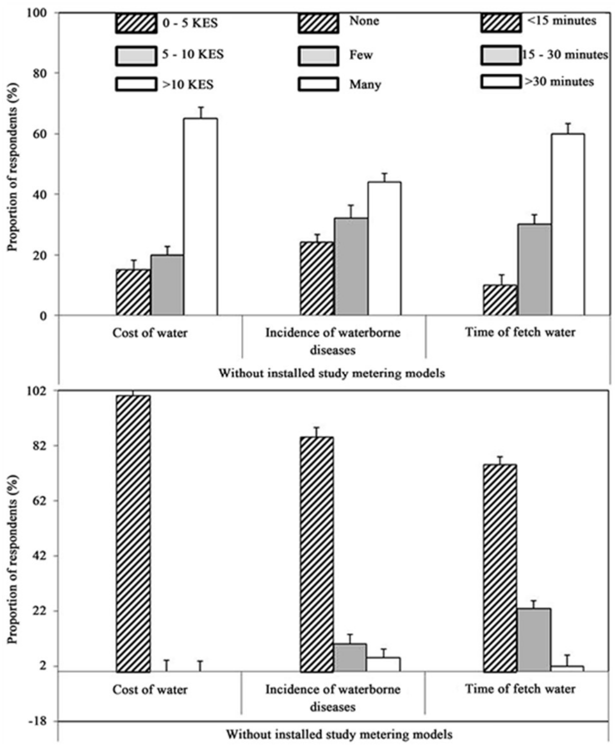

Figure 4-2: Summary Responses from Household Interviews

Source (Hanjahanja & Thine, 2018)

The number of times there were recorded water outages in Kisumu (84%) and Nakuru (61%) was in direct collation with the level of non-revenue water in the two study areas, i.e. Kisumu (76 -78%) and Nakuru (45 -49%). Interviews with utility staff revealed that NAWASCO staff in Nakuru was more diligent in network management and field supervision in comparison with KIWASCO staff in Kisumu. This was why this key indicator, NRW was so high in Kisumu; there was less vibrancy in checking for leaks, illegal connections and other vices. From a geological point of view, the study areas in Nakuru have fewer alternative sources of water and there are fewer water vendors than Kisumu. This suggests that users in Nakuru appreciate and take better care of water points and their reticulation network. All these cited issues contribute to the fact that NRW is lower in Nakuru than Kisumu, and the factors were addressed in the areas where the DMM and CPM were installed (Table 4-1).

It appears that as a direct result of the CPM and the DMM, consumers in the areas became more conservative in water use. Improved service delivery through improved management approaches in the study areas was evident for both metering models. In Kisumu, the strategy to use master operators, who were residents of the study areas, and who had delegated authority over their supply areas was deemed effective as all the key indicators showed improved service delivery. In Nakuru, the same result was noted through the communal prepaid meter. The meters are managed by the WSP but are situated within the community and the users are highly incentivised to police and protect the facilities against vandalism and other illegal activities. Both WSPs produce as a practice high quality potable water, and as such, are compliant to KEBS and WHO standards, and the advent of the two study models did not change that fact in any significant way.

During observational field visits, it was observed that for both study areas there were many incidences of water outages even though the frequency was higher in Kisumu than Nakuru. There were also more pipe bursts recorded by KIWASCO compared to NAWASSCO records. These results speak to the fact that there is more coverage in Nakuru than in Kisumu in the areas without study models. These results suggest that there are more operational challenges in the communities without DMM in Kisumu in comparison to areas without CPM in Nakuru. There was significant improvement when the study models were installed because for both leakages and water supply outages reduced to below 20% (Table 4-1).

These results suggest that the metering models did have significant impact on improved water supply. They also indicate that water users should have a role in sustaining improved water service delivery.

4.5 RESEARCH RELEVANCE

There is not much information that is detailed and comprehensive that is readily available about the dynamics of the high-density peri-urban communities of Kenya. This is especially true for all the different innovations that are ongoing in the water sector, so there is very little evaluation on the impact of these interventions, and how they compare to other interventions in the country or indeed in sub-Sahara Africa. However, in that difficult context, this study has fully achieved the objective, as described in section 1.2 of this study to develop a replicable model for improving the provision of water services among urban poor communities in Kisumu and Nakuru by:

- Assessing conventional water service provision in urban poor communities in Nakuru and Kisumu.
- Examining the DMM for service delivery in low income areas in Kisumu.
- Examining communal prepaid metering for water service delivery in low income areas Nakuru.
- Evaluating the performance, relevance and effectiveness of delegated management and communal prepaid metering models over conventional water service provision models.

The results of this research provide an expedient and dynamic tool for water utilities in the region, government agencies, NGOs, civil society and institutions. These agencies can use these tools in interrogating and quantifying how they can register improvement in water service delivery using the two interventions on display, the delegated management model and communal prepaid metering, bearing in mind the distinct difference between the two approaches, and the differences in the two communities where they have been implemented. The outcome of this research also provides a useful benchmark to easily gauge when their innovations seem to have little or no impact in service improvement and provides an opportunity for comparison with other interventions. As the research is dualistic, focused on both delegated management and prepayment, these results should provide opportunities for other water utilities, with a clear picture, where emphasis should be lent as they engage their peri-urban communities and make decisions on how best they can be served with sustainable water service delivery which is equitable, targeted and meets their needs.

4.6 CONTRIBUTION TO KNOWLEDGE

The hypothesis that 'innovative applicable engineering and financial solutions are valid tools for performance enhancement for water service delivery to urban poor communities' and that they are useful in helping water utilities taking significant steps towards achieving the Sustainable Development Goal: 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all' has been demonstrated in this research.

The results showed the delegated management model improved service delivery for peri-urban dwellers. The results also showed that communal prepaid meters are a valid pro-poor tool in improved water service delivery for peri-urban areas and the role of prepaid meters can no longer be ignored by policy makers. If household water connections and universal access is to be achieved low income communities, there is an opportunity for replicating these models, and also for further research on similar interventions.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study aimed at developing innovative water metering technologies to improve water service delivery in the urban poor communities in Kisumu and Nakuru. In this study, CPM was developed and installed successfully as a pilot in Nakuru. Likewise, the DMM was modified, improved and piloted in the peri-urban areas of Kisumu. Subsequently, a comparison of the CPM and the DMM was done and the results were analysed.

From results generated by ANOVA, it is concluded that there is no statistically significant difference between communal prepaid metering and the delegated metering models. From the Odds Ratio, it is observed from the Odds Ratio that for four (4) of the performance indicators, i.e., coverage, potable water, time to fetch water and incidence of water borne diseases, the CPM performed better than the DMM. For the other three (3) indicators, Cost of Water, Non-Revenue Water and Customer Satisfaction the DMM performed better than the CPM. The indicators that the DMM performed better in are commonly used to assess the operational performance and profitability of water utilities while the indicators that the CPM performed in are usually used to measure the utilities' ability to adequately quality and level of service delivered to its customers.

OBJECTIVE 1

It was concluded that it was possible to develop and install communal prepaid metering in the peri-urban areas in Nakuru. The CPM is a model that can be used by water utilities to effectively service peri-urban areas, and from this study, it can be concluded that the CPM leads to better customer service and satisfaction.

OBJECTIVE 2

From this study, it was also concluded that by modifying and improving delegated water service provision low income communities in Kisumu, the DMM can be used by water utilities to effectively service peri-urban areas, and that from this study, it can be concluded that the DMM leads to utilities becoming more commercially oriented and high performing.

OBJECTIVE 3

A comparison of the DMM and the CPM, against respective conventional means of water service provision in the same areas showed that both DMM and the CPM were an improvement over the conventional methods of supply. (See table 5-1) These results confirm that the DMM and CPM are better models of service delivery compared to conventional means of service delivery, i.e. communal water points. The results confirm that there is no significant difference between the two models, but that if a utility is focused on profitability and is commercially oriented, it may wish to adopt the DMM while if it is customer oriented and wants to improve the level of service and customer satisfaction in urban poor areas, it can adopt the CPM.

5.2 RECOMMENDATIONS FOR FURTHER RESEARCH

A few issues were identified for which further research in water service provision models in urban communities. The details below provide other possible research areas:

This study aimed at developing innovative water metering technologies to improve water service delivery in the urban poor communities in Kisumu and Nakuru. Poor water services in high density areas are directly collated to poor sanitation services in the same areas. This study did not address the subject of provision of urban sanitation. It is therefore recommended that studies be done to appreciate the coloration between water service delivery and urban sanitation in peri-urban areas.

There is not enough research or new knowledge on improving water services in small towns. These small towns are uniquely challenged in that since they are not rural areas, so water services can't be given free, neither can some of the service options like wells be provided for, and yet, the communities are not large enough to provide the numbers required to make any investment cost effective, unless there is cross-subsidizing through cost recovery tariffs that are charged to other users in other towns. This is an interesting area to explore.

OBJECTIVE 1

The Communal Prepaid Metering is an approach that helped NAWASSCO to improve on incidence of water borne is recommended as a model for utilities that are focused on improving service and the livelihoods of their urban poor residents.

OBJECTIVE 2

The DMM is an approach that has helped KIWASCO to improve on these indicators, Customer Satisfaction, the Cost of Water and NRW. As such, it is recommended as a suitable model for WSP water service delivery to peri-urban areas. The model is suited for utilities that are focused on commercialization, improvements.

OBJECTIVE 3

Since there was no cross testing by implementing the Communal Prepaid Metering in Kisumu as well and the Delegated Management Model in Nakuru too, therein lies an opportunity for further research. As such, it would be highly commendable if there was cross testing between the CPM and DMM to see the opportunity for more individual strengths to be drawn.

This research focused on exploring the DMM and the CPM for the two cities, Kisumu and Nakuru. Replication of this study to involve countries in sub-Sahara Africa would provide a wider catchment and a broader prospective around how to better serve low income communities.

This research focused on innovations in urban poor communities, and a lot has been learnt and observed, but it would be interesting to see just how effective these two models, prepayment and delegated management, are in affluent areas in the same sort of cities and countries. Are the experiences the same, are the lessons the same, and is the impact the same?

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APPENDIX A

RESEARCH CONTEXT

RESEARCHER

The researcher, Eng. Robert T. Hanjahanja is a Registered Engineer (2004) with the Malawi Board of Engineers. He holds a MSc. in Planning and Management of Urban Services from Loughborough University, UK (2001) and he holds a BSc. in Engineering (Civil), from the University of Malawi (1992). He is also a Utility Management Specialist (certified with the Institute of Public-Private Partnerships) (IP3), USA, (2008). His passion is service to the urban poor. He sees the poor as customers and not consumers; he sees the low-income earners as partners in development and a key stakeholder in any engineering effort that focuses on development. His previous research during his masters examined the hypothesis: *"Inadequate Capacities and unsuitable approaches at Lilongwe Water Board reduce the quality and extent of service delivery to the urban poor within the city of Lilongwe*." He built on the experiences learnt in this research as he carries out his work in Kisumu and Nakuru. The research done in Lilongwe (Hanjahanja, 2001: post-graduate MSc. thesis) attracted the interest of WaterAid who eventually financed a partnership with Lilongwe Water board (in Malawi) which developed a pro-poor unit which became a model in the region and is used to date by utilities in sub-Sahara Africa as they develop their own pro-poor units (WaterAid, 2008). He considers it quite commendable that his Master's Degree thesis became the platform from which there was an evolution in the approach to water service delivery to the peri-urban areas in Lilongwe and that the work in Lilongwe became a model which has been replicated throughout the region. The work that the investigator carried out in Kisumu and Nakuru has been presented as a paper (in part) at the 16th African Water Association International Congress in Marrakech, Morocco where it was reviewed by his peers. (www.afwamarrakech2012.org) [accessed 18 March 2012]

ROLE OF RESEARCHER

The researcher as stated earlier, was an employee of USAID/SUWASA. Sustainable Water and Sanitation in Africa (SUWASA) was a six-year USAID activity which promoted WASH reforms and innovative finance for providing potable water and decent sanitation services in Sub-Saharan Africa. In Kenya, the project linked the expertise and experience of microfinance institutions with the business plans of the utilities, to improve WASH services to the low-income communities in Kisumu and Nakuru, (SUWASA, 2011). The researcher who worked as a Water Utility Operations Specialist was the desk officer for this project and was involved in planning and conducting the research study at all levels of this project. He drew from the research that SUWASA is carrying out to inform and conduct his own investigations for this study which draws its baseline from the same SUWASA activity.

SITE SELECTION

In selecting Kisumu and Nakuru as the cities for this research, the principal investigator was looking for cities that have large urban, low income communities which have a reasonable amount of water supply of good quality provided by a utility which is functional, vibrant and is able to adopt knew innovations. It was also vital that the cities had recent or on-going water projects which the research is focused on.

Kisumu, is one of the largest and busiest cities in Kenya, and their WSP, KIWASCO is engaged in the demand management model from which this study was derived, 60% of the population consists low income community dwellers, it has recently doubled its water supply, KIWASCO has an ambitious target of achieving 9,000 new connections every year and the management team is gifted, skilled and focused. In According to the 2015 Water and Sanitation Regulatory Board (WASREB) Impact Report, 29% of Kisumu City is provided with water by the WSP, KIWASCO. This made it suitable as a research area.

Nakuru, is also another large and fast growing city in Kenya, and has a vibrant WSP, NAWASSCO, it has large low income communities, has recently invested in infrastructure and it is partnering with the African Development Bank to increase its production by 50%

(SUWASA, 2011). It has very low coverage and many debtors who are very reluctant to pay for the service of water through the orthodox means of a monthly bill.

At a population of almost 500,000, the growth has been influenced by rapid urbanization, in the low-income communities, as many people prefer living in those areas because of inadequate housing in the suburbs. 14,000 metered connections.

APPENDIX B

ETHICS WHEN CONDUCTING RESEARCH

When conducting any study, it is necessary to be sensitive to what is considered as ethical and morally appropriate. This research was responsive to all the moral and ethical issues that were of concern and important in the study areas, as articulated by the researcher and by the respondents both from the communities and the water service providers. Concerns that were considered include:

- Before respondents were engaged, they were clearly informed of the duality of the questionnaires, in that while the research was for purposes of fulfilling the mission of USAID-SUWASA, this researcher had a further and ulterior academic purpose.
- All respondents volunteered willingly without any obligation or being pressured to participate.
- All recordings during interviews were taken in full view and with the knowledge of the interviewee and with their consent.
- No participant in the interviews was at any point subjected to physical danger because of participating in the research.
- All participants remain confidential and their responses will in no way reflect who they are and who they are identified as. To do this, all respondents were coded, and no names were used, both for the communities and service providers.

APPENDIX C

DATA TABLES

Delegated Management Model (Kisumu)	**Without Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**
Performance Indicator	2013 (Jan – April)	2013 (May – Aug)	2013 (Sept - Dec)	2014 (Jan – April)	2014 (May – Aug)	2014(Sept – Dec)	2015 (Jan - April	2015(May– Aug)	2015 (Sept- Dec)	2016 (Jan– April)
Coverage	61%	61%	68%	68%	72 %	75%	80%	82%	85%	85%
Customer Satisfaction	75%	76%	78%	82%	90%	92%	95%	95%	95%	95%
Non-revenue water	49 %	48%	48%	42%	42%	35%	33%	30%	27%	27%
Cost of Water	85%	85%	90%	90%	92%	92%	95%	95%	98%	98%
Water Borne Disease Incidence	5/1000/ persons/ year	5/1000/ persons/ year	5/1000/ persons/ year	5/1000/ persons/ year	4/1000/ persons/year	4/1000/ persons/year	3/1000/ persons/year	2/1000 persons/year	2/1000 persons/year	1/1000 persons/year
Time taken to fetch water	30 minutes	30 minutes	15 minutes	15 minutes	15 minutes	15 minutes	15 minutes	15 minutes	15 minutes	15 minutes
Potable Water	87% compliant to WHO & KEBS Standards	87% compliant to WHO & KEBS Standards	95% compliant to WHO & KEBS Standards	95% compliant to WHO & KEBS Standards	97% compliant to WHO & KEBS Standards	97% compliant to WHO & KEBS Standards	99% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards
Conventional Communal Water Points (Kisumu)	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**	**Conventional Communal Water Points (Kisumu)**
Performance Indicator	2013 (January – April)	2013 (May – August)	2013 (September - December)	2014 (January – April)	2014 (May – August)	2014 (September – December)	2015 (January - April	2015 (May– August)	2015 (September- December)	2016 (January– April)
Coverage	61%	61%	60%	62%	62%	62%	59%	59%	59%	60%
Customer Satisfaction	75%	73%	73%	72%	70%	70%	70%	71%	71%	71%
Non-revenue water	49 %	48%	51%	52%	52%	51%	51%	52%	53%	57%
Cost of Water	85%	85%	85%	83%	83%	83%	81%	81%	81%	82%
Water Borne Disease Incidence	5/1000/ persons/ year	5/1000/ persons/ year	5/1000/ persons/ year	8/1000/ persons/ year	8/1000/ persons/ year	8/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year

Time taken to fetch water	30 mins	30 minutes	30 minutes	38 minutes	38 minutes	38 minutes	38 minutes	37 minutes	37 minutes	37 minutes
Potable Water	87% compliant to WHO & KEBS Standards	85% compliant to WHO & KEBS Standards	89% compliant to WHO & KEBS Standards	87% compliant to WHO & KEBS Standards	80% compliant to WHO & KEBS Standards	89% compliant to WHO & KEBS Standards	88% compliant to WHO & KEBS Standards	88% compliant to WHO & KEBS Standards	88% compliant to WHO & KEBS Standards	84% compliant to WHO & KEBS Standards
Communal Prepaid Meters (Nakuru)	**Without Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**	**With Study Model**
Performance Indicator	2013 (January – April)	2013 (May – Aug)	2013 (September - December)	2014 (Jan – April)	2014 (May – August)	2014 (September – December)	2015 (Jan - April	2015 (May– August)	2015 (September-December)	2016 (January– April)
Coverage	85%	85%	90%	90%	90 %	90%	90%	92%	92%	92%
Customer Satisfaction	45%	45%	55%	55%	55%	55%	60%	60%	65%	65%
Non-revenue water	62 %	60%	53%	52%	48%	45%	40%	38%	35%	32%
Cost of Water	55%	55%	60%	60%	60%	60%	65%	65%	65%	65%
Water Borne Disease Incidence	7/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	6/1000/ persons/ year	6/1000/ persons/year	5/1000/ persons/year	5/1000/ persons/year	5/1000/ persons/year	4/1000 persons/year	4/1000/ persons/year
Time taken to fetch water	30 mins	30 mins	15 mins	15 mins	15 mins	15 mins	15 mins	15 mins	15 mins	15 mins
Potable Water	87% compliant to WHO & KEBS Standards	87% compliant to WHO & KEBS Standards	95% compliant to WHO & KEBS Standards	95% compliant to WHO & KEBS Standards	97% compliant to WHO & KEBS Standards	97% compliant to WHO & KEBS Standards	99% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards	100% compliant to WHO & KEBS Standards
Conventional Communal Water Points (Nakuru)	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**	**Conventional Communal Water Points (Nakuru)**
Performance Indicator	2013 (January – April)	2013 (May – Aug)	2013 (September - December)	2014 (Jan – April)	2014 (May – August)	2014 (September – December)	2015 (Jan - April	2015 (May– August)	2015 (September-December)	2016 (January– April)
Coverage	85%	85%	81%	81%	82%	82%	81%	81%	82%	82%
Customer Satisfaction	45%	45%	43%	40%	42%	40%	44%	46%	46%	46%

Non-revenue water	62 %	65%	65%	64%	64%	65%	66%	67%	65%	64%
Cost of Water	55%	55%	55%	57%	57%	57%	56%	56%	56%	61%
Water Borne Disease Incidence	7/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	8/1000/ persons/ year	8/1000/ persons/ year	8/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	7/1000/ persons/ year	8/1000/ persons/ year
Time taken to fetch water	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes
Potable Water	87% compliant to WHO & KEBS Standards	82% compliant to WHO & KEBS Standards	83% compliant to WHO & KEBS Standards	82% compliant to WHO & KEBS Standards	85% compliant to WHO & KEBS Standards	79% compliant to WHO & KEBS Standards	80% compliant to WHO & KEBS Standards	78% compliant to WHO & KEBS Standards	82% compliant to WHO & KEBS Standards	82% compliant to WHO & KEBS Standards

APPENDIX D

COMMUNAL PREPAID METER PICTURES

Communal prepaid meter in Nakuru (Source: Author)

Communal prepaid meter in Nakuru (Source: Author)

DELEGATED MANAGEMENT MODEL METERS

Installation of Delegated Management Model Meters in Kisumu (Source: Practical Action in East Africa)

Delegated Management Model meters in Kisumu (Source: Author)